THE FUTURE OF PRAXIS
APPLIED RESEARCH AS A BRIDGE BETWEEN THEORY AND PRACTICE

ARCC 2019 International Conference
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Conference Chair
Yew-Thong Leong

Editors
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THE FUTURE OF PRAXIS
APPLIED RESEARCH AS A BRIDGE BETWEEN THEORY AND PRACTICE
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Kat Martindale is a researcher, writer, consultant and lecturer in architecture and urbanism. Originally educated as an architect (Plymouth), then urban designer (Oxford Brookes), and urban geographer (Oxford) before landing in Sydney to read for a PhD in planning policy, Kat has won nine international awards and scholarships for her work. Kat has worked for academic institutions, private consultancies, think tanks and government offices in the UK, US and Australia. This has included working on land use policy, new town masterplans, city and town centre management, residential development policy, citizen engagement and participation, post occupancy evaluation and management, community development, heritage management, fuel poverty, environmental benchmarking, homelessness and housing for the elderly and disabled. Kat is Director of Architecture + Urbanism Research Office, a columnist for the Cities section of the Guardian, an Academician at the Academy of Urbanism and is a member of the Planning Institute of Australia’s International Division Committee.

Vivian Loftness, FAIA, is an internationally renowned researcher, author and educator focused on environmental design and sustainability, climate and regionalism in architecture, and the integration of advanced building systems for health and productivity. In addition to eight book chapters and over 100 journal articles, she edited the Reference Encyclopedia Sustainable Built Environments. She has served on over 25 Board of Directors, including EPA’s NACEPT, DOE’s FEMAC, and the National USGBC and AIA COTE Boards. She has been a member of twelve National Academy of Science panels as well as the Academy’s Board on Infrastructure and the Constructed Environment and given four Congressional testimonies on sustainable design. Her work has influenced national policy and building projects, including the Adaptable Workplace Lab at the U.S. General Services Administration and the Laboratory for Cognition at Electricity de France. In the past five years, Vivian has been recognized as a LEED Fellow, a Senior Fellow of the Design Futures Council and the Scott Institute, and one of 13 Stars of Building Science by the Building Research Establishment in the UK. She received the Award of Distinction from AIA Pennsylvania, holds a National Educator Honor Award from the American Institute of Architecture Students, and a “Sacred Tree” Award from the US Green Building Council.

Matti Siemiatycki is Canada Research Chair in Infrastructure Planning and Finance, and the Interim Director of the School of Cities at the University of Toronto. His work focuses on delivering large-scale infrastructure projects, public-private partnerships, and the effective integration of infrastructure into the fabric of cities. His recent studies explore the value for money of delivering infrastructure mega-projects through public-private partnerships, the causes and cures for cost overruns on large infrastructure projects, the development of innovative mixed use buildings, and the diversity gap in the infrastructure industry workforce.
ARCC 2019 International Conference
FUTURE PRAXIS: APPLIED RESEARCH AS A BRIDGE BETWEEN THEORY AND PRACTICE

In the world of increasing complexity and competing ideas, approaches, resources and techniques, how does architecture mediate these tensions? What is the role of academics and researchers in developing research outcomes that are meaningful and measurable? What is the role of practicing designers (architects, engineers and scientists) in developing an applied research agenda in architecture?

The ARCC 2019 International Conference in Toronto wishes to explore applied or practice-based research in architecture. RMIT professor Laurene Vaughan’s 2017 book, “Practice-based Design Research”, argued for the validity and importance of practice-based design research. In the same book, Cameron Tonkinwise of Carnegie Mellon University apologized for practice-based design’s “defensive insularity as it tried to shore up its epistemological claims throughout the 2000s”. He concludes that applied or practice-based design research, today, has a valid and important status as a discipline: “This means that the practice of expert designing involves precisely the sorts of meta-cognitive, processual knowledges that characterize a discipline.”

ARCC 2019 seeks the identification, definition, positioning, defense and formalization of applied research as a bridge between theory and practice in the future praxis of architecture.

Yew-Thong Leong, Conference Chair

TOPIC SESSIONS

Design Thinking
Design Thinking in the conception and realization of buildings and infrastructure. The late architectural theorist Dr. Marco Frascari argued that an architectural detail underpins techniques and bridges the concept and the realized. When an architectural theorist argues for architectural production, there must be something cogent in the argument. Could it be that architecture design is primarily celebrated - and understood - in its built form?

Applied History
Applied History, a term first used by political scientist and historian Benjamin Shambaugh in 1909, saw a re-emergence in 1974 when Harvard University historian Ernest May used history to improve policy making by studying precedents to understand and examine the challenges of the present. Architecture, rooted in history, can benefit from such an applied approach and can answer to the criticism that questions the practical applications of architectural history and theory.

Cultural Production
The role of the built environment in the Production of Culture - as our buildings project the ideals of the individuals and groups whom inhabit them, the study of such reveals much about ourselves that might not at first be apparent. Cultural and humanities-orientated research in architecture might leverage history, social interaction, formal artifacts and the effects of built form on human relationship structures. Can it be that understanding the role of buildings in the construction of multiple scales of cultural identity can help us understand who we are?
Autonomous + Smart
Autonomous and Smart buildings, and Infrastructure. The late Dr. Stephen Hawking (and the billionaire Elon Musk) cautioned us against AI and even predicted an apocalyptic end of the human race. Could AI be the salvation for future buildings and infrastructure, in an industry that still builds very much by hand, or does it represent a curse?

Environmental Stewardship
Environmental Stewardship of buildings and infrastructure. The Iroquois believe that the decisions we make today should result in a sustainable future seven generations away. Can we, as designers, affect such a future without resorting to certifications and checklists? Is there something very meaningful and measurable in this First Peoples’ refrain and their approach to the world around us?

Resource + Process Management
Fabrication as centered on Resource and Process Management. Future makers, fabricators and constructors continue to be engaged in the application of management, design, and technical skills for the design and integration of systems, the execution of architectural designs, the improvement of manufacturing and assembly processes, and the management and direction of physical and/or technical functions of a project, firm or organization. What are the ways of managing the project, firm or organization in the future age where ideas and making are becoming much more digitized?

Practicum-Focused Pedagogy
Practicum-focused Pedagogy, which bridges theory and practice, and is the hallmark of professional education. Clinical skills education is the keystone in medical schools, as are moot courts in law schools and laboratories in STEM education. In architecture, the Studio is meant to be this juncture, but increasingly the Studio has move from a medium of applied learning to that theoretical explorations and speculations. Can applied research re-inform the Studio, and return it to its keystone relevance?

Architecture for Health + Well Being
Architecture for Health and Well-Being, exploring the impact of the built environment on human health, satisfaction, and well-being. In particular, this theme seeks holistic approaches to promote healthier lifestyles, facilitate health-supporting human behaviors in buildings, as well as link design with health-outcomes. Projects exploring the relationship between architecture, urban design, and public health are also sought.

ACKNOWLEDGEMENT
The ARCC 2019 International Conference provides an important venue for the exchange of ideas in architecture. ARCC brings disciplinary and interdisciplinary discussions into focus while engaging a wide range of research methods, modes of inquiry and insights for the architectural community and beyond. Globalization, rapid urbanization, sustainability and climate change, material and construction innovation, data visualization, cultural critique and social engagement are but some of the issues inscribing the axis between theory and practice.

ARCC 2019 would not have been possible without the support and generosity of Ryerson University. Special thanks to Conference Chair, Yew-Thong Leong, for his leadership, communications, organization and on-the-ground logistics. And many thanks to his entire team for much behind-the-scenes activity. We would also like to thank the ARCC Board of Directors for their advice and feedback throughout the planning and organization of ARCC 2019.
Conferences provide the opportunity to share ideas, debate differences, meet new people, and learn from others. Bringing people together to exchange ideas has been our charge. The topics of ARCC 2019 have been explored in numerous and thoughtful ways by the authors in this proceeding. They help us reflect on various contemporary issues and dilemmas, from the social and environmental to the political and formal. What will be the impact of this good work? What influence will this work have at our home institutions and the field at large? And what effect will it have on future architectural research? Only time will tell. It's really up to all of us.

Chris Jarrett, Philip Plowright, Hazem Rashed-Ali
Conference Advisory Committee
DESIGN THINKING
The economic case for form-based codes

M. Clay Adams

Department of Architecture University of Oregon, Oregon

ABSTRACT: As many communities across the US look to Form-Based Codes (FBCs) as an alternative policy tool to segregated land-use zoning, increased research seeks to understand their impact beyond the physical built environment. FBCs have received both criticism and praise by academics, lawmakers, and citizens for desired or resultant social and economic effects. However, there are limits to what FBCs can and should control as a policy tool, and as each iteration is created uniquely for a given area, the intent and principles that form the basis of that code are, potentially, more influential on the repercussions experienced than the type of code employed. As such, criticisms and praise are often wrongly ascribed to FBCs. There is little research to determine the scope of misunderstanding surrounding FBCs and the varied players involved in their implementation. Additionally, as modern FBCs are still relatively new as implemented policy governing the built environment, examples of mature development formed under their direction, or academic studies of the resultant social and economic effects of those developments, are few. This gap in knowledge allows for the continued dissemination of misleading information attributed to FBCs, both positive and negative. Using a mixed-method approach, I will perform a comparative economic analysis of mature developments formed under both conventional segregated land-use zoning and FBCs in Kendall, Florida. This analysis will aid lawmakers in making evidenced-based decisions for community economic development and will help inform planners and government officials of clarifications needed during the participatory process.

KEYWORDS: form-based codes, policy, zoning

INTRODUCTION
Cities, towns, or communities are comprised of three main components: the built environment, or the physical component, the people who live within the built environment, or the social component, and the underlying purpose for living in close proximity, at least in modern society, economic activity, or the fiscal component. (Ciccone and Hall 1993; Inniss 2007) All three are inherently linked, where changes to one often impact the others. (Rothwell and Massey 2010) There are simple and direct examples, such as where local tax incentives impact development activity — a fiscal to physical connection, the emergence of economically vibrant hot spots from once dead parts of town due to music and the arts — a social to fiscal connection, or community groups acting in unison to have bike lanes installed — a social to physical connection. These changes can occur organically or through conscious thoughtful planning efforts, many times through the implementation of policy, gradually over time, and in accordance with the will of the local community. (Campbell 2016) As community demographics differ by location or regions, ideologies and local governing policies do as well. However, the underlying premise for policies that govern much of our physical built environment, segregated land-use zoning codes (SLU), permeated the United States as part of a mass adoption of zoning codes in the early twentieth century. (Fischel 2004) While the creation and adoption of zoning codes occur on a local basis as well, the segregation of use as a basic organizing framework was ubiquitously applied, despite demographic variances, and had complex, indirect, and unanticipated negative repercussions to our physical built environment, social fabric and fiscal health at the local level in the long-term. (Harvey and Clark 1965) (Brueckner 2001) As many communities across the US look to Form-Based Codes (FBCs) as an alternative policy tool to SLU zoning, increased research seeks to understand their impact beyond the physical built environment. For clarification of what a FBC is, the following is a description from the Form-Based Codes Institute.
Form-based codes address the relationship between building facades and the public realm, the form and mass of buildings in relation to one another, and the scale and types of streets and blocks. The regulations and standards in form-based codes are presented in both words and clearly drawn diagrams and other visuals. They are keyed to a regulating plan that designates the appropriate form and scale (and therefore, character) of development, rather than only distinctions in land-use types. (FBCI 2018)

1.0 BACKGROUND

1.1 Ancient law
Rules that govern our built environment have a long and extensively researched history. Imhotep, believed to be the first architect, wrote an encyclopedia on architecture that was used as reference for thousands of years after his death, around 3,000 BC. He designed a 37-acre complex as a model city, to be ruled in the afterlife. Nearing 4,000 years old, the Code of Hammurabi addressed liabilities for poorly built structures in ancient Babylon. (Johns 1903) Branching from these roots, working toward the evolution of western society, Plato’s Laws (Bury 1967), clearly describe how new cities should be built, with attention given to housing, civic buildings, theaters, temples, and the market. In describing the spatial relationship of these primary components, it is clear that the segregation of use was not the recommended approach. In a theoretical debate with Socrates about the “indispensable minimum of the city,” Plato emphasizes a balance of the economics of the individual, the city, and the nation state with the virtue of being just to its citizens. (Shorey 1969) The collocation of commercial activity, a consumer base, and requisite individual domestic needs, whether proximate or collocated in a single structure, provide the conditions needed for a functional economy with the exchange of goods and services. Regardless of nuances, these use categories: residential, civic, cultural, religious, and commercial, remain the primary (use) components of a city. The agglomeration of these uses can be found in almost every culture, as a basic building block of modern civilization. (Davis 2012) In addition to rules and laws governing the physical organization and planning of urban areas, theorists, architects, and later urban planners, also understood the relationship between the built environment and socio-economic conditions. (Campbell 1996)

1.2 The birth and life of modern zoning
The American Dream, up until the mid-twentieth century, followed a vision of a land of opportunity, where upward mobility was a reward for hard work. (Lamoreaux 2010; Blackford 2003) Mixed-use structures, rural or urban, were a fundamental component of achieving that dream. A family could simultaneously manage their domestic and commercial responsibilities, without a need to consider transportation or additional care for family members, both young and old, as additional costs. This morphology contributed to entrepreneurship and self-reliance, was financially efficient from the familial unit to the urban scale, creating a density that was appropriate for pedestrian-based economic activity. (Davis 2012) Free market forces also govern density by a ratio of businesses to residents served within a given distance, simple economic viability. (Inniss 2007) As industry and mass production transformed economies, from the kitchen table to the nation state, personal transportation modalities transformed in lockstep. Rising incomes and innovation allowed for greater distances, in shorter time, for a growing percentage of the population. Where commutable distances between inexpensive land and commercial centers allowed, single-family housing increasingly became a viable option for an aspiring supply of single-income families, to be known as the middle-class. The spatial repercussions, over time, are the sprawling suburbs that are loved by many.

1.3 New Urbanism and Form-Based Codes
New Urbanism (NU) was a response to this crisis of sprawl. (Urbanism 2000) FBCs emerged jointly with New Urbanist principles in the late twentieth century, and there is often conflation between the policy tool and principles with which they are most often associated. (Inniss 2007) (Garde and Kim 2017) (Inniss 2008) These principles concern the social, economic, and physical realms, and would require policy to govern each pursuant those principles. (Urbanism 2000) (Bohl 2000) FBCs, in regulating the physical built environment, are one part of that
equation, and there are limits to what FBCs can and should be expected to control as a policy tool. To be clear, regulation of one does not preclude an impact on the others. (King and Clarke 2015) The Congress for a New Urbanism (CNU) promotes the development of mixed-use walkable neighborhoods; however, FBCs, have, and can be created to govern any type of built environment, from sprawling single-family suburbs, to commercial strip centers, to high density mixed-use districts. (FBCI 2017; Woodward 2012) As each iteration is created uniquely for a given area, the intent and principles that form the basis of that code are, potentially, more influential on the repercussions experienced than the type of code employed. (Woodward 2012) (Talen 2013) FBCs, as a tool divorced from morphology, are said to be beneficial for their ease of use, simplified creation and implementation, and as part of a streamlined development process. (Woodward 2012) (Barry 2008) (Geller 2010) (Hughen and Read 2017) This would certainly have a beneficial economic effect, but a quantitative analysis of that aspect is beyond the scope of this paper. Rather, I will perform a comparative economic analysis of mature developments formed under both conventional SLU zoning and FBCs in Kendall, Florida.

2.0 ANALYSIS

2.1 Analysis perspectives

The analysis was conducted on two fronts. The first was a simple comparison of two sites within the research area governed by FBCs, in downtown Kendall, Florida. One was developed under the previous SLU code and the other under the new FBC. This analysis considers the impact to the developer/land-owner and also the budget of the governing body collecting property tax revenue. The second analysis is of three areas within Kendall, containing both commercial and residential uses of differing densities, from 1990 to 2017. This analysis is primarily concerned with census data to track the evolution of community characteristics.

2.2 Kendall, Florida

Kendall, Florida is an unincorporated census designated place (CDP) southwest of Miami. It is within Miami-Dade County, and was entirely governed by county-wide segregated land-use codes. Kendall CDP has an area of 16 square miles, with a population of around 75,000 people. It is bordered on the east by US Highway 1, which is paralleled by a commuter rail, in service since 1984. Of the 23 total stations, two are located in downtown Kendall, Dadeland North and Dadeland South. In 1998, the Chamber of Commerce, along with property owners, community members, business owners, elected officials, and appointed technical experts, participated in a charrette conducted by local planning firms Dover-Kohl and Duany-Plater Zyberk & Company, for downtown Kendall. The community’s vision to convert the commercially zoned downtown to a mixed-use metropolitan center, formed the basis of the resultant plan, taking advantage of the adjacent transportation system. The existing built environment consisted of strip retail, accompanying parking lots, hotels, office towers, and a cluster of multi-family residential units to the north. I did not include the residential sector in my analysis, as it remains residential to date. The tool to achieve this vision was the adoption of FBCs in 1999 that took precedence over county zoning codes. This impacted 324 acres that were auto-centric and fully built out per the existing SLU codes.

2.2 A two-site analysis

Aside from being located within the research area, there were two requirements for selection of sites for analysis: similar square footage of commercial space, and date of construction. Site SLU is a two-story, standard big box strip totaling 114,900 square feet of building area and approximately 250,000 square feet of surface parking. It was completed in 1999 under the prior SLU codes. Site FBC is a 25-story mixed-use building with 98,800 square feet of commercial space, 463,900 square feet of residential space, and integrated garage parking. It was completed in 2006 under the newly adopted FBC. As downtown Kendall was built out, new development required demolition of existing structures. Prior zoning limited construction to two-story commercial structures for some areas, which, under the FBC were permitted 25-stories and a specified mix of uses under the new FBC. As is common in older, low-density
areas, there was stagnation in development due to financial viability, given restrictions in buildable square footage and demolition costs for older structures. This was alleviated by up-zoning under the new FBC. As it would be difficult to parse out economic gains due to FBCs from those attributed to up-zoning, this analysis is based on what was possible under the prior SLU codes to that under the new FBCs.

In *Retrofitting Suburbia*, Ellen Dunham-Jones lays out the resultant boom in construction from adoption to 2004: “3,000 residential units, 350,000 square feet of retail/commercial, 110,000 square feet of office space, and a hotel.” (Dunham-Jones and Williamson 2011, 201) There is no question that the adoption of new, less restrictive zoning codes, had a beneficial economic impact. This aligns with basic economic theory; Edward Glaeser notes, with respect to land-use regulation, that “each extra type of rule is associated with about 10 percent less building.” (Glaeser 2012, 192) The question then becomes, in what ways, in addition to up-zoning, is it economically beneficial.

Sprawl is chiefly responsible for a widespread and growing municipal budget crisis due, principally, to the inefficient use of infrastructure. (Burchell et al. 2005) Studies show that property taxes between urban and suburban homeowners are comparatively equal, while the suburban costs for utility infrastructure is 40 percent higher than compact development and road costs are 60 percent higher. (Burchell et al. 2005) This amounts to a regressive tax on urban households which subsidize their suburban counterparts. (Burchell et al. 2005) Not only is the cost of infrastructure reduced for compact development over sprawl, but tax revenues are greater for a given area as well. The rule holds true for urban commercial centers as well. If we look at the property tax per acre in Table 1, we see that Site SLU generates only $98,000/ac, where Site FBC generates $383,000/ac between the commercial space and all residential units. As for infrastructure, as Site SLU is not occupied 24 hours a day, it sits dormant for a portion of the night, yet must be sized for peak loads. Additionally, since it has no residential component, employees and customers must come from elsewhere, and the same dormancy rule is true for their infrastructure, both utilities and roads. This is without taking distance and corresponding infrastructure needed to reach their residences into consideration. While the dormancy between uses exists in a mixed-use building as well, they offset, generating a more regular demand curve by spreading use over a 24-hour period. In downtown Kendall, there is no added distance between uses, and both are located close to the city center and other properties with similar characteristics, an exponential increase in efficiency.

### Table 1: Site Specific, Financial and Spatial Characteristics.

<table>
<thead>
<tr>
<th>Site</th>
<th>Lot Area (Acres)</th>
<th>Bldg Area (SF)</th>
<th>Bldg Area per acre (SF)</th>
<th>Value per acre</th>
<th>Property Tax (per month)</th>
<th>Property Tax per acre</th>
<th>Projected Rent $39/sf ($/mo)</th>
<th>Cash on Cash Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLU</td>
<td>7.60</td>
<td>114,900</td>
<td>15,000</td>
<td>$42.3M</td>
<td>$5.6M</td>
<td>$61,700</td>
<td>$98,000</td>
<td>$308,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.7%</td>
</tr>
<tr>
<td>Site</td>
<td>1.36</td>
<td>98,800</td>
<td>27,700</td>
<td>$8M</td>
<td>$2.2M</td>
<td>$10,800</td>
<td>$37,000</td>
<td>$308,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.9%</td>
</tr>
<tr>
<td>FBC</td>
<td>3.75</td>
<td>463,900</td>
<td>355,200</td>
<td>$108.7M</td>
<td>$83.2M</td>
<td>$141,700</td>
<td>$1,300,000</td>
<td></td>
</tr>
<tr>
<td>Tot</td>
<td>4.90</td>
<td>562,700</td>
<td>115,300</td>
<td>$116.7M</td>
<td>$23.9M</td>
<td>$152,500</td>
<td>$383,000</td>
<td></td>
</tr>
</tbody>
</table>

For a developer, return on investment (ROI) is a requisite indicator. ROI is the overall return upon completion of a project. In the development of a project such as Site FBC, valued at $116,700,000, it requires financial services to execute, and completion of the project could take many years. Due to the unknowns of long-term projects, the second-most cited measure of return for developers, cash-on-cash return, is often used to determine project viability. (Peiser and Hamilton 2012) Cash-on-cash return is cash flow after debt services, divided by investment costs. A simple example can be demonstrated with the purchase of rental property (Table 2). Option 2 is the more lucrative choice for both cash flow and cash-on-cash return. However, Option 2 also benefits from continued reductions in investment costs and increased
equity for each house with each monthly loan payment. As the investment costs are reduced, the cash-on-cash return increases; coupled with increases in equity, this can be leveraged toward future loans for additional rental properties.

Table 2: Cash-on-Cash Return

<table>
<thead>
<tr>
<th>Option</th>
<th>Cash Investment</th>
<th>Equity</th>
<th>Loan Amount</th>
<th>Monthly Rent</th>
<th>Monthly Loan Payment</th>
<th>Monthly Property Taxes</th>
<th>Monthly Cash Flow</th>
<th>Cash on Cash Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$200,000</td>
<td>$200,000</td>
<td>$0</td>
<td>$2,000</td>
<td>$0</td>
<td>$200</td>
<td>$1,800</td>
<td>0.09%</td>
</tr>
<tr>
<td>2</td>
<td>$50,000</td>
<td>$50,000</td>
<td>$150,000</td>
<td>$2,000</td>
<td>$715</td>
<td>$200</td>
<td>$1,085</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$50,000</td>
<td>$50,000</td>
<td>$150,000</td>
<td>$2,000</td>
<td>$715</td>
<td>$200</td>
<td>$1,085</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$50,000</td>
<td>$50,000</td>
<td>$150,000</td>
<td>$2,000</td>
<td>$715</td>
<td>$200</td>
<td>$1,085</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$200,000</td>
<td>$200,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$4,340</td>
<td>2.2%</td>
</tr>
</tbody>
</table>

In the analysis of Site SLU and Site FBC, the lending details are not available, but a similar calculation can be made (Table 1). In doing so, for sake of comparison, property value was used for investment and/or sales figures, and equity will be omitted. Site SLU, with 114,900 square feet of commercial space and 250,000 square feet of surface parking, returns $308,300 in revenue per month after property taxes. The developer has $42,300,000 in either cash investment or debt into the project. Site FBC, at 98,800 square feet of commercial space with parking below, also returns $308,300 per month in revenue. However, while the project is valued at $116,700,000, the 463,900 square feet of residential space was sold for $108,700,000, leaving the developer with only $8,000,000 in cash investment or debt. The cash-on-cash return for Site FBC is more than five times that of Site SLU. Not only is this a more profitable venture, it allows the developer of Site FBC to undertake other projects, as capital is not tied up. This example is cash-on-cash return for a single project, but with available capital from sales or additional potential for lending, and like the rental property example above, the developer can acquire additional properties and calculate the cash-on-cash return for an entire portfolio. The margins of Site FBC would not be possible without mixed-use development. Another benefit of mixed-use development for a developer is risk mitigation. The ability to flex ratios of residential, retail, and office space to market fluctuations allows developers to move forward with a project and make spatial-use decisions later in the development process. (Hughen and Read 2017) Quantifying this benefit is nebulous given the numerous externalities, but that it’s beneficial is clear. Additionally, the predictability of form, a cohesive plan, and other qualities set forth in a specific FBC reduce the development risk of negative externalities from neighboring sites. (Hughen and Read, 2017)

2.3 A longitudinal study

As discussed earlier, prior research indicated that increased densities in mixed-use developments have a beneficial impact on municipal coffers due to infrastructure efficiencies and tax revenue. The two-site analysis showed the benefits of mixed-use development to developers. But, as approval of zoning changes by elected officials is impacted by voting, how zoning changes affect those that live within the applicable area is key. To analyze the impact of FBCs on community characteristics for a given area, I compared current data as well as a longitudinal analysis for downtown Kendall (DK) and two reference sites within Kendall CDP (KCDP), and also included KCDP as a reference measure as well. As the FBC for DK was adopted in 1999, I used the 2000 census to mark the beginning of the study and the 2017 American Community Survey for the end marker. The two reference sites selected had similar populations to DK in 2017, although the land area varied, and as a result, the densities of these sites varied as well (Table 3). The Falls (TF), like DK, was located on US Highway 1, with a character reminiscent of suburban America, SLU zoning with single-family housing and low-rise commercial strip centers. The second was Snapper Village (SV), also SLU zoning, but with a higher density of multi-family housing and similar low-rise commercial strip centers. I used archival data to determine multiple indicators for comparison; a comparison of 2017 statistics were the most appropriate measure for some indicators, while the measure of performance over time provided the most insight for others. For an equivalent comparison,
given the variation in area, certain indicators were best leveraged as a ratio to area (per square mile). Also, as tract lines can vary between census counts, much of this information was sourced at the block level for continuity and accuracy. This analysis looked to address some misconceptions with mixed-use development governed by FBCs, with respect to families and density, housing and affordability, and jobs and income. There aren’t a multitude of academic criticisms in this milieu, rather, there is an overwhelming amount that attempt to disprove these uncited misconceptions. Being uncited doesn’t negate their existence as I have heard these criticisms declared, as if fact, much of my life living in the largest of US cities, specifically in Texas.

Table 3: Population and Families, 2000-2017

<table>
<thead>
<tr>
<th>Area (sq. mi.)</th>
<th>Percent of KCDP</th>
<th>Pop 2017</th>
<th>Pop Percent of KCDP</th>
<th>Pop Density (/sq. mi.)</th>
<th>Number of Families 2017</th>
<th>Family Density 2017 (/sq. mi.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK</td>
<td>0.45</td>
<td>2.8%</td>
<td>4,700</td>
<td>6.3%</td>
<td>10,500</td>
<td>1,600</td>
</tr>
<tr>
<td>TF</td>
<td>2.06</td>
<td>12.8%</td>
<td>5,500</td>
<td>7.4%</td>
<td>2,700</td>
<td>1,400</td>
</tr>
<tr>
<td>SV</td>
<td>0.41</td>
<td>2.5%</td>
<td>4,300</td>
<td>5.8%</td>
<td>10,500</td>
<td>1,000</td>
</tr>
<tr>
<td>KCDP</td>
<td>16.10</td>
<td></td>
<td>74,500</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Anecdotally, and in some published research, developments formed under FBCs, and a motivation for their expansion, is described as a solution for retiring baby boomers or single young professionals. (Geller, 2010) While DK and SV were almost identical in area, total population, and population density, more families live in DK than SV, or TF. When considering area, the family density in DK for 2017 is 50% higher than SV, more than three times KCDP, and more than five-times that of TF. At only 2.8 percent of KCDP in area, 6.3 percent of families live in DK. From 2000 to 2017, the population density of DK increased by 32 percent (Figure 1). That was more than five times the rate of the nearest reference site, while KCDP contracted during the same period. Given that population density is commensurate with SV, it alone cannot account for the increased family density of DK. Additionally, given the lower, albeit similar population totals of DK to TF, the higher number of families in DK, for a given population, cannot be attributed to a preference of single-family housing to a denser mixed-use neighborhood.

Figure 1: Percent Growth Population Density, 2000-2017

Criticisms of denser, more walkable developments are that they are exclusive enclaves with rental premiums only affordable to the elite. (Grant, 2006; Song and Knaap, 2003) Basic economic theory would say that an increased supply of a given item would lower costs, if demand is constant. Housing counts in DK were similar to both SV and TF in 2000, and housing density was also comparable to SV (Table 4). Housing counts and density for DK grew by 106% between 2000 and 2017, compared to negligible increases for TF or SV. The housing density in 2017 was more than double SV, almost five times KCDP, and near ten times TF. This increase served to accommodate local growth as well as providing second homes for many wealthy Latin Americans that would otherwise increase housing costs. (Dunham-Jones and Williamson 2011) Additional studies infer that mixed-use development, akin to what materialized in DK under FBCs, result in displacement and a decrease in affordability (Koschinsky and Talen 2015), yet DK was comparable to TF and KCDP in 2000 and rents had become homogeneous by 2017 (Table 5). Affordability, for this analysis is shown as a rent-to-income ratio. DK was comparable in rent-to-income ratio, at a lower median household income, to SV in 2000, and due to outperforming growth in median incomes for DK, the margins in affordability narrowed between the group. The change in the rent-to-income ratio for all test sites increased, but DK produced the second lowest growth rate, and 37% lower than KCDP (Figures 2 & 3). While it would be prohibitively difficult to trace every citizen
DESIGN THINKING

from 2000 to 2017, I considered increases in household income, comparable to the rent per unit, and family incomes, which would indicate the potential for dual-income households for a given rental unit. The percent of the population in a family was the highest in DK at 34%, 40% higher than the closest reference site, but the lowest percentage under 18 years old at 11.4%. The percentage for SV was commensurate at 11.6%, and 19% for TF, indicating a bias towards married couples without kids. However, given the higher family density of DK over all sites, but specifically TF and KCDP, and a higher housing density, TF is the more exclusive enclave of the three test sites. Median rents for TF stayed consistent with the other test sites, but the housing counts were half of DK, housing density was 10 times less, and median income remained historically higher.

Table 4: Housing, 2000-2017

<table>
<thead>
<tr>
<th></th>
<th>Total Housing Units 2000</th>
<th>Housing Density 2000</th>
<th>Total Housing Units 2017</th>
<th>Housing Density 2017</th>
<th>Housing Density 17-year change</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK</td>
<td>2,043</td>
<td>4,560</td>
<td>4,214</td>
<td>9,406</td>
<td>106%</td>
</tr>
<tr>
<td>TF</td>
<td>1,976</td>
<td>959</td>
<td>1,959</td>
<td>951</td>
<td>-1%</td>
</tr>
<tr>
<td>SV</td>
<td>1,671</td>
<td>4,076</td>
<td>1,676</td>
<td>4,088</td>
<td>0%</td>
</tr>
<tr>
<td>KCDP</td>
<td>29,652</td>
<td>1,844</td>
<td>30,561</td>
<td>1,901</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 5: Rent, Income, and Affordability, 2000-2017

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DK</td>
<td>$734</td>
<td>$33,000</td>
<td>27%</td>
<td>$1,446</td>
<td>$55,000</td>
<td>32%</td>
<td>5%</td>
</tr>
<tr>
<td>TF</td>
<td>$736</td>
<td>$58,000</td>
<td>15%</td>
<td>$1,448</td>
<td>$80,000</td>
<td>22%</td>
<td>6%</td>
</tr>
<tr>
<td>SV</td>
<td>$1,005</td>
<td>$49,000</td>
<td>25%</td>
<td>$1,482</td>
<td>$62,000</td>
<td>29%</td>
<td>4%</td>
</tr>
<tr>
<td>KCDP</td>
<td>$780</td>
<td>$51,000</td>
<td>18%</td>
<td>$1,400</td>
<td>$63,000</td>
<td>27%</td>
<td>8%</td>
</tr>
</tbody>
</table>

The exclusive enclave status for TF should be given a frame of reference with respect to the age of housing stock. TF, similar to KCDP, had only 16% of units built after 1990 (Figure 4). In fact, 36% of the housing is more than 50 years old. Prior to 1969, whether the age of a unit is a positive or negative attribute is on a case by case basis, where craftsman and mid-century modern homes can bring a premium. I cannot, in this study, go into that level of detail, however, it would provide additional evidence towards economic exclusivity. Excluding these exceptions, both reference sites and KCDP contain a higher percentage of residential units built between 1969 and 1989 than DK. Only 17 percent of housing units in KCDP were built after 1990, and the figures for TF were within that range as well. For SV, it was less than 5 percent, yet while comparable in rent, 49 percent of housing units in DK were built after 1990, and only 18% prior to 1969 (Figure 4). A simple calculation for DK reports that only 30% of the added housing units were at the expense of older units. This would suggest that a variety of housing options, with respect to age, are available within DK. This diversity of housing marks a clear difference between the criticisms of affordability in denser mixed-use developments, and the implementation of a FBC that allows this type of development to be collocated within an existing urban fabric. While the zoning code allowed for new development,
and whether that new development is affordable becomes, at most, ancillary to the larger scale economics of an area governed under FBCs. I would argue, and basic economics would support, that any new construction, without an external supplement to consider, is more expensive than older units of the same build quality of their time.

Figure 4: Age of Housing Stock, 2000-2017

Income growth was previously discussed, and income is directly related to jobs. The last comparative measures pertain to the validity of mixed-use development, governed under FBCs, towards a preferential job/housing ratio. Job density in DK dwarfed both reference sites and KCDP, and for 2014, was 30,700 jobs per square mile (Figure 5; U.S. Census Bureau, 2018). The nearest comparisons were both KCDP and TF, at 2,700, while SV was 1,800 jobs per square mile. Between 2004 and 2014, DK added 6,000 jobs, while TF added 400, SV added 500, and KCDP contracted. Urban economic theory posits that this elevated rate of job creation was not derived solely from direct job creation but included induced job creation, or indirect jobs, partly from increased population density. Local direct jobs are market dependent, but local indirect jobs result from both the market and the density of consumers within a given market area. To be clear, using statistics from 2015, almost 12,000 people commute into DK for work, which bolsters both direct and indirect jobs disproportionally (U.S. Census Bureau, 2018).

Figure 5: Job Density, 2014

While not analyzed, additional benefits attributed to collocation of jobs and housing within a defined area are reduced congestion and commute times, reduced costs for employees, reduced costs needed to enter the job market, reduced employee tardiness, a 24-hour market for local businesses, reduced stress to roadways and accompanied services (such as police), the previously mentioned infrastructure savings, and reduced carbon emissions and accompanying air quality. (Armstrong et al., 2001) From that list, the costs to enter the job market were considered integral for upward mobility and positive impacts to community characteristics. Between 2010 and 2017, after the banking crisis of 2009, poverty in DK was reduced 3.6 percentage points. This reduction was 56% greater than TF, 620% greater than KCDP, and the poverty rate increased for SV.
CONCLUSION
This study was a precursory analysis in discovering the economic benefits of FBCs, but quantifiable results clearly indicate benefits to DK after the adoption of FBCs. The benefits to municipal coffers are well documented by numerous researchers, and tax revenue benefits are clearly demonstrated. Benefits to the development community, in the manner reflected in this paper, are market flexibility, risk mitigation, and most importantly, financial arrangements that exponentially increase cash-on-cash returns. For the urban scale case study, the notion that denser, mixed-use developments do not support family populations is shown to be a misnomer. Additionally, exponential symbiotic relationships between increased densities of citizens, housing, and resultant jobs had a positive impact on incomes, poverty, upward mobility, and a diversity in housing options. There were certainly externalities, such as up-zoning, that played a role in the success of DK over comparable reference sites or KCDP as a whole, but as increased density is promoted by the Form-Based Codes Institute, this change is also in alignment with intent. These initial findings support FBCs as a beneficial policy tool for economic development, much needed relief for the balance sheets of governing bodies, and the flexibility needed to reduce risk for developers. If this is an example of how America returns to the original dream, it is a worthy path to replicate. There is clearly a need for continued research on this topic, a task I wish to assume with an expanded scope, in the future.

REFERENCES
Form-Based Codes Institute. From Desert to Oasis: Transformative FBC Will Help Turn a “Big Blank Piece of Sand” Into a Diverse, Attractive Community. 2017.


Rothwell, JT, and DS Massey. 2010. “Density Zoning and Class Segregation in Us Metropolitan Areas” *Social Science Quarterly*


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1 Financial data is in thousands of dollars. All property data sourced from the Miami-Dade Property Appraiser, property search portal. Residential units were not retained by the developer (sold), figures represent a total sum of data for 400 units sourced independently. (Appraiser 2018) For a relative comparison, I use a per acre figure to describe attributes. Projected rent (PR) is figured for a full year at the median rate per square foot for commercial space in Kendall CDP. Market Data sourced from 42Floors.com. (Inc. 2019) For Site FBC, being mixed-use, Site FBC 1 represents the commercial space, Site FBC 2 represents the residential space, and FBC Tot are the combined figures.

2 Current average rate per 42Floors.com.

3 The majority of data was sourced from the US Census Bureau’s American FactFinder. (Bureau 2018b) The varied sources within include: Decennial Census Survey’s for 2000 and 2010; Census Gazetteer 2010; American Community Surveys for 2010 and 2017; and the Longitudinal Employer-Household Dynamics Surveys for 2004 and 2014. The decennial Census Survey for 1990 was sourced from the US Census Bureau.
ABSTRACT: This paper draws connections between building enclosure technologies from the time of Le Corbusier’s mur neutralisant and respiration exacte concepts to a present-day double-skin glass façade system, the closed cavity façade (CCF). The successes and failures of Le Corbusier’s thermally controlled interior and hermetically sealed wall concepts are examined as they were applied to Villa Schwob (La Chaux-de-Fonds, Switzerland, 1916), Centrosoyuz (Moscow, Russia, 1928), and the Salvation Army Building in its originally built form (1933). Building on this historical context, the paper discusses facade technologies that emerged in 1980s and 1990s that sought to improve upon the performance of sealed glazing by eliminating condensation, improving thermal comfort and integrating solar control: the ventilated double-skin façade and the less widely discussed façade pressurisée (pressurized facade) and façade respirante (breathable façade). The façade technologies are elaborated upon in the cases of the French National Library (1989-1995) and the Grenoble Law Court (1994-2002) where facades were fabricated by French manufacturer Rinaldi-Structal. In these projects, non-standard building technologies were developed and applied through the aggregate efforts of French government research labs, manufacturers, architects, and insurers. Today, breathable façade technology is largely limited to use in France; each application receives technical review by a state agency during the design phase. On the other hand, pressurized façade technology has spread to other parts of Europe and beyond under the name CCF. Innovative forms of CCF developed by Gartner/Permasteelisa, based on initial experimentation in coordination with a German research institute, continue to push the performance envelope: CCF with facade-integrated ventilating floor slots (Roche Diagnostics, Rotreuz, Switzerland, 2011), CCF with operable windows (LEO Building, Frankfurt, Germany, 2013), CCF with wooden louvers in the cavity (EY Center, Sydney, Australia, 2014), CCF with tilted exterior faces (JTI Headquarters, Geneva, Switzerland, 2015). The built works and the threads of technological development between them are identified as applied research that bridges between theory and practice.

KEYWORDS: breathable; closed cavity; double-skin; façade

INTRODUCTION
Most, if not all technologies go through an initial phase of development in which there are competing technical ideas, which eventually resolve themselves into what is recognized as the mainstream of development (Yeomans 1998, 59).

Closed cavity facades (CCF) are presented by the industry as new, state-of-the-art glass curtainwall technology. In fact, the pressurized sealed double-wall technology was developed and applied over two dozen years ago in the final Mitterrand-era Grand Project, the French National Library in Paris (1989-1995) designed by Dominique Perrault (Fig. 2). Superior thermal performance in CCF is maintained by a steady stream of dry air supplied to a sealed air space between two glazed skins. Pressurization, which requires minimal energy to operate, prevents condensation in the glazing cavity and avoids the need to clean the interior of the window units. The desire to have a tightly sealed wall with superior thermal and operational performance is not new, and a number of insulated glazing technologies were developed and deployed before and alongside CCF. From a starting point of Le Corbusier’s theories about active walls, the following sections discuss how theories about sealed walls have been elevated into current practice through applied research.
1.0 SEALED GLASS WALL CONCEPTS

1.1. Mur neutralisant and respiration exacte

Le Corbusier’s Five Points for a New Architecture—pilotis, free plan, free façade, ribbon window, and roof garden—were theoretical principles that the architect applied and developed through experimentation with actual buildings, often in collaboration with engineers and other architects. Le Corbusier’s attention to natural ventilation, light and solar control is evident in the architectural forms. Less visible perhaps is Le Corbusier’s interest in combining passive and active techniques to achieve thermal comfort (Solla 2011). The successes and failures of the thermally controlled interior and hermetically sealed wall concepts can be followed in the Villa Schwob (La Chaux-de-Fonds, Switzerland, 1916), Centrosoyuz (Moscow, Russia, 1928) and the Salvation Army Building (Paris, France, 1933). Through these built works Le Corbusier learned certain boundaries that building physics placed on his theories and that glazing required ventilation and shading to avoid excessive heat build-up.

Glass facades have always been a source of light to interiors, and only sometimes a source of natural ventilation. In the first decades of the 20th century, glass architecture grappled with the new possibilities and technical challenges offered by mechanical central cooling. The idea of hermetically sealed interiors that would keep out noise and air pollution of industrialized cities competed with recognition that natural ventilation has energy-free practicality and capability to overcome stuffy and potentially unhealthy interior air. For a time, Le Corbusier promoted sealed walls alongside the active concepts of mur neutralisant, thermally conditioned air cavities between sealed glass or opaque wall construction, and respiration exacte, mechanical air conditioning capable of controlling both temperature and humidity.

In an early experiment at Villa Schwob, Le Corbusier placed heating elements between two fixed glass layers in a large multistory window of the residence (Solla 2011). Later at Centrosoyuz, a social housing project designed with Russian architect Nikolai Kolli, Le Corbusier intended for a thermally conditioned air cavity to be used in both opaque and glazed wall areas. The interwall air spaces were to be served by a secondary mechanical system, separate from the building mechanical air conditioning system. This time the experimental ‘hermetically sealed’ proposal was tested before construction by the glass manufacturer St. Gobain and the American Blower company, who found the wall concept to be impractical and consume excessive amounts of energy (Wigginton 2000). In the adapted design, stone walls were built as a single layer with no air space. Ribbon windows were built as two glass layers with an unconditioned air cavity and sliding windows; solar control remained an unsolved problem for Centrosoyuz residents (Fig. 1).

Le Corbusier proposed the mur neutralisant idea again at the Salvation Army Building. The south-facing facade of the building was to have a closed-loop air conditioning system dedicated to conditioning the air space between two all-glass wall layers. The system was again deleted due to uncertainty and cost. The facade was constructed as a single, sealed glass wall. In the first summer, overheating proved intolerable for the occupants, and Le Corbusier was forced to have a series of sliding windows installed in the upper third of each window area as a retrofit. Shortly after these experiences, and inspired by travel and commissions in hot climates, Le Corbusier is observed to make a transition from active to passive wall concepts in order to avoid the solar overheating and glare problems associated with large expanses of glass (Taylor 1987).
**1.2 Insulating glazing units**

Even while Le Corbusier’s own work evolved to include solar control and ventilation as necessary accompaniments to glazed walls (consider the *brise soleil* and *aerateurs* of the Carpenter Center, for example), the theory of the ‘hermetically sealed’ glazed wall remained a compelling concept. From the mid-century emergence of Thermopane, the sealed glass wall concept has been under continuous development. Insulated glazing units (IGU) and manufacturers’ proprietary curtainwall framing systems are produced with ever-improving thermal performance and durability. Material technologies continually improve the performance of windows and curtainwalls. In the areas of glazing: plate glass, tighter and more durable seals, tints and reflective coatings, low-emissivity coatings and films, gases in the sealed cavity. In the areas of framing: thermally broken frames and factory-sealed unitized construction. With the advent of of low-iron content glass and frameless, structural glass technologies, it is now possible to specify ultra-transparent walls with high thermal resistance and high visible light transmittance.

But even the highest performing systems have limitations. Heat build-up in sealed glass units, especially those with blinds integrated into the cavity, limits the durability of gaskets, reradiates heat to the interior and creates risk of condensation. Double wall technologies were developed that sought to improve upon the performance of single-skin sealed glazing. A variety of construction strategies, including both ventilated and unventilated designs, aim to eliminate condensation and improve thermal performance while still integrating solar control.

**2.0. VENTILATED DOUBLE-SKIN GLASS FACADES**

In addition to seeking daylight and transparency with thermal comfort, double-skin glass facades were developed in response to factors such as acoustic buffering and energy conservation. These criteria motivated the construction of early double-skin architecture including the Cattle Dealers Savings Bank by Behnisch and Partner in Stuttgart, Germany (1969), the Occidental Chemical Center by Cannon Design, Niagara Falls, New York (1981), and Briarcliff House by Arup Associates, Farnborough, England (1983). In each of these buildings, facades were externally ventilated. The introduction of an outside air stream passing between the two glazed skins serves a critical role of evacuating excess heat and humidity and reduces the chance for condensation forming on any of the surfaces. Externally ventilated
facades are found with a wide variety of details regarding glazing, ventilation openings and cavity depth profiles. Many have openings in the inner skin that permit natural ventilation of interior spaces; some have provisions to draw warm air from the cavity to supplement building heating. The general principle of an externally ventilated double-skin is shown in Figure 3a.

Early double-skin facades were also developed with internal ventilation. The air space between two glazed skins serves as a return air plenum integrated with building mechanical systems. Conditioned room air is drawn between the two skins where it creates a constantly refreshed thermal buffer against heat gain and losses through the facade. Cavity air is returned to the building services for energy recovery. Typical airflow in an internally-ventilated facade is upward (Fig. 3b), however, in one of the earliest versions of this technology, Lloyd’s of London by Richard Rogers, London, England (1986), airflow is downward (Fig. 3c).

Figure 3: Ventilated and unventilated double-skin glass facade schematic configurations. Source: (Author)

3.0 UNVENTILATED DOUBLE-SKIN GLASS FACADES
Less widely discussed are early double wall innovations that do not feature pass-through cavity ventilation: facade respirante (breathable facade) and façade pressurisée (pressurized facade). These unventilated facade technologies will be elaborated upon in the cases of the Grenoble Courthouse (1994-2002) and French National Library (1989-1995).

3.1. Facade respirante (breathable facade)
The courthouse in Grenoble, France designed by Claude Vasconi employs both ventilated and unventilated double-skin facades in its enclosure. Glass, daylight, and transparency in the architecture are intended to convey the “light of justice” in France’s modern judicial system (APIJ 2003). A multistory ventilated double-skin facade clads an eight-story office block, and an unitized box-window breathable facade forms the backdrop to a large public atrium space (Fig. 4). Opaque facades are clad with lacquered steel panels.

The thermal performance of the southwest-facing office block facade relies on external ventilation of a 692 mm (27 in) wide, multistory airspace. Motorized dampers at the base and the top of the facade control airflow between the two glass skins. Clear low-iron glass is single-glazed in the outer skin and double-glazed in the inner skin. Motorized louver blinds for solar control are protected from weather inside the cavity. Catwalks are integrated into the structure so that the facade interior surfaces are accessible for maintenance. Although still considered innovative at the time the courthouse was built, this climate-adaptable type of ventilated double-skin had been in use in Europe since the 1980s.

In a contrasting design solution, the double-skin in the courthouse’s west-facing atrium consists of tightly sealed modular facade units fitted with fine mesh filters permeable only to vapor. Small oblong filtered openings in the lower frame area link the double-skin air space with the exterior environment, a technique that allows vapor pressures to balance between the
air space and the exterior, thus preventing condensation in the cavity (Fig. 5). Glazing here is also clear low-iron. Solar control is provided by fixed external metal louvers. As discussed in Section 4 below, application of breathable facade technology required (and still requires today) technical review by an agency that works on behalf of the French government to support the emergence, development and safe use of innovative building technologies.

3.2. Façade pressurisée (pressurized facade / closed cavity facade)
The French National Library in Paris, France designed by Dominique Perrault also aimed for utmost transparency with the highest level of thermal control. The performance challenge of cladding the iconic book-shaped glass towers was met with an innovative new pressurized facade double-skin technology (Fig. 6). Called closed cavity facade (CCF) outside of France, the application at the French National Library is likely the first in France and possibly first in Europe.

In the French National Library facade, a pressurized supply of filtered and dehumidified air is continuously fed through tiny tubes in the modular unit frames to a sealed air space (Van Santen 2001). The dry air, supplied in minute quantities based on external climate conditions, prevents condensation in the air space and, because dust and other contaminants are not brought into the airspace, eliminates the need to clean the cavity. Pivoting wooden panels set back from the glazing provide solar control (Fig. 7). The extra-clear glazed outer skin is structurally glazed to the frame using a silicone sealant specially engineered for the application (Dow Corning).

4.0. APPLIED RESEARCH MECHANISMS
Some details about how the facades for the Grenoble Courthouse and the French National Library came into being give a glimpse into the workings and drivers of innovation. In these buildings, experimentation with non-standard techniques occurs on a grand scale with the cooperation of client, architect, facade manufacturer, government research lab, and insuring bodies who shared the common goal of developing and applying new building technologies while managing the risks of innovation (Bonham, 2012). French facade manufacturer Rinaldi-
Structal fabricated the facades for both landmark buildings, working in close collaboration with the buildings’ respective architects and project teams to realize ambitious design visions.

Figure 6: French National Library. Double-skin pressurized facade (CCF). Single-glazed outer skin, 90 mm (3.5 in) wide pressurized air space, double-glazed IGU inner skin. Source: (CC-BY: Fred Romero)

Figure 7: French National Library. Floor-to-ceiling wooden panels pivot to control light. Source: (Author)

4.1 Progression of breathable wall technology

The theory of *respiration* that led to breathable facades was first studied by the French Scientific and Technical Centre for Building (CSTB) in the late 1980s as a solution to the problem of condensation forming in standard insulating glazing units in which seals would typically fail after years in use. The experimentation developed into the present day double-skin configurations with vapor permeable filters. Air space widths can range from 40 mm (1.5 in) to 500 mm (19 in). The wider versions can accommodate architectural elements such as operable louver blinds in the cavity (CSTB Dec 2007; Keinlin 1994).

With roles somewhat akin to the National Institute of Standards and Technology (NIST) and national labs like the National Renewable Energy Laboratory (NREL) in the United States, scientists and engineers in CSTB labs test and develop technical innovations. Manufacturers may come to the CSTB requesting preliminary assessment of new products; design teams in collaboration with builders and fabricators may request assessment in order to apply unproven building techniques. After technical evaluation, products and techniques can seek acceptance by a technical committee of French insurers with the goal to earn normal cover status in damage and responsibility insurance (Atkinson 1995).

Breathable facades are manufactured by a number of companies who are allowed to commercialize their product lines referencing a technical appraisal by CSTB called an *avis technique*. Based on lengthy analysis and tests of products in their first years of existence, this technical notice denotes a level of security and quality comparable to traditional products and processes (CSTB 2009). Technical review of a breathable facade includes a project-specific study of the proposed application’s climatic conditions, materials and dimensional configuration, after which recommendations are made for details such as the number and size of the filter openings (CSTB 2009).

Rinaldi-Structal fabricated all the facade types for the Grenoble Courthouse (APIJ 2003). Though largely constrained to distribution in France, breathable facades are presently being...
manufactured by a number of fabricators, including Arcora, Kalory'R, and Wicona, each of whom is competing to add value and performance to their version of the technology. For example, Kalory'R promotes a breathable window unit with operable vents and integrated blinds as the “new generation of breathable windows.” Like other breathable facades in France, the window meets stringent thermal and airtightness regulations and is marketed under a CSTB technical document specific to that product (Cyberarchi 2014).

Breathable facade technology is employed throughout France in projects such as the 28-story Oxygène Tower in Lyon by Arte Charpentier and the Louis Dreyfus Building, a renovation in Paris with a retrofit facade fabricated by Groupe Goyer (Hespel 2011). Rinaldi-Structal was again the fabricator for the breathable facades of a new hospital in Douai, France designed by Brunet and Saunier (CSTB May 2007).

4.2. Progression of CCF technology

The pressurized facade concept first employed in the French National Library is now being widely marketed under the name CCF by European façade manufacturers. CCF can be seen as an evolution and a hybrid of preceding strategies. Designers and manufacturers sought the thin profile, thermal performance, and maintenance benefits of double or triple glazing with blinds sealed in the IGU cavity, but wished to avoid the problems associated with blind controls passing through the unit seal and the increased levels of trapped heat created due to the thermal mass of the blinds. They sought the ability to expel heated air from the cavity as could be done with internally or externally ventilated double-skin facades, but wished to avoid condensation on the glass and eliminate the cleaning cycles necessitated by air passing through the cavity. With units as thin as 40 mm (1.5 in), CCF and other double-skins with thin-profile air spaces have a reduced facade zone compared to earlier-developed thick-profile double-skin facade options.

In comparison to ventilated thin-profile double-skin facades, CCF have comparable thermal, visual and acoustic performance without the disturbance to occupants those systems require when the facade units must be accessed for periodic cleaning of the glass and the blinds. According to a leading manufacturer, U value of CCF glazing is 0.89 W/m²/°K (0.16 Btu/h/ft²/°F), g value is .55 (0.15 w/blinds), and light transmission = 69% (De Bleecker 2012).

CCF performance comes with a cost that currently limits applications to high-end properties. According to an account of the London market, CCF installation costs are in the same range as an all-glass thin-profile ventilated double-skin facade, costing 30 or 50% more than a base case of single-skin curtainwall with 50% solid panels. The cost premium allows projects to have a conventional facade zone depth, larger window-to-wall ratio, and an improved thermal, visual and acoustic environment while still meeting strict European energy codes. The expectation is that life-cycle costs support the investment, however, data on maintenance and operating costs is lacking (Mudie, Coleman and Watts 2017).

Working both inside and outside of France, facade manufacturer Josef Gartner, a subsidiary of Permasteelisa, is known for progressing a number of developments in CCF technology beginning with the in-Haus2 project in Duisburg, Germany (2008-2009). The building for the Fraunhofer Society is a research facility for the study and promotion of intelligent facades, room and building systems. It features five types of experimental curtainwalls including a closed cavity facade prototype for Gartner/Permasteelisa (Rudolf 2012). Permasteelisa quickly brought CCF technology into serial production with their MFree-S (moisture/ maintenance-free sustainable) line. Press releases for subsequent projects celebrate one ‘first’ after another: Roche Diagnostics, Rotkreuz, Switzerland (2011): First CCF application in Switzerland, and first ever integration of CCF with fresh air preconditioning ventilation slots. LEO building, Frankfurt, Germany (2013): First full-scale CCF application in Germany (after in-Haus2), and first ever CCF with operable windows. The major refurbishment project replaced the existing Poseidon House building facade with CCF, glass fiber reinforced concrete facade panels, and BMS-controlled parallel-opening windows. EY Centre / 200 George St., Sydney, Australia (2014): First CCF application in Australia, and first ever integration of wood solar protection in the CCF air space (Permasteelisa).
CCF modules create a unique quilted appearance for the facade of the JTI Building in Geneva, Switzerland (2015) designed by SOM (Fig. 8). The design takes advantage of a feature that all double-skin facades have when the inner skin forms the primary thermal and air control layer for the interior: because the inner skin is constructed with thermally broken frames and tight seals, the outer skin can be designed with more freedom. In the JTI facade, the triple-glazed inner skin of each sealed unit is vertical and flush to abutted modules. The outer skin is diagonally split into panels that tilt alternately inward or outward such that projections shade alternate panels (Ijeh 2014).

With innovative high-profile building applications and widely-distributed press releases, Gartner/Permasteelisa’s leadership in the CCF market is unmistakable, but they are only one of the companies that offer the high performance facades. Wicona and Rinaldi-Structal are among the list of manufacturers who have developed CCF systems.

4.3. Disappearance or diffusion
CCF technology appears to be spreading globally. But breathable facade technology, which offers a completely passive configuration without the integration of the air supply system, does not appear to have the same momentum. A breathable facade was applied for the first time outside of France in the European Court of Justice of Luxembourg (2007). Designed by architect Dominique Perrault (of French National Library fame) with facade planning specialist Ralf Rache Engineering, the court’s breathable facade was fabricated by Gartner/Permasteelisa (Fig. 9). This latest first had potential to be a harbinger of more widespread use of breathable facades. CSTB engineer Jean-Louis Galea says about the Luxembourg project:

> For this project, CSTB has made a provision of a rather special kind. On one side, there was no question of applying the French legislation; on the other hand, it was normal to benefit companies of our expertise... We hope the use of this French technique on a landmark building is only a first step that will help other developments abroad (CSTB Dec 2007).

Subsequent news of breathable facade export outside of France is not readily found, however. The barrier to technology transfer could perhaps be related to intellectual property or other legal or political boundaries.

While there are no completed CCF projects in the United States known to the author at this writing, the increasing practicality of unitized, thin-profile high performance facade systems is beginning to be recognized in this market. The National Institute of Building Sciences (NIBS) awarded Permasteelisa North America with a 2017 ‘Beyond Green’ Honor Award for company’s propriety CCF system. The “writing is on the wall” that CCF will soon be a first in North America.
CONCLUSION
CCF manage to merge the seemingly incompatible strategies of ventilation and hermetic seal. The space-saving sealed units perform on par with externally ventilated double-skin facades and have the added benefits of minimal maintenance and avoidance of visible ventilation openings on the façade exterior. The tiny flexible air tube infrastructure is easily integrated into perimeter floor edges, and the air handling system required to pressurize the supply of dry and filtered air requires minimal energy. If power goes out, the facade units are tested to remain condensation-free for up to twelve hours. Both *mur neutralisant* and *respiration exacte* concepts are present. With CCF, have we finally realized the perfect marriage of Le Corbusier’s passive and active principles? Or will all-passive solutions like breathable facades prevail in the long run?

In the North American market, answers to such questions will likely be pinned on practicalities such as the development of regional manufacturing, design, and construction expertise related to the new technologies. To become mainstream practice, these high performance facade solutions will need to meet cost and procurement criteria as well as support project goals for energy conservation and architectural intent.

REFERENCES
De Bleecker, H. 2012. Permasteelisa MFee-S Closed Cavity Façade: Cost-effective, Clean and Environmental, presented at the Council on Tall Buildings and Urban Habitat (CTBUH) 9th World Congress.
ABSTRACT: Architectural projects contribute to economic development through many channels, including the specifying of materials and building systems. As specification systems become more standardized, relying on familiar manufacturers or product lines, architects inadvertently contribute to concentrations of opportunity – and potentially resulting wealth – along established supply chain channels. With increased globalization of product manufacturers and supply chains, those who benefit from this system are frequently distant from the community in which the project resides. This research identifies an interdisciplinary process to help refocus the economic benefits of material choices through repositioning the design professional within the ecosystem of those decisions. This process leverages architectural services to enhance local economies through social and material capital.

INTRODUCTION

Architectural design and construction projects contribute to economic growth through numerous channels. Frequently local tradespeople are engaged in building assembly, and occasionally architecture itself becomes an economy-fueling attraction, demonstrated by the well-documented regeneration of Bilbao (Franklin 2016). Sourcing of construction materials and building systems is another potential economic driver, but – due to competing project forces such as budget, schedule pressures and even habit – its ability to propel targeted economic growth is frequently underexploited. Few practitioners have a clear understanding of the economic impact of their choices on regional and global wealth distribution.

With increased globalization of product manufacturers and supply chains, architectural materials are now frequently sourced from locations distant from the community in which the project resides. Without rigorous research into – and even creative repurposing of – local resources, architects may inadvertently contribute to concentrations of opportunity and wealth along established supply chain channels, potentially to the detriment of local community economic health.

This research explores the opportunities for architects to redirect the financial benefit of material choices to targeted locations in support of robust local and regional economies. The project began in 2016 and is co-led by HGA Architects & Engineers and the University of Minnesota through a national research consortium connecting academia and architectural
practice. The research probes the following questions:

1) Do current architectural material procurement processes reinforce existing wealth distribution, thereby rewarding global supply chains at the expense of local networks? What are the potential roles for the architect in reinforcing or reshaping this trend?

2) What are the economic drivers that privilege non-local sourcing, and how can they be disrupted?

3) How do traditional design and documentation processes contribute to these trends? How could these processes evolve to re-center the investment benefit?

The following pages will outline the research context, findings and conclusions, and speculate on the state of practice and its place in navigating global and local economic dynamics.

1.0 MATERIAL ECONOMIES

A material’s life-cycle influences an entire ecosystem of economic impact throughout its stages of extraction, production, use, and end of life. With varying degrees of wealth distribution, the labor and logistics involved at each stage can be traced to a single locality or individual. Two examples illustrating the relationship between declining material production and community economic health are described below.

1.1 Shifts in U.S. aluminium production and economic impact

The decline of aluminum production in the U.S. and its impact on employment has gained significant national attention over the past decade. Several decades ago, over 30 primary unwrought aluminum smelters operated in the U.S. As recently as 2011, there were 13 smelters nationwide; by 2017, only 5 remained in full operation while 2 continued with limited production (Tsuji and Torsekar 2017). New York Times correspondent Binyamin Appelbaum analyzed the causes of this decline and revealed the beneficiaries of the industry’s national exodus in a story published in 2017. Appelbaum describes the impact of decisions made by Alcoa, an American-owned aluminum production company, formerly known as Aluminum Company of America, which has closed plants in the U.S. and is now primarily operating in Iceland.

While the decline of domestic aluminium production is frequently attributed to Chinese competition, the high cost of U.S. electricity has also played a role, along with the age and inefficiency of U.S. plants. Iceland’s unique geography enables the island to harness melting glacial water to create inexpensive electricity, attracting industries like Alcoa with heavy energy demand; already low energy prices were further subsidized to entice development.

As a result, Reydarfjordur, located on Iceland’s eastern coast, has experienced a remarkable revitalization of its community, economy, and population since 2007 due to the influx of new jobs created by the burgeoning aluminum industry.

This is precisely the kind of globalization that economists have long told us is beneficial. Iceland gets jobs. Alcoa shareholders get higher profits. Shoppers in the United States get lower prices. Of course, there is also a hefty cost: factories closed, jobs gone, communities torn apart (...)(Appelbaum 2017)

One of these communities is Wenatchee, Washington, whose Alcoa plant closed in 2016. In addition to the 428 jobs provided by the plant itself, Alcoa was estimated to drive $60 million annually into the local economy according to Eastern Washington University’s Institute for Public Policy and Economic Analysis. The plant closure has left the community scrambling to replace the revenue source, and an effort to reopen the plant has been ineffective. Facing a similar fate, the state of New York agreed to pay Alcoa $73 million in public funds to maintain plant operations in struggling upstate Massena for 3.5 years. That agreement expires in March of this year.

1.2 Community decline and the wood industry in Oregon

The U.S. wood product industry has been subject to economic fluctuations, most recently during the Great Recession of 2008 which devastated home builders and the construction
While the Great Recession precipitated a steep drop in wood production nationwide, the Pacific Northwest has seen steady decline since the 1990s due to environmental protection regulations, changes in land use policies, and technological innovations. This area’s rural regions were profoundly affected, as the wood products industry “has played an important role in rural employment for decades and few other skilled labor jobs are available” (Gale et al. 2012). Towns that were once reliant on logging as the main source of economic revenue and jobs suffered exponentially with the gradual disappearance of an industry.

Sweet Home, located in West-Central Oregon’s Linn County, still experiences economic instability and high unemployment resulting from the regional deterioration of the wood-based economy. Classified in the American Communities Project as “Graying America” – defined by low diversity and a large senior population (Chinni 2016) – the community faces increasing homelessness, low wages and a poverty rate over 20%.

The food bank has a more secure future than remaining industrial jobs, and the town is full of people looking for second or third acts without much of a script to guide them. (Johnson 2014)

As logging jobs have disappeared, so has the young adult population, leaving behind an aging community struggling to adapt and attract new industries. Despite an elevated unemployment rate, nearby Roseburg has lost major employers to nearby regions due to frustration with the ability to attract quality workers (Matassa Flores 2015).

Sweet Home is working to grow its economy through a community trail network “to draw more hikers and cyclists.” (Johnson 2014) Successful economic rebranding in the region is not without precedent; Bend, another former Oregon logging town has reinvented itself as a tourist destination. Such change is complex and slow to evolve, however, and at this time the path to economic stability for Sweet Home is unclear.

2.0 CONSTRUCTION MATERIAL SOURCING AND ECONOMIC AND ECOLOGICAL TRENDS

While the U.S. continues to see rapid growth in many non-manufacturing industries, such as healthcare, more than half of the twenty most rapidly declining industries are from the manufacturing sector (Bureau of Labor Statistics 2017). Several of these declining industries are closely connected to construction, such as logging, iron and steel, and machinery manufacturing2. As major manufacturing industries that supply the construction industry deteriorate, the sourcing of materials by necessity shifts elsewhere, exacerbating the rate of decline. As the examples in Section 2 illustrate, the results can be disastrous for communities.

Industrial flight has a dramatic impact on everyone. Depleted industrial centers endure the long term effects of unemployment and diminished public services. The declining tax base means less money for schools, roadways, and public safety. (Alliance for American Manufacturing 2016)

Shifts in architectural material sourcing have ecological, as well as economic, impact. Next to food production, the construction industry is the largest consumer of raw materials (Berge 2009). Architects can act as indirect – and unintentional – enablers of unsustainable consumption through the specification of building systems and materials. For example, Brazilian exports of ipê increased by 500 percent between 1998 and 2004 in response to classification of mahogany as an endangered species, and wood products treated with chromated copper arsenate as a preservative were determined to be unsafe. A very dense material resulting from a slow growth rate, ipê’s sudden popularity led to unsustainable harvesting practices in Brazil; soon ecologists began branding ipê as the “next mahogany” (Hutton 2016).

Understanding the economic and ecological impacts of material sourcing can be challenging for practitioners. Architectural practice is often confined to a well-established scope of services
that limits the time and resources available to research these topics in depth (AIA 2017). Further, these two issues do not necessarily align as one may expect. Architects have become accustomed to the distances defining “local” in LEED and other sustainability guidelines, but interviews with economic experts revealed that “local” capital flows and geographic distance may be only loosely related. Economic regions can easily be impacted by topography, resource distribution, as well as financial and social networks, making an accurate definition of “local benefit” challenging to articulate.

Finally, while sustainability principles encourage local materials and system sourcing, economic and ecological agendas may occasionally be at odds, particularly in communities based on legacy manufacturing industries. Navigating these issues requires a deeper understanding of economic and ecological forces than most practitioners currently possess.

3.0 FACTORS DRIVING MATERIAL SELECTIONS
In order to understand how the priorities governing materials sourcing can be augmented, it is useful to analyze the factors that frequently drive selection decisions, as well as the process limitations that reinforce current practices.

Through this research project, the team assessed the priorities frequently driving material choices within the sponsoring firm. Deciding factors included local conditions such as constructability or availability (often within tight timeframes) and project constraints such as budget or construction type. Other considerations included warranty, reliability, production capacity and client preferences or standards. Ecological impact was often considered, but frequently clients prioritized cost or schedule over less calculable benefits, particularly as project budgets became strained. Several projects explored local material sourcing to build community favor and benefit local industry, particularly in smaller or rural communities, but these examples were generally limited in measurable economic impact. Ultimately the research team did not uncover a standard process for the selection of materials, but rather a carefully studied list of priorities, which frequently shifted as projects developed.

Our research into the materials selection process also reinforced the limitations of time and project fee on material and system choices. Driven by the need for efficiency and consistency, the sponsoring firm relies on a robust set of standard specifications to establish system quality levels and avoid unexpected problems during or following construction. Interview teams frequently relied on these standards for many material and system choices, reinforcing existing procurement systems.

Given the pressures already faced by practitioners, as documented through the research, the time required to develop deep knowledge of local material availability – and its economic impact – would require an offsetting benefit or service line opportunity to be financially viable. Alternatively, incentivizing manufacturers to document and publish economic relationships and regional impact could shift much of the considerable time investment to supply chain partners. This will be explored further in Section 7.

4.0 CHALLENGING NORMS AND UNCOVERING ROADBLOCKS: PILOT PROJECT
As illustrated above, the local economic impact of materials selection is typically a lower priority for architectural projects – if it is a consideration at all. However, what if a project team – architect, client and contractor – deliberately prioritized this issue? To what degree would “standard” material selections be altered, and could the local economic benefit be quantified? These are the questions the research team explored through a pilot project in 2017.

The pilot was tied to a live project at the sponsoring firm – a small, rural hospital located in a coastal community in the Pacific Northwest. This project was selected due to its potential alignment with the goals of the research and the interest on the part of the client; the community had experienced declining local industry, and 49% of households earned less than the basic
cost of living for the state. The project was also a useful case study, as the broader healthcare system providing oversight had recently identified system-wide material standards it planned to implement on all future projects. Project stakeholders wondered whether local economic benefit derived from alternative material choices could encourage reconsideration of the system standards.

In collaboration with local economists and industrial ecologist partners, an initial economic analysis revealed systemic gaps and potential opportunities to deliver local economic benefits through strategic material selection. In particular, the availability of wood products, local masonry production and stone quarrying showed promise.

Success in implementation, however, was mixed. Given stringent budgetary challenges and fire code restrictions, locally-sourced interior wood was eventually replaced by standardized product systems provided by nationally-recognized manufacturers. The specific geographic sources for the wood products comprising these systems were not well-documented by the manufacturer, so assessing regional relationships and potential economic benefit was challenging. Exterior wood cladding wasn’t considered, as the extremes of the coastal environment would require significant maintenance or unpalatable treatment expense. Stone and masonry choices proved more successful; in particular, a locally-quarried stone was selected to replace the system-wide standard product, which was sourced from China (the local client and healthcare system did not previously know the origin of this material and appreciated that a local alternative was identified). Locally-sourced masonry products were selected to complement the stone cladding. In addition, regional site materials, such as hazelnut shells and seashells for mulch, raised some intriguing sourcing ideas.

Challenges to fully implement large-scale impact included the following:
1) A relatively small number of materials that could be locally sourced. Given the stringent requirements of the hospital environment (including infection control and maintenance), many healthcare-tested interior products lacked a viable local alternative. In addition, major building components – such as the structure and HVAC system – simply couldn’t be provided by local fabricators.
2) Difficulty in quantifying the ROI. The client was prepared to spend marginally more for local products in return for community good-will and partnership-building. However, their resolve was tested when the contractor – required to deliver the building for an established cost – questioned the quantifiable value of local choices. Calculating the tangible economic impact proved challenging, as it required a detailed understanding of local capital flows beyond the capacity of the team; quantifying the intangible benefits was even more difficult.

The pilot identified several gaps in industry processes and typical design team expertise needed to leverage material selections to impact the local economy in a meaningful way. The research team used these findings, as well as previous research regarding typical material decision drivers, to formulate a potential framework that aspires to enact change more consistently and at a larger scale.

5.0 TURNING THE TIDE WITH A SPECULATIVE FRAMEWORK
Fueled by the unique convergence of academic research and research in architectural practice, this project posits that the challenges of material procurement standards are aligned with the consequences of volatile global economic trends. Both the construction industry and the architectural profession are enablers to deeply embedded economic networks benefiting global development with limited attention to the local impact. The processes in place for material selections, however organic, could – and ultimately need to – aid building projects beyond the limited ecosystem of the building site, thereby expanding scale and yielding a prolonged growth in a segment of the local economy. By reverse engineering the typical outcomes of building projects, the team developed a speculative framework that could augment current processes to disrupt the inertia behind traditional material selections. As demonstrated by the pilot project, partnering with economists and other experts to better propose avenues for impacting the local economy is essential to make informed specification
decisions. While many traditional design team consultants contribute to these decisions, the scale of their roles and agencies remains tactical, limited to introspection within the project site and building. This research calls for the need to partner with experts skilled in realizing the benefits of connecting with broader ecosystems that specifically look towards economic development. Ideally, an economist would have a significant impact to early design phases when site analysis and preliminary assessment of building systems takes place by uncovering that segment(s) of the project area’s economy that could be impacted by material selections or other strategies.

With an expert guiding some of the early decisions in the project, such decisions could deliver a degree of sustained local economic impact in the project area extending beyond the duration of the project. To track and properly assess this type of outcome, an integrated process informed by robust evaluative tools would be needed within the design and construction process. Establishing direct links between material selection and metrics such as jobs created, or even quantitative indirect impacts on the economy, could help the design team refocus and reprioritize the critical factors informing material selection. Precedents for other broader community benefits already exist in construction, such as zoning ordinances, fire codes and energy codes.

Engaging an expert and the development of a tracking tool are two practical strategies uncovered by the literature review and the challenges faced in the pilot project. A third component is establishing the ROI of sourcing locally to impact economic growth both for project teams and the client. For project teams, it would likely involve a series of synchronized projects to demonstrate significant impact and a defined period of time to reflect on the economic impacts of the decisions made.

Figure 1. Implications to the design process. Source: (Cervantes 2017)

6.0 PROJECTION
The findings of the research led to broader questions seemingly remote from construction yet suggesting interesting parallels regarding patterns in material procurement and specification. The local food and small business movement are key precedents to consider in this regard. Once considered highly costly and unsustainable, farmers, local food producers and supporters were able to raise awareness around food production – and the ecological and economic benefits of buying local – inspiring a dramatic shift in national consumption habits (Walker, Keane, and Burke 2010). Similarly, small businesses and pop-up shops represent a slow but promising movement supporting local makers, craftspeople, and inventors demonstrating social, cultural, and economic value (Hallsworth, Ntounis, Parker, and Quinn 2015).

A local material movement may face similar obstacles before ultimately earning support from policy makers, economists and construction material “consumers.” Clients, contractors, manufacturers and architects will need to embrace long-term return and even some risk in the face of immediate budgetary and schedule pressures. Benefits to clients offsetting potential challenges may include a strengthened and sustained economic base for services or products provided, a skilled labor force, and the community richness engendered by a thriving economy.
Architects, in turn, may see reward in the form of expanded value-based services, enhanced interdisciplinary partnerships and a deep understanding of local resources that could beget additional business. Moreover, by engaging economic challenges and the complexity of potential solutions, architects have the opportunity to recalibrate their professional and societal value, elevated to generators of economic development versus casualties of cyclical downturns.

One potential avenue to integrate this initiative into a broader movement is by appending an existing framework such as LEED or another sustainability guideline. LEED’s credit for materials manufactured within a given radius could be expanded to acknowledge local economic development (USGBC 2017). By extension, this could catalyze a greater movement enabling more concentrated economic impact. A second opportunity to build a local materials movement could take the form of direct economic policy including incentivization programs such as tax relief.

In closing, we must note that this research and the approaches promoted do not represent rejection of global development or partnership. It rather challenges the notion that the forces underpinning current trends in economic benefit distribution are of such a scale that they cannot be redirected or reshaped by informed stakeholders. Further, it has been demonstrated that global and regional resources can produce synergies that do not benefit one locale at the direct expense of another. As noted by Katz and Nowak in their work The New Localism: Globalization not only creates a hyperconnected world, it also opens up new means for expressing local identity and new possibilities for local development strategies. The importance of local capacities and action is augmented by global and technological change (Katz and Nowak 2017, 47).

This paper acknowledges the daunting complexities of creating new economic policies, but the reward structure and beneficiaries are not unlike those represented by recently established movements that have reshaped the architecture industry. Given the rapid rise of income inequality, propelled in part by the evolving economic forces described in this paper – and the potential to reposition architects as drivers of economic value – this topic warrants consideration and further exploration by the industry.

7.0 RELATED TRENDS IN ARCHITECTURAL PRACTICE
Climate change, energy consumption, and pollution are only some of the wicked problems facing the planet, and the architecture industry is evolving to provide leadership in the face of these changing conditions (Cramer 2017). Recent interest in alternative practice models has propelled architecture practices worldwide to challenge the architect’s traditional scope of work through partnerships, pro-bono services, joint ventures, and other clever collaborations (Kim et al. 2007).
In addition to the work described above, this research project also analyzed for-profit practices representing an array of cross-disciplinary collaborations related to aspects of economic development. These case studies demonstrated the value of applying architects’ skills in systems-based thinking to complex problem-solving, connecting otherwise disparate systems and foreseeing opportunities of improvement.

In addition to the “local economy” framework described within this paper, this case study analysis identified trends in architectural practice that intersect other emerging economic models: the circular economy, the sharing economy, and financial partnership. In each model, the architect’s scope of services produces economic value for the community in different forms. The local economic growth approach encourages distributed, targeted financial benefit through thoughtful material sourcing. A circular economy approach involves regenerative material systems deployed within the community. A sharing economy approach suggests unprogrammed spaces that shift function over time. The financial partnership serves as a funding model through financial institution collaboration to grow economic development.

While the majority of this research project addressed the local economy research agenda, relevant literature and a proposed framework for the remaining three agendas was developed to propel future research that could expand the architect’s role and agency in solving complex economic problems.

REFERENCES


ENDNOTES

1 Primary Unwrought Aluminum production involves the mining and processing of raw materials such as bauxite ore, which is smelted to create aluminum. Unwrought aluminum production employs mechanical processes, such as rolling, extruding, drawing, or forging to make wrought aluminum products from primary or secondary aluminum. (Tsuji and Torsekar 2017)

2 According to the Standard Occupation Classifying system, Architecture and Engineering Occupations are a major group of the iron and steel mills manufacturing sector; the logging subsector includes the harvesting of timber; machinery manufacturing includes the Agriculture, Construction, and Mining Machinery Manufacturing industry groups (Bureau Labor of Statistics 2017).
An architectural traverse: the idea-reality connection, argument for social housing

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ABSTRACT: The assertion that housing propagates the mixing and division of socio-economic classes in cities constitutes a significant portion of studies on socio-spatial segregation and integration. Of the two themes, studies portray housing as being responsible for driving more division than mixing. One of these such housing is social rental housing (SRH), which although designed as a vehicle for integration has often resulted in ostracization of the occupants and even of the housing development (Pendall 1999, Tighe 2010). While countrywide statistics demonstrating this ostracization and consequent opposition is not typically documented, cities around the world; in Australia, Canada, United States, and Europe show rising percentages across themes known to prompt opposition. As a social asset; we hypothesize that the problem with housing, specifically as it pertains to facilitating integration for the poor, is one of transference; that is, how can a bridge between ideas for socialization and the realization of integrated communities be effected through the design of SRH? It is our submission that a review of situations where attempts at transference are evident is necessary to understand its process. In this present paper, the intention of the authors is not to prove their hypothesis but to test it by making connections between several elements – education, educational model, and the role of the architect – as an indication of the complexity of the issue, and designing a conceptual/flow model to reveal the forces at play in the transference process. Therefore, while we discuss the aforementioned elements responsible for the mismatch of architectural idea and outcome, our focus is on architectural practice with respect to the transference of the architect’s social intentions into lived reality in the resulting building and its community. By deploying literature investigation into intellectual posturing, and best practices, we discuss two case studies (Tete En L’air and Hatert Housing) that hold promise for the future of successful transference. Initial reviews indicate that the motive for design for these projects was not solely for the purposes of providing accommodation and comfort for its inhabitants but for mixing of socio-economic levels and neighbourhood integration, which was ultimately achieved. Alongside case study review, this paper considers some philosophies of pragmatism in design - specifically those initiated by John Dewey, with the hope that his suggestions could constitute a basis for the actions implemented in the cases.

KEYWORDS: architecture, social housing, socialization, realization, design thinking

INTRODUCTION

"Bring ideas in and entertain them royally, for one of them may be the king."
Mark Van Doren (BrainyQuote, 2019)

The idea-reality connection is a delicate one that is discussed mostly philosophically. In order to grasp our argument about these two concepts, we consider the definitions from Descartes and Hegel noteworthy. According to Descartes (cited in Smith 2018), an idea can be defined “as an operation of the intellect… that expresses the objective sense”. Hegel (2014) builds on this definition by opining that, “ideas are something far too excellent to have actuality” (par. 10) although “they may be co-extensive with reality itself” (par. 1), and reality, “the result of a process of mediation; not a first principle, but a last result” (Hegel 2014, par. 2). The Hegelian philosophy (2014, par. 2) further emphasizes that: Reality must be defined, and its definition comes only with developing experience and the growth of knowledge. It is only the labors of thought that can lead us to the land of reality (Hegel 2014).
While the expectation that an idea be completely realized may be futile, there should be substantial similarities between an idea and its end product. T. S. Eliot compares idea and reality to motion and action, and like Descartes, acknowledges the divide between both concepts. However, Eliot also opines that every idea does contain a level of objective reality, which implies that they are not completely disconnected from that which is ultimately representative of them. The same can be said of the idea-reality connection in housing design. Generating a good idea is one of the most important parts of the design process; and a good idea requires the accumulation of knowledge towards conceptualization. Conceptualization differentiates the idea-reality connection in philosophy from that which exists in design. While the word in itself does not constitute a third wheel when the idea-reality connection is discussed in design, it is a necessary phase in the translation of design ideas to reality. Some of the foremost designers and Architects such as Frank Gehry not only advocate the importance of the idea-reality connection but also that of conceptualization in its implementation.

While Architects have “traditionally seen themselves primarily as creators of static objects called buildings” (Simpson 2014, par. 5), Dreessen (2015) adds that architecture through the same static buildings, is capable of bringing communities together. These buildings which are “teeming with human activity, constantly changing, and adapting to the needs of their occupants” (Simpson 2014, par. 5) can improve physical experience, preserve and amalgamate communities, and meet socio-economic needs of the community’s residents (Dreessen 2015). It is with regard to the last two arguments that this paper focuses – improvement of socio-economic standing for the poor through housing towards community integration.

The authors have selected SRH as the specific housing type for the study, because rented accommodation elicits more opposition than owner-occupied houses (Obrinsky and Stein 2007); pro-poor housing – the category within which SRH belongs – and its occupants are characteristically marginalized and resisted by the larger community when situated within non-poor neighborhoods (Pendall 1999, Tighe 2010); and our goal is to understand and achieve idea-reality transference in SRH design towards creating socially integrated communities. Based on studies conducted by Harvard University (Matta and Ashkena 2003), we acknowledge that there are other reasons why housing designs, which set out to propagate social integration within neighborhoods fail, such as: insufficient research, lack of commitment, lack of strategy to execute, limitations surrounding timing, and the unrealistic expectation of the designer but by far the most recurrent is the one our study discusses (Bashier 2014).

1.0 UNDERSTANDING THE IDEA-REALITY RELATIONSHIP IN DESIGN
This section discusses three elements known to constitute obstructions to the idea-reality transference in architecture. While we discuss the impact of architectural education and the educational model, and architectural practice, we do so solely as a means of highlighting the forces known to have the greatest impact on the architect’s ability to appropriately execute his/her role, as well as on the overall performance of the architect.

1.1 The underpinning of the transference challenge – architectural education
The transference challenge in architectural design has remained a major cause for concern for researchers globally (Bashier 2014). One of the triggers identified to be at the root of this failure to transfer is architectural education; the past century has witnessed very little change in architecture pedagogical culture (Koch et al 2006). Design education, as undertaken in the schools of architecture, appears to be preparing students for models of practice that are no longer in full accord with the current professional context (Nicol and Pilling 2005).

A report by the American Institute of Architecture Students (AIAS) indicates that the issue with architecture education is linked specifically to the “design thinking process, which is the most critical aspect of design education” (Bashier 2014, par. 2). The “report casts doubts on the effectiveness of current studio practices in providing adequate design-thinking education” (Bashier 2014, par. 2). The report focuses on design-thinking education as it relates to the
design process and ultimately, the final product. It opines that the inadequate teaching has resulted in students paying either too little or too much attention to the design process and the final product respectively (Koch et al 2006). This implies that there may be a strong design idea but the effort required to translate this design to reality is a process that students are willing to “jump over” (Bashier 2014, par. 5). The consequence of this being the students’ “reliance on intuition, disregard for the design process” (Bashier 2014, par. 6), lack of focus on idea translation, “focus on self-satisfaction, and the lack of interest in achieving social targets” (par. 6). The danger in this is that the end product is typically inadequate.

Weaver’s (1999, 35) study on a similar topic confirms that the very essence of architecture is its end product - to “determine human needs and to express them in space and form”. In principle, he opines that architecture is about practice, and revolves around pragmatism. Architecture and design can only candidly be learned and mastered through practice, through continuous attempts at problem solving (Weaver 1999). In the academic context, these problem-solving opportunities are called a ‘crit’ or ‘jury’. The crit (critique) is not only an assessment method but an essential educational tool, which is a standard feature of architectural education and is employed all over the world wherever students are taught in manageable numbers (Weaver 1999, 38-39).

The pragmatic nature of architecture implies that the student cannot be taught everything but they should be taught to think like an architect. Although the crit, which is the medium through which the student begins to express their ideas and build ‘experience’, is the strength of the architecture student, Cuff (1991) opines that the crit is one of the weaknesses of architecture education (6).

1.2 Architecture: a profession of experience… and communication

According to the National Center for Information and Documentation (NACID), architecture is one of few professions, that typically makes mention of ‘practical experience’ in its definition. To be an architect, the individual has to have garnered specialized training comprising several years of an advanced education as well as a period of practice during which the training is tested and experience is built towards earning a license to practice. In fact, the most fundamental definition of Architecture, provided by the Cambridge dictionary, defines it as an “art and a practice of designing and building structures and especially habitable ones”, where practice speaks of the “repeated exercise in the performance of an activity to acquire or maintain proficiency in it” (Cambridge Dictionary). David Lau (2018) who also emphasizes practice/experience in his definition of architecture highlights that not only is the experience of the architect important but also that of the user. He states that:

Architecture is basically designing for the user based on the experience of both the Architect and the user on a physical and spatial level, where space is just another medium and buildings and structures are the interfaces and frameworks that users can interact with (par. 5).

Besides the experience – on the part of the Architect - that Architecture requires, communication/consultation is another key issue that Architecture appears to be lacking at both the educational and practice level. In Dana Cuff’s (1991) book, Architecture: the Story of Practice, Cuff asserts to the inward focusing that transpires in the design studio, while students prepare for their crit; students begin to isolate themselves “from the outside world, knowing only how to talk to other architects” (6). This, Nicol and Pilling (2005) say carries through to the student’s professional career, where they very seldom consult users except in situations where the design/project is owner occupied. This is what Cuff (1991) terms ‘the primacy of the individual’, which should not be but rather, in contrast, the role of the architect “should be one of ‘translator’… and ‘integrator’” (Nicol and Pilling 2005, 6). The former, so that the architect can “mediate between human function and the final form” (6), and the latter, so that the design and its final form can “draw people, process, and place together” (Nicol and Pilling 2005, 6).

1.3 Architecture: providing neighborhoods and residents social assets – housing

One reason why SRH continues to be confronted by opposition is because of the stigma it is
associated with (CMHC cited in Victoria Homelessness 2014). The stigma is categorized along 6 themes (Victoria Homelessness 2014, 2): (negative impact on) property values, (fear of) crime and (fear for) safety, density (resulting in congestion and strain on infrastructure), (fear that the low quality materials, aesthetic unpleasantness, and poorly integrated structure will ruin the) neighborhood character, new resident behavior ["influx of residents that may not share similar values or social norms" (Victoria Homelessness 2014, 2)], and existence of enough pro-poor housing (therefore developers should look elsewhere). Half of these fears are linked to the structure itself, which implies that the problem is rooted predominantly in the poor design of SRH (Iglesias 2002). Hulse et al. (2012) states that this issue with poor design poses a hindrance to allowing SRH play its key role, which is largely one of propagating social inclusion. How? In a majority of countries, SRH is deployed as a housing type provided for the poor, who otherwise are unable to compete in the marketplace for housing of an acceptable standard (Oxley 2009). The rationale behind SRH is that as a social asset, it should provide the “household with a safety net, sense of citizenship, and belonging” (Urban landmark 2009). SRH is sometimes considered one of the policies provided “under the banner of social inclusion” to “ameliorate problems that are manifestations of socio-economic disadvantage” and to “enhance the capacity of those excluded from accessing mainstream services and employment opportunities” (Hulse et al. 2011, 12).

SRH, when properly designed and constructed should first, provide the status improvement that enables its residents be perceived as a worthy population in the neighborhood and be accorded due respect that enables social mixing (Gregory et al. 2016); and second, be perceived as an important and necessary part of the neighborhood for creating heterogeneity and ultimately a balanced ‘community’, rather than be considered an unwanted land use (Gregory et al. 2016).

1.4 Defining the specific problem
As this study seeks to support the hypothesis about (idea-reality) transference, it is important to determine that indeed the architect holds primary responsibility for such transference. Additionally, because our paper makes the case for SRH, which has continuously been confronted with issues of opposition, we find it is also necessary to determine that the architect indeed holds the pivotal role of integrator towards the goal of realizing integrated communities. Despite the assurance in research about what SRH should be, the reality is that its goal is very seldom actualized. Therefore, this paper seeks to answer the question of how SRH can be used as a ligament between ideas for socialization and the realization of integrated communities. To answer this question, we have chosen to approach it from the viewpoint of the architect because housing and housing design – key elements in this study - are fundamentally the responsibility of the architect. Because an individual’s profession is directly and significantly impacted by their education, we focused on architectural education as the foundational cause of this problem.

To understand what either drives or interrupts the idea-reality translation in the architect’s design (of SRH), research makes mention of design theories related to pragmatism.

1.5 Pragmatist theory on architecture (and design)
According to the de facto design theory, John Dewey’s philosophy, design is a creative action that should “create something preferable and respond to expectations” (Ostman 2005, 12). The only way we can know that a design idea has been successful, which is the central aim of Dewey’s theories, is that the outcome is favorable. Although Dewey admits to our inability to guarantee exact outcomes, he insists that we can create a reasonably reliable outcome through skill and inquiry, where the latter is the very means for ensuring that changes and processes are controlled towards achieving the desired outcome (Ostman 2005, 12). Dewey’s pragmatic philosophy of design is not reduced to conceptualization and reasoning on an abstract level but should touch real life problems and actual situations… which must then be brought back to real life for verification (12).
This implies, according to Dewey (1958, 36), that “secondary conclusions” (36) made by the architect be crosschecked and reflective of “the things of ordinary experience” (36) derivable from those for which the design is made. Dewey (1980) states that the bridge that enables the successful cross over of ideas to reality is emotion. He refers to emotion in this context as a “fusing power” (Ostman 2005, 13), one that forms an integral part of the pragmatist theory and therefore must not be excluded. Based on his studies, he opines that although emotion is linked to our exercise of value judgment... it is a manageable unit in the understanding of design problems, processing of design solutions and successful execution of design operations (13).

2.0 LESSONS FROM THE PRAGMATIST THEORY-CASE STUDY COMPARISON

This section justifies our rationale for hypothesizing the existence of a connection between the lessons from cases and John Dewey’s pragmatist theories.

2.1 Why look to the pragmatist theory of architecture?

Over the years, the object of architecture has been investigated such that despite the architect (designing the idea), and the approach, the result typically is a building that has fundamentally been reorganized – one with little dissimilarity from what previously existed (Ostman 2005). Ostman (2005) compares this to industrial design where, traditionally, with every design, consumer and market surveys are initially conducted, which results in characteristically functional products. One could therefore argue that the architect may need to grasp and apply the idea and process of inquiry into user experience, so that architecture can be what it is - an important vehicle to support healthy human life. In the same vein, Dewey (1938) rejects the thinking that the physical is the most important in investigations towards design; rather, he proposes that the prime focus should be relational. His attention was on altering the relations in real world situations while emphasizing the need to trust in the human experiential contribution and the democracy of those contributions (114, 245). Essentially, Dewey (1938) was making an argument for the architect to focus more on the source of knowledge founded on daily interactions and experience, which he indicates is the “true knowledge” (66) required. He adds that this in no way negates the importance of scientific methods, research, and the architect’s logic/reason, and experience from practice, which are all necessary for creating the knowledge required for successful design outcomes (Dewey 1938). However, in isolation of any of the other elements, Wolfe (1999) calls the architect’s logic/reason incomplete and “improper” (17).

The whole "truth" about architecture and architectural design is not to be found in the reasoning. Reasoning is but one tool (Wolfe cited in Ostman 2005, 147). Another noteworthy element Dewey highlights is the difference in tastes according to social class. He emphasizes that design must appeal to all social classes (Dewey 1980). We believe that this element may be one of the key reasons for the continued opposition towards SRH within non-poor neighborhoods. Based on Dewey’s (1980) assertion, and in alignment with our estimation, it is at the point of design/construction that the architect determined that the selected materials – specifically those used externally – were befitting to the development and the status of the residents, without considering the perception of the existing neighborhood residents. According to Dewey (1980), addressing the aesthetics is “not a short moment of insight... but a whole process of doing”, it is not a “simple pleasurable activity but one of undergoing, of suffering, ... which might be painful” (41). This is because when the architect believes he may have concluded work on his design, he has to continue to work on that design, refining it to ensure that it fits into its designated site - in terms of the existing fabric and character of the neighborhood. The idea of the new design fitting into the existing fabric and character of the neighborhoods refers specifically to another prong within the aesthetic section of Dewey’s theory - that of context-relationship (193), which holds that every design or object should not be designed in isolation but always in context to avoid the introduction/injection of conflicting elements that may unfavorably impact the situation (36, 195).

Dewey (1980) also highlights a theory that removes the architect from having the sole responsibility for the design, and the direction/outcome of the project (Ostman 2005, 322) to
making it the role of “the users and other parties” (322) so that the outcome is a product of cooperation and therefore holds a higher probability of success.

The final theory amongst Dewey’s (1980) theories that the authors discuss is that of newness. Design is a controlled creative action. The control, however, cannot be complete. There is always a space for changes and discoveries, and therefore the creation of something new. The implication of this is that although the object to be designed remains the same, the findings from previous attempts should inform future efforts, and result in a positive/more favorable change of outcome. This then begs the question as to why SRH has continued to maintain a global reputation of prompting opposition despite innumerable design and construction attempts. Where is the newness that should be manifested with the execution of subsequent efforts?

2.2 Social rental housing cases with evidence of the idea-reality transference

For decades, in the SRH discourse, “anything above the bare minimum was lavish, and anything lavish was an insult to the public purse” (Williams 2017), and therefore considered a waste of funds. The pride of housing ministers at the time was speaking “about stripping ‘unnecessary’ extravagancies such as balconies and windows” (Williams 2017, par. 1) from SRH developments. The result was a “dishevelment of social housing” (Williams 2017); where developers delivered faceless, characterless, poorly planned, high-density blocks, situated on lands with high costs, which are an antithesis of what SRH should be. SRH should not “just provide a roof and four walls but should utilize creative design to make low-cost buildings feel like high-quality homes” (Nettler, 2013). The poor nature of these developments has persevered until today, and has begun to impact the universal ability of architects to create a “proud… and awesome social housing building and environment” (Williams 2017, par. 3).

Amidst the stigma associated with SRH, a handful of countries have realized that one of the best combat strategies against the opposition stemming from the typically unpleasant SRH development is to ensure that the development affords those who need them the dignity of well-designed and distinctive homes. Mostly within Europe, a majority of the notable examples include developments from Slovenia, Spain, France, Belgium, and Netherlands. These developments have been termed ‘successful’ for the following reasons: (I) effective land use planning, (II) appropriate design, (III) assurance of social cohesion, (IV) affordability, (V) aesthetic pleasantness, and (VI) appropriate construction (Oyebanji et al. 2017). These translate into housing developments that successfully mix people from the different social classes.

The two cases this study will review are Tete en L’air Social Housing and Hatert Housing. In 2014, Arch Daily rated both of these developments among the top five SRH developments worldwide (alongside Monterrey Housing by Elemental, Tetris Apartments by OFIS Architekti, Savonnerie Heymans by MDW Architecture) (Scott 2014). These cases will serve as both instrumental and intrinsic case studies, which Barzelay (2007) states refers to cases used to understand a bigger sample and reveal the richness of the case respectively. In this era of increasingly conscious SRH designs, these two cases have maintained top ten ranking among SRH developments globally by various articles, and have also been noted as breaking the mold of what SRH has typically been by helping to undo the negative stereotypes, and serving as remarkable works of architecture thus eliminating opposition. This prompts us to assume that because the projects appeal to a wide range of assessors, there is the possibility that they were successful in achieving aesthetically pleasant designs and integrating both the building and its residents into the neighborhood. According to Wood (2017), both developments are “safe and resilient housing projects” (5-6), which “foster the greatest sense of community between its residents... and build lasting personal relationships within the neighborhood through direct and indirect connections established by sharing common areas of living” (6).

While we are unable to state emphatically and explicitly that these cases are success stories, a review of the intentions of the architects and the outcome for both designs reveal an alignment with the ideas and hypothesis of the authors. Furthermore, based on the criteria of
success proffered by Oyebanji et al. (2017) above, we are convinced that the cases reviewed are indeed, favorable.

In the following paragraphs, the authors will discuss various other noteworthy points from the cases alongside some of Dewey’s.

**TETE EN L’AIR by KOZ Architects**

While there is little to no academic review of the project, the popular Architectural Digest, Arch Daily, which accords the building the ‘Building of the Year’ award for 2013, shares excerpts from interviewing the architects behind the design.

The Tete en L’air (Tel) social housing, built in 2013, is situated on a deep and narrow plot in a working class area in Northern Paris. With this building, the aim of KOZ Architects was to provide SRH that could be perceived as a “small scale utopia” for its inhabitants and promote the idea that SRH can evoke a feeling of pride, community and togetherness for the entire neighborhood.

To transfer their intentions to reality, the initial idea of the architects was to avoid altering the character of the area allocated for construction. Their primary step therefore, was to study the street-life of the area, which they found to be “dense and energetic” (Vassilopoulou 2014). The first thing the architects did was to ensure that the old structure, which was in extremely poor condition, on the allocated site was not demolished rather the “original structure was preserved in order to maintain the picturesque nature of the street” (Vassilopoulou 2014). Their knowledge of the street and area is noted as being the main influence to the design of the structure. Furthermore, the building was designed to emanate sophistication even while engaging with the neighborhood. The design, which features boxes “plugged into the façade rhythmically, gives the building a spontaneous character” (Vassilopoulou 2014) that resonates with the energy of the street and neighborhood. The architects were convinced that to blend the building into the neighborhood, it had to have a very ‘natural-looking’ façade/exterior. To achieve this, they decided on building completely in wood, as well as incorporating courtyards, shared spaces, pathways, and public gardens within and through the premises to allow the residents enjoy a high level of comfort/quality of living, and for the building to draw neighbors and members of the community unto the premises thereby fostering inclusion and mixing.

**Figure 1:** Tete in L’air. Photography by Cécile Septet (Chua 2014)

**Figure 2:** Housing Hatert. Photography by 24H architecture (Chan 2011)

**HATERT HOUSING by 24H Architecture**

Hatert housing, popularly known within its city’s boundaries as ‘the crown of Hatert’, was built in 2011 in Nijmegen Netherlands. At the time of design/construction, “housing in the Hatert area was undergoing a great renewal project” [Natufied, 2019 (formerly one-half of the
An architectural traverse: the idea-reality connection, argument for social housing

foundering partnership for 24H Architecture) because a significant amount of the city’s housing required substantial renovation. The intention of the architects therefore, was to produce SRH that would comply with contemporary housing standards that the city was working towards (24H Architecture 2011). The first step towards achieving this was to work in collaboration with the city of Nijmegen and the office of Khandekar to access the city’s master plan in order to either identify available land within (a) neighborhood(s) where “most of the present houses were renewed, or identify a new neighborhood, which would be filled with new housing projects. Following the option of the former, and therefore well suited to the neighborhood within which it would be constructed, the architects designed a 72-unit, 13-storey tower atypical of the traditional boxy-block social housing buildings. To create the intendment modern design, the architects chose to add some irregularity in its form in order to express a strong visual identity thus the building featured “free-form balconies wrapped around the building with metal screen railings” (24H Architecture 2011), visual harmony with its surroundings, and elements (such as a public space and community health center) that would facilitate socialization among the residents of the building and members of the neighborhood (24H Architecture 2011). Its contemporaneous nature has resulted in it becoming a landmark within the neighborhood that is located.

2.3 Correlations between the reasons for success in the cases (lessons learned) and Dewey’s theories

“There have been recent attempts to invoke the pragmatist philosophy into architecture” (Ostman 2005, 321).

Dewey’s theories, unlike the relationship proposed by several others, have been able to take an approach that is most devoted to social action and comprises some ideas with which our idea finds the most common ground. The cases introduced above, similar to Dewey’s theories, focused their designs around the same theme; towards ensuring that their ideas for socialization resulted in the realization of integrated communities through housing design.

Based on the review of the two cases highlighted above as well as myriad other SRH success stories, research reveals that SRH successes fall under one overarching intangible reason; the architect never losing sight of the goal of the development. The present review also divulged the following sub-reasons and recommendations:

Successful idea-reality transference is primarily a result of cooperation. In thinking that the architect is fully ‘in charge’ or is the ‘lone designer’ of the project, the source of input into the design is limited to a circle of fellow architects, which severely impedes the probability of neighborhood acceptance and integration. What Dewey suggests and what is observed from the case studies is a project, where “each party works on his/her own understanding of the design’s qualities” (Ostman 2005, 322). For instance, “the architect cannot administer aesthetic judgment alone” (322) and therefore requires a variety of perspectives. Because of the diversity of aesthetic thinking especially as it concerns parties who are directly impacted with the project, the architect should act as a tool for these parties, who may build on the architect’s own aesthetic ideas. The architect therefore, should collaborate with other parties on such projects but maintain some form of autonomy. As seen in both cases, there was cooperation between the architects and the neighborhood/planning authorities/government. However, following this collaboration, the onus was on the architect to decide to what extent contribution from stakeholders will be retained/implemented in the design.

Our studies showed a solid, on-going communication and relationship with authorities, governments, and a host of other stakeholders within the cities that the SRH developments are erected during the period of their construction. In a bid to avoid working in isolation, and in the midst of a barrage of contributions, the architect risks losing the clear image of the end product initially set for the proposed development. Thus, while guiding theories, evaluations, and opinions are necessary, the decision on which contribution to implement or disregard should lie with the architect so that the end product, which may have been modified based on stakeholder participation, still reflects the architect’s idea towards neighborhood socialization and integration.
Communication is critical because the cases identify it as being the backbone of their projects. In fact, the initial steps taken towards the design of the cases revealed continuous and clear communication between the architect and stakeholders. For project success – as evidenced by the cases – the architect must use communication effectively and be influenced by properly understood and processed information. According to Taleb et al. (2017, 2), “project outcomes increase due to effective communication”. 24H Architecture, the architecture firm responsible for Hatert Housing, emphasized their utilization of the two forms of communication, verbal and non-verbal communication. Studies show however, that the architects considered verbal communication the more efficient of the two. Information between the architects and the other stakeholders was executed via channels that were both physical and electronic, and comprised renderings, drawings and written documentation. Based on excerpts from both Architecture firms, communication with stakeholders commenced prior to conceptualization of the project and was carried through to completion with specific groups such as: the planning authorities and the residents of the neighborhood (24H Architecture 2011; Vassilopoulou 2014). The content of the communication between the architect and the stakeholders varied according to the group. For instance, 24H Architecture reveals that the firm collaborated with the city (planning authorities) for general information (site history, topography, boundaries, plans for future expansion, etc.) and planning/building considerations (impact of local development, rights of access, party walls etc.).

In alignment with Dewey's (1980) arguments, the architect is only able to exercise autonomy through communication. The architect's ability to articulate the design, design process, design qualities, and the design motivation is crucial.

The execution of a good design often requires verbal motivation. The design process is far too fraught with conflict, and the parties often too far from each other, to trust that the solutions speak for themselves (Ostman 2005, 322).

The architect needs a thorough knowledge of the design they propose and its benefits in order to enforce its validity and suitability to the context.

From studying the breadth of information available on both cases from the websites of their respective architecture firms, the clarity and understanding of the goal and objectives for each project was explicitly stated from inception. This enabled the architects to recognize which portions of suggestions from stakeholders could be disregarded/observed -- which compromises/sacrifices they could make in order to ensure that the stakeholders identified with the project.

Looming large is the development of a practically-thinking mindset. The architects with the responsibility of designing the SRH development focused primarily on executing a functional design. This, we observed is evident in the step-by-step outline of the bases for the decisions taken in the creation of the SRH design. While both cases have evidence of this, the latter does more so than the former. Besides the creation and construction of a SRH design that would be capable of satisfying the needs of its residents with regards to the provision of shelter, affordability, and adequacy, the architects also achieved a building design that would be practical in its goal of integration and acceptance within the neighborhood by including amenities on its premises that would guarantee the visitation of the larger community.

Although architecture needs the knowledge, perspectives and grounding of theory, these should be instrumental in making design execution more intelligible. The architect should always remember that “a good-looking, well functioning and economic design is preferable to those where there are deficiencies” (Ostman 2005, 330). We believe that with this pragmatist mindset, architects would desist from designing SRH buildings that are ugly, and unfavorable to both the residents and neighboring community specifically when research indicates that such designs/buildings are frequently abandoned, demolished, and/or underutilized (Fatoye 2009). In some circumstances, as is seen with the first case discussed in this paper, the housing provider proceeds to return to the initial site to erect another development resulting in a duplication of effort/resources. This is avoidable if architects can consider the practicality in...
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...doing away with the long-standing notion of faceless, characterless, poorly planned, high-density SRH blocks, and make the goal of every SRH design be to get it right the first time. Education matters. The aim of learning is improvement and understanding. The architecture firm, KOZ Architectes, responsible for the first case referenced in this paper, referred to the education gained from not only their academic study, but that gained from considering older, global successful SRH examples, the desire to continually improve on future social housing projects, and the experience gained from years of designing social housing as influential to their continued success in social housing provision. Dewey (1980) agrees; he discusses the idea that one cannot learn all about their profession from the requisite academic education but must reach into other areas – life, practice, and related fields. For such an integrative discipline like Architecture, the architect needs “an interdisciplinary approach to learning, combining and comparing ideas from different fields” (332).

“A stronger integration of design knowledge from various (design) fields and sources - than the current situation - will presumably produce more than a few successful architects… an architect will not be able to execute design successfully in the field just because he knows the basics of design” (Ostman 2005, 332).

CONCLUSION

In the present paper the authors have argued for greater connections between education and practice, for heightened efficacy in both realms. Even more emphatic is their argument for enhanced collaboration between the architect and stakeholders; most notably on the part of the architect - the architects willingness and ability to listen, learn and respond; to communicate. Our suggestion that communication be used as a vehicle to bridge the idea-reality divide (in the form of the communication technique applied, points in the time line of the project that communication was critical, types of communication utilized, and the subject of communication during the lifespan of the project), the critical review of the literature, the case study methodology, and our model (that views the forces at play in this context more completely) are contributions we believe are necessary, and that we have made, which are significant advancements, albeit insufficiently developed at present, to build support towards our hypothesis.

![Education-Practice Relation Model](image)

**Figure 3.**

The model noted above underscores the pressing need for systemic reform whereby the architect (and associated stakeholders) work in close cooperation with clients and users to bring solutions to fruition that are responsive, responsible, respectful and appropriate. Too often the players in the equation operate in isolation, with inadequate evidence and with narrow agendas in action. The authors suggest that new ways of seeing, learning, conceiving and constructing are in order at the present juncture. For housing to better suit its needs, and to be embraced by a broader audience, architects must connect meaningfully to the
communities in question, must discharge their responsibilities ethically, and must realize solutions that resonate with needs, culture and context. To achieve this, both education and practice need overhauling in rather dramatic and innovative ways.

For the global community in an era such as this, where the expectation from professionals – one of whom is the architect - is ever increasing, the present paper has dealt with architecture and the idea-reality/transference concept, with particular emphasis on John Dewey’s pragmatist theories. Designing for the benefit of different social classes; to guarantee comfort, for effective functionality, and to attend to the needs of the users requires a more relevant architectural educational background alongside experience/practice, and continuous professional development. The combination of these is able to furnish the architect with the knowledge to successfully convert design ideas to reality and in so doing, provide SRH that breaks the mould and achieves the primary purpose for which the housing type is provided – to drive social mixing and integration within neighborhoods. We are of the opinion that the more architects are able to acquire well-rounded knowledge, the more opposition towards SRH will continue to diminish. As in the cases highlighted, a SRH development that excels in integrating neighborhoods is indeed achievable and in the present paper, we discussed elements we found that are: i) present in both cases, ii) lessons that are transferrable architect to architect, and, iii) foundational for successful transference.

Upon commencing the study, we speculated about the need for more practicality in architecture towards successful transference. A review of John Dewey’s pragmatist theories on Architecture divulged a substantial connection with realizing architectural ideas. The connections we discussed do not form an exhaustive list therefore we recommend that supplementary cases be studied simultaneously in order to uncover additional connections and lessons. We also make recommendations for improved architectural education and the acquisition of knowledge and skills in order to make the global SRH change needed. This work remains urgent and timely as part of an on-going research. The present paper is connected to the doctoral research of the first author, with an intention to broaden the understanding of forces in place towards that the development of opposition-free, integrated, affordable, and adequate SRH.

REFERENCES


Gregory, James, David Mullins, Alan Murie, and Pete Redman. “Social housing and the good society.” Housing and Communities Research Group (2016)

Hulse, Kath, Keith Jacobs, Kathy Arthurson, and Angela Spinney. "At home and in place? The role of housing in social inclusion." *Australian Housing and Urban Research Institute* 177 (2011)

Hulse, Kath, Keith Jacobs, Kathry Arthurson, and Angela Spinney. “How does the concept of social inclusion play a role in housing policy?” *Australian Housing and Urban Research Institute* 156 (2012)

Iglesias, Tim. “Managing local opposition to affordable housing: A new approach to NIMBY.” *Journal of Affordable Housing* 12, no. 1 (2002): 78-121


Weaver, Nicholas. "Atelier Principle in Teaching." *Paper delivered at the Conference on Project-Based Learning*, Denmark: University of Roskilde

Methods of knowing: grounded theory in the study of future-use architecture

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ABSTRACT: Unlike disciplines defined by well-established methodologies, no single method characterizes architectural research. Instead, scholars and practitioners adapt approaches from across disciplines in the humanities, natural, and social sciences to answer the questions at hand. Questions in, of, and about contemporary practice demand the systematic creation of new knowledge; but design inquiry necessarily yields knowledge highly-situated in specific projects, and struggles to integrate qualitative and quantitative data, to address uncertainty, and to demonstrate validity. While the discipline produces and consumes research, the study and dissemination of research methods in education and practice remain rare, ad hoc, and anecdotal. This paper traces the methodology of a multi-year research project bridging research and practice conducted by a team of academics in response to a call from the profession for research advancing adaptive and regenerative buildings. The work builds on years of speculative design research and historical-theoretical scholarship in the context of the academy and was awarded a significant research prize to support a two-year program of research seeking significant advances in the profession. The resulting knowledge addresses both scholars and practitioners, supporting application in practice and scholarly discourse about the built environment. The team adopted a grounded theory approach: seeking not to test a specific hypothesis but to develop an organizing theory. Through a mix of methods, architectural practice and architectural products became both the subject and object of research. The team conducted dozens of structured interviews with selected designers, clients, and building occupants, which were recorded, transcribed, coded and synthesized. Nearly one-hundred building projects were identified as possibly valuable case studies, and documented through analytical design drawings, and compared using graphic matrices. This paper describes and evaluates the methodological choices and their implications for research in the built environment.

KEYWORDS: grounded theory; research methods;

INTRODUCTION

Like all systematic efforts to identify new knowledge, architectural research depends on the paradigm, or system of inquiry, in which research is conducted. Beyond the ontological consequences on what questions are asked; paradigms’ epistemological stance inevitably shapes the forms and methods of inquiry, dictating how a study is conceived and executed (Groat and Wang 2013, 65). As a multidisciplinary practice, architecture encompasses a great breadth of paradigms, engenders diverse research topics, and thus offers a great many methods from which to choose. This paper traces the application of one method—grounded theory—for a specific inquiry situated in a particular locus of research and practice.

1.0 BACKGROUND: THE CALL AND THE PROPOSAL

1.1 Proposed research program

The project described here addressed a call for a two-year program of research leading to significant advances in the profession of architecture and focused on research about buildings that change and adapt over time. Under the banner of Adaptive Reuse and Regenerative Buildings, the call emphasized responses to new uses and to dynamic environmental conditions. In response, the proposed project, titled Future Use Architecture: Design for Persistent Change expressed the goal of designing today to allow a building to support human
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occupancy in many possible but unknown futures. By questioning design based on programmatic determinism, the proposal suggested buildings organized around the inherent logics of building systems, their architectural arrangement, and the resulting cultural value. This idea wove together numerous threads of prior individual and group inquiries about the balance between flexible and fixed building systems; buildings’ response to dynamic and unforeseeable contingencies; and the conservation of essential architectural design and performance. Furthermore, the proposed work built on a long-standing approach using the lenses of resilience and future change to help students enrolled in the Comprehensive Design Studio at Northeastern University develop integrated, comprehensive design.

For years before embarking on this project, the research team had been developing and co-teaching the Comprehensive Design Studio and the associated lecture course Integrated Building Systems, which together challenge teams of students to integrate architectonic, environmental, and structural systems into high-performing, long-lasting buildings that adapt to unknown future environmental, spatial, and human conditions. The technical rigor and theoretical grounding in precedent buildings discussed in the lecture course, coupled with the speculative, open-ended inquiry of design studio helps students develop fully-integrated environments that engage building and landscape systems at multiple scales. Thus the students engage in design research, a projective form of inquiry examining the modifications of places, spaces and practices over time (Leatherbarrow 2012). This example suggested that unconscious knowledge from practice may be discovered by subjecting practice to similarly provocative questions.

1.2 Proposed research plan
To build a rigorous research study from this existing speculative framework, the proposal outlined an empirical approach based on investigating selected case-study buildings to identify physical, and non-physical attributes associated with buildings that have successfully changed use over time. Those attributes would form the criteria to select illustrative precedents that demonstrate and explicate the principles through scholarly and professional publications and exhibitions. The practical focus of the investigation precluded purely speculative, or theoretical approaches in favour of ones based on real buildings. While experimental methods like a randomized controlled trial set the standard for rigor, they are often impractical for building-scale questions, whereas empirical can rigorously observe variations that exist in the world. Empirical methods do have limitations. One—described by the cum hoc fallacy—lies in mistakenly attributing each building’s survival to its unique features although the features are present and the building survived, the correlation does not prove one caused the other. So expanding the sample to include negative examples of projects that had failed to successfully adapt can test whether the absence of specific attributes limited or precluded future-use. More importantly, mixed methods that incorporate other forms of evidence that cannot be gleaned from analysing the artefact itself—for example personal accounts of the social context and history of buildings—can explicitly connect building attributes with decisions to preserve or not. As with all case studies, collecting, documentation, and analysing multiple examples constituted the bulk of the proposed effort, and highlights a second challenge: selecting the right buildings to ensure they represent the breadth of relevant conditions, comprehensively cover the investigation space, but do not bias the findings with preconceptions. Fortunately, a decade of teaching, sharing, and collaborating with a diverse studio faculty had produced a geographically, typologically, and chronologically diverse list of example buildings. The proposal described these lists, and the method itself as a starting point which would expand and evolve as the project progressed.

2.0 METHODOLOGY: GROUNDED THEORY
Existing research methods can quantify the costs and benefits of long-lasting buildings, for example life cycle cost assessment can test Alex Gordon’s ideal of “long life, loose fit, low energy” by measuring durability (long life), adaptability (loose fit) and sustainability (low energy); by quantifying the tangible and intangible costs and benefits of buildings over time (Langston 2018). However, many aspects of Future-Use Architecture specifically—like architecture generally—defy quantitative analysis: design processes; human motivations for
or against preservation; and socio-cultural factors make it impossible to measure or predict the long-term reuse of buildings. Furthermore, the attributes that allow (or cause) buildings to endure are inherently project-specific and context-dependent cases of broader general phenomena. These types of complex, multivariate problems can only be understood through observation and analysis of projects, practices, and people, operating in different contexts: in other words, through qualitative research. Quantitative methods are considered top-down (from theory to hypothesis to data), while qualitative methods are considered bottom-up (Bollo and Collins 2017). In this case observing phenomena or studying examples leads to patterns and themes which in turn coalesce into a theory. Grounded theory is a systematic method of analysis to make research based on qualitative data rigorous and validated. The bottom-up research method used in this project is illustrated in Error! Reference source not found.

Figure 5: Simplified, linear concept diagram of the research process, grounded in multiple data sources (bottom), which are synthesized and analysed to identify the attributes, which are in turn explained and ultimately disseminated (top). Dates on the left indicate a rough timeline, while the words at right characterize the dominant mode of enquiry.

2.1 Interviews
A major form of data for this project consists of structured interviews which ask architects, clients and users a set of identical and pre-planned questions (while allowing varied follow-up questions as each interview progresses). This method allows the researchers to understand the many aspects of projects not visible in the drawn or built work, including ways architects learn from older buildings, the challenges of working with historic structures, and the lessons from witnessing projects evolve. Interviews can trace the intersection of design theories with the complexities of practice, and outline the role of clients, users and other stakeholders in future adaptability. In short, these personal accounts fill in the context of design decisions otherwise inaccessible through the work itself.

As mentioned above, the quality of interviews depends on the selection of subjects, and the years of teaching provided a list of people and practices doing relevant work, starting with those who designed, occupied or managed the case study buildings. The team cast a broad net, inviting architects, engineers, developers, financiers, lawyers, contractors, construction managers, property owners, facilities managers and researchers based on their connection to specific buildings or the topic in general. Research that involves people carries an ethical imperative to protect human subjects, even when, as in this case, the work is far removed from the biomedical research that gave rise to the Belmont report (1979). The team prepared a complete human subjects protocol, anticipating a designation as exempt human subjects research based on the interviews presenting "no more than minimal risk of harm" (45 CFR: Public Welfare 2018, §46.101(b)(2)). In this instance, the project was determined not to be human subjects research, on the basis that buildings rather than people were the subject of the study, and any people we interviewed were acting only in their professional rather than
personal capacity. The compliance staff at our institution suggested the helpful analogy of an oral history project: the information needed was not written in books, it was remembered by people, and interviews were the only way to get it. Even though the protocol was ultimately not needed, the process of preparing it helped develop the interview questions, systematize the research procedures, and produce documents such as standard outreach letter.

Table 1: List of questions for the structured Interview

| WHEN and WHERE has your work considered change over time? |
| Can you suggest specific projects should we talk about? |
| WHY are the buildings you’ve worked on—whether new, renovated, or in general—worth keeping? |
| HOW does the design process change when considering long-term future change? |
| WHAT design strategies and project attributes enable long-term future change, and which preclude or challenge it? |
| WHO prompts considerations of future change, who benefits, and who pays? |
| WOULD you be willing to share documentation with us to support our research? Is it okay if we contact you with any follow up questions? |

Interviews—particularly structured interviews—depend on good questions, with sufficient specificity to elicit useful responses about a consistent set of issues and to afford structured analysis. On the other hand, open-ended questions often yield unexpected, and therefore uniquely valuable insights. Naturally, good questions avoid leading the subject to preordained responses that simply reinforce the interviewer’s initial bias. To develop the questions for this project, the researchers first individually brainstormed open-ended and specific questions. Working together in several meetings, the principal investigators merged, sorted, and categorized these questions into a set of overarching root questions, shown in Table 1. We sent the questions to the interview subjects in advance, so they could prepare, and explained the methodology as a sort of informed consent for use the information. With the first draft in hand, we conducted an initial interview with a highly sympathetic (and patient) subject as a pilot of the questions, the logistics, and the method of analysis. Reviewing the transcript (with time stamps, see below) revealed that the researchers spoke too much, both in length and content; resulting in a thoughtful but wandering conversation rather than the rigor of a structured interview. In response, the team organized follow-up questions by topic in an interview reference guide to keep the researchers focused, and the interviews consistent.

Once the questions and structure were established, the effort switched to logistical rather than intellectual aspects of the method, for example scheduling fixed blocks of time each week, and coordinating travel to maximize in-person (rather than telephone) interviews. The team found a simple voice-memo app on a smart phone produced adequate audio quality if the microphone was centrally placed and background noise kept to a minimum. A large external battery ensured the phone did not power off mid-interview. Audio recordings raise numerous privacy and legal issues. During in-person interviews, researchers could simply ask permission prior to starting a recording device, and leave the device visible as a reminder. Remote interviews must consider legal restrictions on wiretapping, and several technologies were considered for conducting and recording phone interviews, including online-meeting platforms. Ultimately the team adopted the free application Google Voice, which can record calls and save files to a Google Drive with reasonable quality, and also announces the start and end of recording. For both in-person and phone interviews, recording was mentioned first in the invitation letter or email soliciting the interview, and the structured interview protocol includes confirming consent before starting the recording. In person, the subject can see the researcher turn on the device, while on phone calls, the Google Voice announcement creates a record of consent directly in the recording and transcript. Both recording methods produced acceptable quality and file sizes, with only minor hiccups in playback. In only one case the interviewee declined to be recorded but agreed to review the detailed notes of the investigators and offered corrections and even additions to the notes, which were then coded like any other transcript. Initially, we hired undergraduate students to transcribe the recordings, hoping to benefit from their subject-matter knowledge and modest cost while offering a research experience and the opportunity to hear these conversations. The students were trained to use a standard syntax
indicating who was speaking, and to tag with square brackets passages when the quality of recording or complexity of accents made the speech inaudible. A similar notation indicated non-speech sounds, and identified the occasional words the transcriber did not know or other points that required following up with the interview subject. To aid with navigating the transcript (and connecting text with audio) transcribers were instructed to put a time stamp in the transcript every five minutes, and at each [inaudible] tag. Our analysis of timesheets indicated students needed about five hours to produce a first-draft transcript of a one-hour conversation. Unfortunately, a typical first also draft required a complete review by another student reading the transcript while listening to the audio, which demanded at least another one-and-a-half times the interview length. In the last step before coding, one of the principal investigators who had conducted the interview reviewed the written second draft for quality and to clarify any remaining tags, and occasionally spot-checked against the audio. In all, this process required about seven to ten times the length of the interview to yield a document ready for coding. Students worked part time, so the process was very slow: delaying the research. Additionally, the quality varied significantly, it proved impossible to predict which students would be most effective; and the large team required extensive supervision and coordination by the PIs. The PIs turned to an external, online transcription service that, while limiting students’ opportunity to participate in research, was much faster and comparably or slightly less expensive. After comparing multiple vendors, the team selected Rev (Rev.Com 2018). Transcripts were typically produced within two days, and the quality was good, except some names (Le Corbusier was a constant problem) and some specifically-architectural terms. To address these problems, the team retained the best student research assistants to complete the second-draft quality assurance, and the PI's continued to review transcripts of their interviews before coding. In an additional benefit, the transcription service provides an on-line editing interface, which allowed the quality assurance and PI review to occur in the cloud, easing coordination. The online transcript automatically links to the correct time stamp in the audio recording; so inaudible, tricky, or interesting passages in the text can be selected and played back with a single click. With better transcripts and fewer students, the QA process was faster and easier.

The coding process is the hallmark of grounded theory, and requires close and careful reading of the transcribed text, and a way to mark or “tag” sections of text with additional information, for example their relationship to another topic. Once texts are embellished in this way, researchers can aggregate and synthesize the tags to interpret and understand the text. While all this can be done manually on paper, or using word-processing software, dedicated software for text analysis streamlines the process, and offers additional benefits of searching and filtering codes, and quantifying frequency, proximity, and so on. The team reviewed many software tools, some open-source, some free, and some fully paid. Many of the open-source tools demanded significant programming and/or lacked a graphic interface. Cloud-based software promised excellent collaboration across researchers and interoperability across platforms however, the limitations of browser-based workflows meant the cloud-based tools required many steps to load and process information. On the other hand, some of the high-end applications offered quantitative analysis features that were not relevant to the proposed work. In the end, ease of use, strong support documentation, and support for both Windows and MacOS led us to select F4analyse software (Dresing and Pehl 2019). To keep consistent tags and links across multiple texts, F4analyse works with a single database file for each project and does not support simultaneous editing of that file. Collaboration across multiple researchers requires external version control, such as scheduling work time. F4analyse does have an effective merge feature, allowing team members to work in parallel on separate documents, and then merge them back together, albeit with enough nail-biting that this remained a less-desirable option.
Figure 6: Screenshot of F4analyse software interface. The corpus of texts is on the left, the selected text in the center, and project codes listed on the right. Note the color-coded underlining tagging the text by code.

Figure 7: Photograph of the table during a work session, showing code categorization as a manual process.

Coding is time consuming; it requires several hours to code a single-hour interview. The team prepared some codes in advance based on prior literature review, and others were added on the fly. With multiple researchers working, and multiple interviews, codes tended to proliferate alarmingly, occasionally with only slight differences in meaning or based on misunderstanding or simple oversight. As shown in Figure 6, F4analyse underlines text with different colors for each code, and the team tried to group and categorize codes as sub codes of larger ideas using related colors. If coding itself is difficult, the synthesis and consolidation of ideas is even more challenging, particularly with a team of three researchers each approaching the problem with unique perspective and expertise. In the end, our team found it most effective to collaborate by printing key coded ideas to work through them manually and collectively as shown in Error! Reference source not found.. Using paper and white boards, with tape and scissors and sticky notes the team could discuss and rearrange our thinking, often arriving at new organizations and insights not possible in the coding environment itself, perhaps because of the limitations of the software. These sessions represent some of the most productive time...
for advancing the grounded theory work. As such, the team learned to schedule and safeguard long blocks of time in a comfortable off-site location with few distractions to have a focused and productive session.

2.2 Design drawings
While the interviews capture the human perspective and history, the architectural nature of this study emerges from case-study buildings. The team initially compiled a list of nearly two-hundred buildings from the prior instructional use; selecting a first-pass of about two-dozen buildings to begin; and then expanding to over forty projects as the interviews progressed. Fortunately, grounded theory allows for and structures iterative selection of case-studies as the project evolves, relieving the pressure to identify a perfect sample at the inception of the project. As shown in Table 1, each interview solicited other buildings and people to study, continuously expanding the study. Some buildings are well documented and previously published, and in some cases designers or owners shared additional documentation. Other cases required extensive archival work to obtain background information, and then knowledge and judgement to interpret multiple sources and bridge gaps while preparing drawings. For example, some wall assemblies are described in written articles, but available section or detail drawings do not illustrate them. Just as writing uses citations in the text, the team developed a system of tags and labels (on non-plotting layers) in drawings and models to track the source of information. That said, accurately recording the process of interpretation and judgement inherent to producing drawings remains a significant challenge.

The production of drawings began with the idea of basic documentation in plan, section, and elevation. The team established a set of drawing standards and conventions for level of detail, layer naming, and so on based on initial hunches about the questions this graphic dataset might help answer. However, some questions could only be known once the drawings were made, and this uncertainty proved challenging for the PIs to describe, and a difficult drawing assignment for graduate research assistants accustomed to drawing for a more-or-less intended deliverable. A typical building required ten to twenty hours to assemble documents and draw the three base drawings, although that naturally varied with size, complexity and availability of information. Making the consistent body of drawings is only a prerequisite: the
research work lies in analysis. In this project, analytical drawings are the graphic analog to the coding process, and each building was evaluated and “tagged” using a consistent diagramming language to interpret specific building features, like aspect ratio, window to wall ratio, structural pattern and dimension, and the arrangement and size of programmatic and circulation space, among others. Some of these analytical diagrams formed the basis for an exhibit, one panel of which is shown in Figure 8, to illustrate the graphic relationships possible.

Drawing each case study building reveals how it works, however, identifying attributes common to many (or all) long-lasting buildings demands a comparative graphic approach. To that end, the team constructed a series of comparative matrices to sort an arrange buildings based on characteristics, for example sorting plans by latitude, or elevations by window to wall ratio to evaluate climatic correlations. More interesting are use-related patterns, especially between programmed space, circulation space (for both people and services) and unprogrammed space. If the drawings are like interviews, the analytical diagramming added to those base drawings is akin to the coding process. Like the integration of codes, analysis and synthesis of diagrams represents the most intellectually-demanding (and rewarding) aspect of the work. We found it was best to print the drawings at the same scale and lay them out on the floor to arrange, compare, trace and annotate (Fig. 5). Initial sorting by obvious attributes—such as aspect ratio—sometimes revealed unexpected affinities, and prompted more sophisticated organizations, such as relating the distance between vertical circulation and the façade to the shape of the building and its height. Working in this way became clear that certain distances between core and exterior wall seem to support long-term adaptability to multiple uses. Even more interesting: identifying buildings that had a significant change in use, revealed that when buildings did not have those advantageous dimensions but were preserved for other reasons (e.g. cultural or economic value) they were often modified to more closely follow those patterns.

Figure 5: Prints of case studies’ plans during a work session, beginning sorting by patterns of circulation.

3.0 RESULTS
An interview on June 26, 2018 with the Austrian firm Baumschlager Eberle illustrates how discussing the case study projects feeds and fosters the development of the theory. The designers of the innovative project Haus 2226 in Lustenau contextualized the work by describing the project through theory, technique, and experience. In response to the research questions, the architects explained their philosophy for durable and sustainable buildings, refining Stewart Brand’s theory of shearing layers (Brand 1995) with specific criteria for the life of the project, saying “the plot of building is 200 years normally, the structure 100, the façade 50”. They described the scientific and technical developments in controls and insulating masonry that capture internal gains from people, lights and equipment and allow the building to remain comfortable without mechanical heating. One of the business leaders emphasized the role of architect as both designer and developer on this project, describing their ambition to deploy and test this model as an experiment and international prototype. Similarly, the drawn analysis of that building became a part of the larger set of patterns, its massive walls, square aspect ratio, and centrifugal circulation cores consistent with other case study buildings we studied.
To date, the team conducted over thirty interviews in the United States and Europe, and graphically analyzed over forty projects around the world. The interviews were coded by each of the three principal investigators, leveraging their unique expertise and perspective and giving rise to a dozen primary codes and one hundred and sixteen sub-codes, which continue to evolve with the project. So far, roughly a dozen themes emerged from the relationships and categorization of codes. The themes range from the physical attributes of buildings (the artifacts) to the human dimensions of reuse (the buildings’ affect on people and communities), and on to the social and philosophical implications of long-lasting architecture (cultural value). Most important—and gratifying—the themes emerging from the interviews and drawings do not align with, and occasionally even contradict, the team’s initial speculations. The fundamental test of a good research method lies in its ability to produce new knowledge, and while conducting interviews and making analytical drawings has the appearance and form of research, the rigorous structure of grounded theory means this project has the \textit{substance} of research, rather than simply reflecting the researchers’ preconceived notions.

\section*{CONCLUSION}

The choice of method for architectural research depends on the nature of the investigation. This paper provides future researchers an example of applying Grounded Theory methods to systematically examine and extract theoretical principles from the knowledge accumulated in practice. We outline collaborative research that provides structure for closely reading multiple media, from multiple perspectives, with multiple expertise. The process of analyzing and the individual coding resembles the creative process of design, including iterative cycles of analysis, interpretation, ideation, and critique. As in creative work, the logistical demands can mask the intellectual activity with a great deal of sometimes-tedious work: tasks like transcribing interviews and preparing base drawings can seem far removed from scholarly inquiry, or the research goals, and the rigors of grounded theory demand a lot of slogging through the weeds. However, the experience of this research team on this project shows it is through—and only through—deep and constant engagement with the material that truly new insights and new knowledge are possible.

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\section*{REFERENCES}


Clyfford Still Museum: The art and science of daylighting design

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ABSTRACT: This paper explores the immeasurable and measurable dimensions of daylighting design strategies, methods, and tools used by Brad Cloepfil of Allied Works Architecture at the Clyfford Still Museum in Denver, Colorado. The author interviewed Brad Cloepfil and Chelsea Grassinger of Allied Works and Christopher Rush of Arup New York to assess design intentions, strategies, processes, and the diverse daylighting design methods and tools used to integrate the poetic and practical dimensions of daylighting design. The paper will consider three issues: 1) daylight design intentions and program, 2) daylight strategies, and 3) daylight design processes, methods, and tools. The case study reveals the diverse processes and methods used by the design team to work back and forth between exploratory methods such as drawing, diagramming and physical study models; performance based analysis and calculations; and spatial and atmospheric renderings and visualizations. The Clyfford Still Museum reveals that the processes of discovery, experimentation, and serendipity are equally as important as is a rigorous analytical approach to the art and science of daylighting design.

KEYWORDS: Clyfford Still Museum, daylighting design, daylight assessment

INTRODUCTION
Throughout history, “masters of light” have artfully bridged the poetic and practical potentials of daylighting to reconcile objective attributes of site, climate, program, and performance with subjective qualities of atmosphere, beauty, and human experience. Skillful integration of daylighting requires balancing the art and science of architectural design, as Louis Kahn, a modern “master of light” explained: “A great building, in my opinion, must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable (Twombly 2003, 68).” The scientific dimensions of daylighting have matured as today’s researchers demonstrate tangible benefits of natural light in the areas of energy, greenhouse gas reductions, human comfort, productivity, and health. Advances in digital rendering, analysis tools, and an ever-increasing number of daylight metrics have allowed designers to more effectively integrate daylight with other design and performance issues. Yet, with the promise of scientific and analytical advances, there also lies a risk of too narrowly framing the parameters of daylighting to those that are measurable and empirically defined. Architectural daylighting and its design processes are complex, multi-faceted, and oftentimes messy and unpredictable, as Alvar Aalto suggested:

[Architecture has often been compared with science. . . But architecture is not a science. It is still the same great synthetic process. . . Its essence can never become purely analytical. Architectural study always involves a moment of art and instinct. Its purpose is still to bring the world of matter into harmony with human life (Schildt 1989, 272).]

This paper explores the measurable and immeasurable dimensions of daylighting design used by Brad Cloepfil and the design team at Allied Works Architecture for design of the Clyfford Still Museum in Denver, Colorado. The author interviewed Brad Cloepfil and Chelsea Grassinger of Allied Works and Christopher Rush of Arup New York to assess design intentions, strategies, processes, and the diverse daylighting design methods and tools used in their design process. The paper will consider three related issues: 1) daylight design intentions and program, 2) daylight strategies, and 3) daylight design processes, methods, and tools.
1.0 DAYLIGHTING DESIGN INTENTIONS AND PROGRAM

1.1 Luminous program

The artist Clyfford Still was a founding member of the abstract expressionist movement and a renowned color field painter of the 20th century. When Still died in 1980, his will bequeathed 95% of the body of his artwork to an unspecified American city that would create a museum dedicated solely to his paintings, drawings, and other studies. Still’s widow Patricia selected the city of Denver as the beneficiary of the estate. From the very beginning, daylighting was integral to the museum program. Architect Brad Cloepfil describes the Clyfford Still Museum as a “chapel to Clyfford Still” (Cloepfil, 2015). Cloepfil’s intentions were to effectively display and protect the artwork and to create a contemplative and reflective architectural experience. Natural light was at the heart of the design: “From the beginning, because Denver has 300 days of sunlight, the body of the building was to be a source of light from outside to inside. No one has ever seen the work in natural light. Our mission was to make the paintings come alive in light (Cloepfil, 2015).” Christopher Rush, Senior Lighting Designer at Arup New York, explains the relationship between the artwork, daylighting, and program:

It was decided early on that the character of the space, materials, and daylighting can embrace the mood of Clyfford Still’s artwork. Brad [Cloepfil] really liked the idea of a moodiness, a raw emotion in all aspects of the building design and that influenced the daylight. One thing we took away from that was to embrace the variability of daylight on a particular day, or a week, or throughout the year as clouds come and go. Not to actively manage it. Not to make it a uniform, sterile, consistent, constant condition - to accept this natural variation (Rush, 2016).

In response to the program and daylighting goals, the 7,620 square meter (25,000 square foot) museum is vertically zoned on two floors (Figure 1). The ground floor contains the entry lobby, reception area, research lab, storage and administration, archives, and circulation corridors, which include an exhibition of the historic timeline for the artist. Visitors circulate around the ground level to look into the conservation lab, painting storage, and archive areas. An elegant glass and wood staircase leads visitors to the nine upper-level galleries. More dynamic and variable daylight is allowed in the lower level entry and public spaces while strict conservation and lighting requirements are met within the upper galleries, including regulation of illuminance levels, distribution of light, ultraviolet radiation, color rendering, temperature, and relative humidity. Six of the painting galleries are illuminated by skylights, while light sensitive works are exhibited in more intimate electrically-illuminated galleries. The upper level also includes an education gallery, a conference room, and two sheltered terraces on the southwest and northeast corners that provide screened views to the surrounding city.

1.2 Site and the luminous journey

Located in the city center, the 0.4 hectare (one-acre) rectilinear site is bound on the east by Daniel Libeskind’s Denver Art Museum Addition, to the north by Gio Ponti’s original Denver Art Museum, to the south by a two-story building, and by busy streets to the west and north (Figure 1). Cloepfil set the museum back from the north boundary of the site to create a...
landscaped forecourt and a journey through light and shadow on approaching the entry and moving through the building:

The first act prepares the site by creating a dense grove of deciduous trees - a place of shadow and light, a place of refuge from the endless summer sun. The second act of architecture looks to the earth, the weight and stillness of it. The new building derives its presence from the earth, pressing down into it, being held by it. The Museum is conceived as a solid, a mass of concrete, crushed granite and quartz - a single construction that is opened up by natural light. The body of the building becomes the source of light for the art. Light is amplified, diffused and obscured by each surface of the building (Allied Works, 2018).

On the outside, the sheltering building mass is animated by a dramatic play of light and shadow as sunlight grazes the vertical striations of the concrete facades and wooden slats of the screened windows and terraces. An experience of discovery unfolds as visitors move from the landscaped exterior of the building through the dappled light of the trees, sheltering entry, and into the light-filled interiors. From the interior, direct views to the site are provided only by recessed glazing at the north entry and select windows on the lower and upper floors. After entering the museum, visitors are welcomed to the upper galleries through a light-filled double-story volume in the main stairway. Vertical light shafts in the lower level circulation corridors capture soft indirect daylight from the upper floor while providing glimpses to the daylit galleries above. Ascending the stairway, visitors move through a sequence of daylit and electrically illuminated galleries, of varied size and intimacy, corresponding with the media, scale, and program requirements for the artworks.

2.0 DAYLIGHTING DESIGN STRATEGIES

2.1 Gallery daylighting

Cloepfil explored a variety of toplighting strategies for the galleries before choosing a deep skylight monitor and perforated-concrete interior screen (Figure 2). The ceiling structure and its interaction with natural light provide a dramatic visual counterpoint to the bold and textural paintings in the galleries below. The intimate scale and relatively low height of the galleries, ranging from 3.6-4.9 meters (12-16 feet), enable visitors to engage smaller drawings and to be fully immersed in the larger canvases. In addition to creating a sublime mood and character of light, the galleries needed to meet practical conservation requirements and lighting goals, which were achieved through a combination of diffuse toplighting, vertically screened and filtered sidelighting, borrowed indirect light from adjacent galleries, and supplemental electric lighting.

Oriented on an east to west axis, the gallery skylights include translucent triple-glazing with an ultraviolet polyvinyl butyral (PVB) interlayer. Below the exterior glass surface is a deep 2.1 meter (7 foot) lightwell that reflects daylight before it enters the gallery. A shade with 50 percent visible light transmittance is provided within the skylight to mediate seasonal light levels and to darken the galleries. The perforated-concrete ceiling plane on the interior, which is suspended beneath the skylights, contains oval openings that provide 25 percent visible light transmittance into the gallery (Figure 2). Rooftop photo-sensors and dimming switches coordinate the diurnal and seasonal integration of daylighting and electric lighting, which includes HIR PAR38 wall washers for large paintings and MR16 lamps for smaller works. Small heaters are integrated into the skylights to prevent condensation.

2.2 Systems integration

Mechanical, electrical, and plumbing engineers worked with the design team to optimize other building systems and overall performance. The integration of daylighting strategies, daylight photo-sensors, dimming controls, high performance glazing, and electric lighting systems resulted in an electric lighting power density of .062 watt per square meter (0.67 watt per square foot), with exclusions, for a code compliance at 30 percent below ASHRAE 90.1-2004 standards (Madsen, 2013). A demand-control ventilation system with CO2 sensors adjusts fresh air based on occupancy loads and reduces the volume of air that is conditioned for heating and cooling, while monitoring humidity and temperature. Arup, which had also provided
the engineering services for the Denver Art Museum Addition by Libeskind, proposed and developed shared building systems. By absorbing excess chilled water and hot water capacity from the neighboring building, steam-to-hot water heat exchangers and other accessories were eliminated from the Clyfford Still Museum (McConahey 2013, 16).

Figure 2: Example gallery and daylighting section. Source: (Left: Eric Allix Rogers 2016; right: Fiona Whooley and author 2017)

3.0 DAYLIGHTING PROCESSES, METHODS, AND TOOLS

3.1 Art and science of daylighting design
On the one hand, daylight is tangible, measurable, and predictable. Luminous characteristics such as light levels, distribution, glare, and contrast ratios can be measured using standardized metrics such as lux, footcandles, daylight factors, and candelas per square meter. Yet there are also dimensions of natural light that are more difficult to quantify, including ephemeral luminous qualities created by the changing weather, climate, time of day, and site forces. Luminous effects on “real materials” of “real natural light” (including the interactions between daylight, color, and surface characteristics such as transparency, opacity, and reflectivity) can also be difficult to anticipate. Physical models and mock-ups using real materials are particularly well suited to exploring daylight as an atmospheric phenomenon and ephemeral architectural material. Mock-ups allow designers to view the serendipitous interactions between the changing moods and qualities of light and material attributes in ways that are oftentimes surprising and unpredictable: the shifting ambiance as a cloud passes over the sun, the visual warmth of morning light, or color changes as light reflects between material surfaces. There is a necessary element of intuition and experimentation required to discover the unanticipated and emergent qualities of natural light as it interacts in time with changing sky conditions, architectural form, and material properties. Juhani Pallasmaa suggests that the atmospheric quality of space is subconscious, holistic, and beyond measure: “[T]he character of space calls for our entire embodied and existential sense, and it is perceived in a diffuse, peripheral and unconscious manner rather than through precise, focused and conscious observation. . . spaces and true architectural experiences are verbs (Pallasmaa, 23).”

3.2 Immeasurable dimensions of daylighting design
Brad Cloepfil and the design team used diverse methods and processes to explore, develop, and refine the daylighting. Early studies included charcoal and pastel concept studies, sketches, iterative concept diagrams and models, freehand and digital renderings, photo-collages, and conceptual and experiential material studies (Figure 3). Physical study models and digital renderings were critical in the early phases, as Cloepfil explains:

The way we work on this kind of project is with physical models, which you can see in front of you and turn around, or to work in a digital 3D space that you can work on quickly. The Clyfford Still Museum was the first project where we explored the interior of the building through a digital 3D model study. We made sure that we could see through the building the way we wanted to, that everything was supporting the experience we were after (Chopra, 2012).
At the site scale, early studies included massing explorations using charcoal sketches and diagrams, iterative cardboard spatial models, concept massing models of wood and plaster, and material experiments (Figures 3 and 4). Cloepfil explained that sketches were used to explore how the massing of the building could be penetrated with shafts of light to the lower level displays and circulation: “I did this really early sketch; in fact it was one of my first sketches where I wanted light to penetrate deep into building. That's what created those shafts and [to go] metaphorically deeper into Clyfford Still’s life (Cloepfil, 2015).” Plaster models explored the connection to the earth and the play of light and shadow on the exterior and interior, in contrast to the neighboring Denver Art Museum Addition: “With Liebskind as such an expressed object, I wanted to de-objectify the Still. This is why we built the huge plaster model. I wanted the building to be surrounded by trees. You would walk through the dappled light of trees, then the surface of the building would have shadows of dappled light and the concrete would cause shadows of dappled light. And the thing would sort of dissolve in the patterns of light. That was the original intent (Cloepfil, 2015).” These early sketches and physical model studies were essential in developing the overall spatial organization, massing, and materials qualities of the museum. The siting, scale, form, and heavy concrete mass with few windows emphasize the quiet internal focus of the building. Within the galleries, Cloepfil sought to transform the solidity of concrete into a light-emitting surface suspended beneath deep skylights.

At the gallery scale, Cloepfil and the team explored a variety of daylight strategies using freehand renderings, diagrams, and small physical models (Figure 5). Interior renderings using Rhino models and Maxwell Render helped to clarify the desired quality of light, as Cloepfil explains: “We did this one rendering using Maxwell lighting software that has that quality [of water]. I said if we could just get that sense of it, almost not being an obvious pattern, but a kind of ripple of light up there [from the ceiling] (Cloepfil, 2015).” At one point, Cloepfil did a sketch and asked the question to the team and engineers how to create light emitting concrete?: “I wanted the light to come through and off the concrete and I wanted it to be like the concrete was emitting light through the ceiling. We tried it with the structural engineers and with the daylighting and it worked. One of the visiting curators said it was almost like ‘liquid light’ and I think they nailed it. It has a visceral quality (Cloepfil, 2015).” Cloepfil emphasized how effective new lighting software is in rendering the quality of daylight: “Software now is so amazing that you can get that qualitative feel (Cloepfil, 2015).” The appearance of a heavy concrete ceiling screen was transformed in density and weight through the ovoid openings, pattern, and detailing to create a water-like quality of light. As though immersed in an underwater world with a dappled play of light on the surface, the direct sunlight is transformed and diffused by the depth of the skylight section and perforated concrete surface of the light-emitting ceiling.
Figure 4: Examples of wood carved concept models (top) and plaster studies (bottom). Source: (Allied Works 2015)

Cloepfil explained that concrete was his material of choice to capture the desired atmosphere and experiential intent: “It’s the idea of compression; the building compresses you. That’s why we chose concrete. All these things come together. I wanted you to feel like one body. It wasn’t about a minimalist aesthetic. It was about keeping the building as elemental as possible. So, when you walked into the building you were being held in the building with those paintings and with natural light. That was it, the body in the building, the light, and the art. And that they are all somewhat indistinguishable (Cloepfil, 2015).” Mock-ups at ½” and 1” to the foot were...
constructed to study the ceiling and wall detailing. These included ceiling studies using grey-painted foam, a full-scale mock-up of half the gallery with skylight details and layering, and exterior wall details to study the effect of light and materials (Figure 6). Reminiscent of the heavy impasto of Still’s paintings, the striated concrete surfaces on the museum’s exterior and interior include vertical fins with rough edges that were created using two depths of formwork with beveled edges and varied gaps. Cloepfil describes his fascination with concrete: “Concrete is like alchemy, you add a little of this or a little of that and you can make it into an entirely different entity. I love the mystery of concrete and how much it can do (Cloepfil, 2015).” He characterizes the surfaces as “corduroy concrete” with the textured surfaces fostering a dramatic play of light and shadow that results from the material details: “I love material dimension and the way light expresses that dimension. Pushing back concrete two inches there or raising something out an inch and a half and seeing what it does with the shadows is beyond belief (Cloepfil, 2015).” Physical mock-ups were essential to gain hands-on experience of the luminous effects and to confirm construction details and methods that would result in the desired quality of light and shadow.

Figure 6: Examples of full-scale mock-ups: gallery (left) and wall detail tests (right). Source: (Arup 2015)

3.3 Measurable dimensions of daylighting design
The challenges of daylight design in the galleries were to celebrate the changing character of natural light, create the desired moods and atmospheric qualities, and obtain an appropriately uniform distribution of light and illuminance levels on the gallery walls. In addition to creating a sublime mood and character of light, the galleries needed to meet practical conservation requirements and lighting goals, which were achieved through a combination of diffuse toplighting, vertically screened and filtered sidelighting, indirect light borrowed from adjacent galleries, and supplemental electric lighting. Collaborations with Brian Stacy and Christopher Rush, engineers at Arup New York, were essential in creating desired atmosphere and mood while also meeting the highest standards for lighting performance. Mock-ups and physical model studies that were used to consider atmospheric and spatial characteristics also served to investigate performance issues. Rush explained how Arup worked with the team to support an integrated daylighting design process:

We used small-scale physical models with accurate geometry and computer simulations throughout the design process to be sure we were on target and that the design allowed some flexibility….This caliber of project usually includes a full scale mock-up to fine tune the design when the gallery is nearly complete and to do some measurements for exterior conditions so the interior condition tracked with predictions. In the final stages of this design we did a full scale mock-up for one section of gallery on the ground next to building while it was under construction. This was a last check to confirm everything . . . and it was partially a confidence booster to be comfortable with the construction, the skylight details, water proofing, finishes . . . and that the daylight levels were correct (Rush, 2016).
Iterative physical and computer models and on-site construction tests verified that the design was successful at meeting conservation goals of limiting daylight exposure to less than 65,000 footcandle-hours per year (65 Kfc-h) while achieving a consistent 20 footcandle (215.2 lux) illuminance on the gallery walls at a 5 foot (1.5 meter) height (Figures 7 and 8). Arup described their approach to lighting targets: “[The] approach was based on cumulative exposure on the art for a typical year instead of maximum illuminance at any one time. The Museum agreed with this, enabling the daylight systems to be designed for appropriate annual exposure, rather than the single brightest hour of the year (Rush, 2016).”

Cloepfil emphasizes that daylighting design is a collaborative process that requires careful selection of correct design methods and media, based on what the designer and team are trying to understand and explore (Cloepfil, 2015). Longtime collaborations with trusted daylighting designers and engineers from Arup have been essential in Cloepfil’s ability to integrate experiential and performance goals. Cloepfil explains that data is not an end in itself. He suggests it is necessary to know when design intuition and experience must go beyond the data: 

You have to trust your eye. [Arup] will give us the data and light ranges . . . and then I always push back. We might need more light or find ways of controlling and diffusing it. It’s a back and forth all the time between the data and what you want the experience to be. That’s why it’s nice working with Arup, they have worked on so many museums. We can talk about different museums and the quality of light and they know the light levels. There are things from Brian [Stacy] that I learned about the eye. There can be a certain level of change of quality of light across a surface and your eye will unify it, if it stays within a certain range. There are certain things your eye does that you have to take into account. That’s where the data really doesn’t work; because you look at the data and you have this range of light across the wall, but yet it’s not perceived. So here is this data, now what do we want to do with it? They understand that the data is not an end, just a base to work from. It gives you a reference that you desperately need, but it’s not an end. That’s a good engineer (Cloepfil, 2015).

In the search for the desired quality of light and atmosphere, the design team used multiple methods and tools, as Cloepfil explains: “We’re just continually searching and trying to understand the available light and trying to understand what to do with it. It’s always about a level of protection, protecting the art and people in the workspace. It’s about general energy
control and keeping sun out of spaces, but then after that it’s the quality of things. And that’s the part where you use every tool (Cloepfil, 2015)."

CONCLUSIONS
At the Clyfford Still Museum, Cloepfil and the design team have achieved a meaningful conversation between the body of art and the body of architecture. Light, materials, structure, and space come together to create a tangible architectural and luminous presence that compliments and reveals the power and mystery of Clyfford Still’s artwork. The key lessons from the case study include the following:

1. **Employ Diverse Daylight Design Methods, Media, and Tools**: The case study reveals the diverse processes and methods used by the design team to work back and forth between exploratory methods such as drawing, diagramming and physical study models; performance based analysis and calculations; and spatial and atmospheric renderings and visualizations. The diverse processes and methods used by the design team enabled them to engage the physical and emotional potential of daylight as a dynamic building material.

2. **Integrate Performance Based Analysis and Calculations**: Computational tools provide insight into both performance and experiential dimensions of design. As Cloepfil explains: “We’d want any tool we use to help us realize our vision for what the space is going to be like, in terms of its experience. I’d say that materials are key, light is key, and the order of the space is key (Cloepfil, 2015)." The attempts are from an analytical point of view [from Arup] and the leaps we [Allied Works] have to make beyond analytics to try to find the quality (Cloepfil, 2015)."

3. **Use Physical Models, Photography, and Renderings to Investigate Experiential Phenomena**: Physical models at multiple scales and levels of detail combine with digital renderings to study, test, and refine the luminous atmosphere and spatial characteristics. As Cloepfil explained: “Something magic happened there. There is design intention and then there is experiential phenomena. The experience is so much richer than hoped. We have a language between us [Arup] that is a quest for the qualities we are looking for [in the museum].

For Cloepfil, design always returns to creating a meaningful human experience in which light plays an essential role: “The goal is that architecture should move you in a way you haven’t been moved before. . . Moments of wonder are what we all want (Cloepfil, 2015).” The Clyfford Still Museum reveals that the processes of discovery, experimentation, and serendipity are equally as important as is a rigorous analytical approach to the art and science of daylighting design.

ACKNOWLEDGEMENTS
The author gratefully acknowledges the generosity of Brad Cloepfil and Chelsea Grassinger of Allied Works Architecture and Christopher Rush at Arup New York for discussing the project and providing graphic materials. A special thanks to Fiona Wholey for collaborating on the daylighting diagrams. The author also acknowledges the photographers Jeannie Keefer and Eric Allix Rogers for access to their photographs via Flickr, including the following attributions: 1) Jeannine Keefer: Clyfford Still Museum: allied_works_architecture, Flickr, taken on March 14, 2015, https://www.flickr.com; and 2) Eric Allix Rogers, Clyfford Still Museum: #dod2016 #2011 #bradcloepfil, Flickr, uploaded on April 24, 2016; https://www.flickr.com.

REFERENCES


Community resilience in the face of riverine flooding: applying lessons from resilient competitions to Pennsylvania’s vulnerable communities

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ABSTRACT: Flooding as an adverse effect of climate change is becoming more pronounced each day, making communities vulnerable to its threats. There is an urgent need for resilience planning and well-coordinated, science-based design intervention. There is significant information on coastal flooding as evident from recent resilience competitions. The goal of this paper is to learn from this information what can be done to address the lack of coordination and communication related to flooding in Pennsylvania’s riverine communities. Only 186 out of more than 2500 communities are safe from high water, making flooding the most frequent and damaging disaster in Pennsylvania according to PEMA (Pennsylvania Emergency Management Agency). A recent survey carried out by DVPRC shows that riverine flooding represents risks in the form of flooding of private properties and roadways and stress on aging water infrastructure like sewer lines and dikes. While the US government has led initiatives to plan for resilience, there is a lack of expertise, coordination and communication to guide the process. Reports on the winning projects in recent competitions are a source to address current short-fallings. By taking a step forward and leading the path towards resilience planning, they have provided resources that can be translated to inform other regions and risks. This research undergoes a case-study review of a couple of resilience competitions to learn about their resilience design process. Using this knowledge, it aims to close the gap in knowledge and address limitations of a traditional planning process across Pennsylvania’s riverine communities. Findings focus on effective community-engagement strategies, need for and ways to adopt multi-disciplinary collaboration, institutional changes required to facilitate resilience planning and the overall resilience design process. The paper concludes that traditional planning approaches by local government bodies could largely benefit from adopting or locally adapting the proposed resilient strategies.

KEYWORDS: Community Engagement, Design, Flooding, Planning, Resilience

INTRODUCTION

Historically people have settled along rivers; However, living next to rivers poses risk. Riverine flooding caused by climatic events create major disruption worldwide. Within the United States, riverine communities face such struggles on a regular basis. Pennsylvania has more miles of rivers and streams than any other state with the exception of Alaska. Most of Pennsylvania’s communities were settled along its 86,000 miles of waterways, during times when these areas were not identified as floodplains. Today, however, flooding has become an increasing burden on community vitality, with only 186 of Pennsylvania’s more than 2,500 communities safe from high water. 2018 was the wettest year on record for the state, with flooding occurring more frequently and in areas that were previously unaffected. Pennsylvania Emergency Management Agency (PEMA) has identified flooding as the most frequent and damaging natural disaster occurring throughout the Commonwealth (PEMA n.d.). While there have been efforts to adapt to and mitigate coastal flooding, as evident from resiliency competitions held in United States in the past decade, the unique conditions of riverine flooding have received less attention. Recent survey findings from Pittsburgh, Pennsylvania suggest that people perceive local flood risks as having increased and are expected to increase further in the
future. The study concludes that, in order to communicate climate change adaptations effectively, it is important to target protection against the local flood risks (Bruin et al, 2014). Many regions in Pennsylvania are prone to flooding risks recurring annually. Snyder County, for example, is likely to flood every year according to data by the National Climatic Data Center (Snyder County Hazard Mitigation n.d.). While there are many existing plans for hazard ‘preparedness’ and mitigation, the current trend of designing for resilience takes a reactionary approach in which solutions are based on past events, presenting a ‘lock-in scenario’ (Laboy and Fannon 2016, 41). Aspiring to return to a ‘status quo’ represents a narrow understanding of resilience. Laboy and Fannon (2016) encourage adopting a social-ecological resilience approach that recognizes that buildings exist in a dynamic relationship between technology, human use and the natural environment. These authors recommend adapting to changing social and ecological context. Analysis of hazard preparedness plans for flood prone counties in Pennsylvania indicate a reactionary approach. In the interest of informing methods for enhanced collaboration and proactive planning, this research reviews some recent U.S. resilient competitions to learn about their resiliency strategies and execution structure to gain a better understanding of how resiliency can be achieved with a vision for the future. It goes on to address the gap in knowledge that exist in the traditional flood-adaptation plans delineated by local government bodies. Recommendations include and are focused on areas of community engagement and collaboration strategies.

1.0 LITERATURE REVIEW

1.1. Towards community resilience

The word resilience is derived from the Latin word ‘resiliere’ which means “to jump back” or “rebound” (Paton 2006, 7). One of the pioneers of this term, Holling (1973, 14) defines resilience from an ecological point of view as a

- measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables

Another widely cited author, Pimm (1991), describes resilience from an engineering perspective. His definition focuses on the return of structural and functional attributes of systems to pre-disturbance conditions following a disturbance. Contrary to Holling’s earlier definition of resilience, Holling and Gunderson (2002) redefines resilience in a system as having the ability to absorb changes to reach a new stable state controlled by different variables and characterized by a different structure. This new definition was termed ‘ecosystem resilience’. Further development by Walker et al. (2004, 5) define resilience as

- the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks

Resilience in planning and design is also informed by the thinking of other disciplines including medical fields and the social sciences. Adger’s (2000) sociological version of resilience discusses the ability of groups or communities to cope with external stresses and disturbances. Defined by Magis (2010, 401) community resilience is the

- existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability and surprise

A community’s resilience is often understood as the capacity of its social system to come together to work toward a communal objective. Butler (2007, 402) defines community resilience as

- good adaptation under extenuating circumstances; a recovery trajectory that returns to baseline functioning following a challenge

Paton (2006) describes it as the capability to bounce back and to use physical and economic resources effectively to aid recovery following exposure to hazards. Rockefeller Foundation president Judith Rodin (2014, 3) shares that resilience can be understood by the capacity of any entity—an individual, a community, an organism, or a natural system—to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from
This addresses the pressing needs for planning ahead for resilience, especially in a world inundated with natural disasters due to adverse climate change.

In every aspect of its definition, the meaning of the term ‘resilience’ revolves around a central theme - identification of some sort of stress to a system and a focus on either adapting or coping with that stress and bouncing back to its pre-disturbance state or ideally, emerge in a stronger state than before. Recent resiliency competitions adopt this theme of communities ‘bouncing back’ and emerging stronger. Central to proposed solutions is a focus towards building adaptive capacity of vulnerable communities through equipping them with valuable knowledge and resilient infrastructure to fight the adversities of the climate change.

### 1.2. Community resilience and adaptive capacity

Berkes and Ross (2013) share that community resilience is rooted in two strands of literature - one strand comes from ecology and addresses the ecosystem while the other comes from the psychology of mental health and personal development. According to these authors, the overlaps and the complementary nature between these two strands makes community resilience of special interest. Magis (2010) explains that resilience is often understood as the capacity of a community’s social system to come together to work towards a communal objective in order to fight against vulnerabilities. This ‘fight back’ attitude is possible in communities that possess ‘adaptive capacity’. Adaptive capacity is defined as “the capacity of actors in the system to manage and influence resilience” (Walker et al. 2004). It is a pivotal concept that ties together vulnerability and resilience literature. The stronger the adaptive capacity of a community is, the better it can work towards reducing its vulnerabilities and enhancing its resilience. According to Chapter 18 of the third assessment report of The Intergovernmental Panel on Climate Change (IPCC), adaptive capacity is determined by a community’s economic resources, technology, information and skills, infrastructure, institutions, and equity (Smit et al. 2001). Thus, it is concluded that, in order to improve community resilience, it is vital to increase adaptive capacity. This research is focused on boosting the adaptive capacity of community by providing access to information, ensuring equity and empowering communities to make decisions for themselves.

### 2.0 PENNSYLVANIA FLOODING SCENARIO AND NEED FOR COMMUNITY RESILIENCE

#### 2.1 Historic flooding-Pennsylvania

Three major watersheds (Delaware, Susquehanna, and Ohio) encompass most of the Commonwealth of Pennsylvania. As a result, Pennsylvania has experienced some of the worst flooding in the United States, leading to loss of lives and a huge economic loss of properties over the years (Flooding in Pennsylvania n.d.; Jeffrey 2007, Hasco 2018). According to a 2000 United States Geological Survey (USGS), no other disaster has claimed as many lives and property damage as floods (Perry 2000). Predictive and proactive measures are needed and some efforts are underway in Pennsylvania’s Delaware River Valley.

#### 2.2 Contemporary flooding- Delaware River Valley, Pennsylvania

The earth has warmed by about one-degree Fahrenheit (°F) in the last century and, according to the Delaware Valley Regional Planning Commission (DVPRC), if today’s trend continues, Pennsylvania is predicted to warm by between 5.4 to 6°F (Flooding in Bristol Township n.d.) and consequently experience higher sea level rise and more frequent heavy storms. Figure 1, by NOAA, of the Philadelphia Tide Gauge, represents flooding risks associated with the aforementioned climate change scenario in comparison with past climatic events. The figure shows the tide height measurements above high tide and portrays how a sea level rise scenario will exacerbate flooding conditions. Figure 2 shows likely flood inundation of areas in Bristol Township, Pennsylvania as a consequence of predicted sea level rise. According to DVPRC, coastal storms may produce any of the heights today, but sea level rise will cause all...
DESIGN THINKING

of these predicted scenarios in the near future. Moreover, some areas under five (5) feet above sea level may be permanently inundated.

<table>
<thead>
<tr>
<th>Event</th>
<th>Current (ft)</th>
<th>2030 (ft)</th>
<th>2050 (ft)</th>
<th>2100 (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%/100-year flood</td>
<td>4.13</td>
<td>4.93</td>
<td>5.53</td>
<td>7.53</td>
</tr>
<tr>
<td>Flood of April 2005 (~April 4, 2005)</td>
<td>3.06</td>
<td>3.86</td>
<td>4.46</td>
<td>6.46</td>
</tr>
<tr>
<td>Hurricane Irene (~August 28, 2011)</td>
<td>3.23</td>
<td>4.03</td>
<td>4.63</td>
<td>6.63</td>
</tr>
<tr>
<td>Hurricane Lee (~September 3, 2011)</td>
<td>1.65</td>
<td>2.45</td>
<td>3.05</td>
<td>5.05</td>
</tr>
<tr>
<td>Superstorm Sandy (~October 30, 2012)</td>
<td>3.94</td>
<td>4.74</td>
<td>5.34</td>
<td>7.34</td>
</tr>
<tr>
<td>10%/10-year flood</td>
<td>3.05</td>
<td>3.85</td>
<td>4.45</td>
<td>6.45</td>
</tr>
<tr>
<td>99%/1-year flood</td>
<td>1.12</td>
<td>1.92</td>
<td>2.52</td>
<td>4.52</td>
</tr>
</tbody>
</table>

Permanent inundation at high tide (mean higher high water)

0.8 1.4 3.4

Sources: NOAA, central estimate from Kopp et al 2016

Figure 1 (left): Flooding estimates at the Philadelphia Tide Gauge (Source: Pennsylvania Coastal Resiliency n.d.)

Figure 2: Flooding inundation due to sea level rise in Bristol Township, PA (Source: Pennsylvania Coastal Resiliency n.d.)

According to a survey carried out in 2017 in thirteen municipalities along the Delaware River Valley, the predicted sea level rise and future flooding conditions add concern in the following categories: 1. Flooding of private property (homes, cars, commercial buildings) 2. Flooding of residential basements. 3. Flooding of roadways. 4. Stress on aging flood mitigation and stormwater infrastructure (sewer lines, storm drains, inlets, dikes, levees). 5. Secondary effects of flooding: siltation, erosion, pollution. 6. Destruction of tidal wetland habitat. 7. Insufficient flood monitoring systems (Pennsylvania Coastal Resiliency n.d.). In light of the above concerns, it is clear that resilience planning - that engages diverse participants and is in line with local needs - is a salient measure that needs to be taken in these riverine communities.

2.3 Planning and community outreach recommendations by DVPRC

To address present and forthcoming flooding challenges in the Delaware river valley, DVPRC has developed a series of recommendations for plans, regulations, and ordinances. These include incorporating flood projections and depth caused by sea level rise in municipal plans.
and ordinances; planning beyond the standard 20-25 year timeline through a community-wide planning process; creating a post-disaster redevelopment plan; protecting community assets from flooding using municipal zoning ordinances; re-designing or retrofitting infrastructure to increase survivability; updating flood elevation data to allow elevation of existing structures or new construction to respond accordingly; and, finally, acquiring certification in the National Flood Insurance Program (NFIP) Community Rating System (CRS).

Moreover, the DVPRC recognized the need for community engagement and responded with a series of community outreach recommendations. These include creating a program for public information to help organize the municipality’s outreach practices on coastal hazards, organizing annual presentations for residents, business owners and other groups to spread awareness, packaging flood preparedness materials to residents in advance, creating a dedicated and easily accessible flood information page on the municipal website. Policy recommendations include a coastal hazard disclosure policy that is used by lenders and real estate agents when speaking with potential buyers. Other recommendations were to conduct regular educational sessions and outreach for flood preparations and disaster assistance to the residents living in vulnerable locations.

2.4 Need for enhanced community engagement in Pennsylvania Communities
A concerted effort is needed to break the cycle of loss of life, destruction of property and irreparable damages to people, property, infrastructure, environment and the historic fabric of Pennsylvania’s riverine/waterfront communities. Organization and resulting recommendations and regulations are useful and necessary based on historical and projected flooding scenarios. However, the majority of Pennsylvania’s historically significant communities do not have the resources, information or coordination to respond in kind (DCED, 2015). Moreover, the flooding in Pennsylvania’s riverine communities are unique, requiring localized approaches and rigorous process. Solutions must be informed by local problems and the needs identified by community members - utilizing climate science research, planning and design capabilities, and facilitated understanding of law and ethical decision-making. The better able a community is to identify a suite of practical solutions to combat flooding and its effects, the more empowered it will be to successfully fund and implement change.

3.0 IN SEARCH OF A RESILIENT WAY FORWARD

3.1 Competition case-study
In order to better understand methods for collaboration and myriad solutions to challenges in diverse locales, research was conducted on how resiliency is planned through a case-study review of winning projects of Rockefeller Foundation supported resilient competitions: Rebuild by Design-Hurricane Sandy and Resilient by Design-Bay Area Challenge. Important aspects of the design structure, significant collaborators in resiliency planning, community engagement strategies, and resilient planning process, are documented which led to learning about innovative strategies to approach design and engage community members in the process.

Rebuild by Design-Hurricane Sandy: Rebuild by Design was a competition that was designed in response to immense damage left in 13 states by Hurricane Sandy. This was organized by HUD (U.S. Department of Housing and Urban Development) in partnership with Municipal Art Society, Regional Plan Association, NYU’s Institute for Public Knowledge, The Van Alen Institute and with support from the Rockefeller foundation and other philanthropic partners. What makes this competition unique is that it draws innovative, scientific knowledge from experts around the world and combines it with insights from local communities to devise solutions that are practical and implementable. The idea here is not just to ‘rebuild’ but rebuild in a way that prepares the affected region for storms worse than Hurricane Sandy. The competition yielded ten (10) winning projects by interdisciplinary teams, out of which 7 projects received federal approval and funding for implementation.
Resilient by Design-Bay Area: Inspired and modelled on the Rebuild by Design competition, Resilient by Design-Bay Area was designed to tackle the resilience issues of the vulnerable San Francisco Bay Area. While Rebuild by Design was created in response to a climatic event, this competition is designed to develop the Bay Area in a way that makes it resilient against rising sea level and future climatic threats. Interdisciplinary design teams (informed by specified criteria) were chosen through an open call and vulnerable sites were identified based on feedback from community members, government staff and regional experts. Much like the Rebuild by Design competition, ten (10) teams were chosen, who devised clever, implementable solutions after a thorough collaborative research and design phase.

3.2 Why adopt a design-oriented process in resilience
Both the Rebuild by Design and Resilient by Design competitions adopt a design-oriented approach towards devising resilience solutions. Henk Ovink, Principal of Rebuild by Design, explains that a design process generates holistic solutions due of its comprehensive nature. He goes on to inform how the ‘innovative’ elements in design can encourage people, including politicians, to engage and be a part of the new opportunities (Cohen, 2016). Resilience process is not only about devising solutions to existing problems but going beyond to perceive new opportunities in the solutions devised, to address the social and economic issues through layered strategies, and to be able to devise solutions for problems that are yet to materialize. A design-oriented process in resilience planning adopted in the resilience competitions reflects how multiple benefits can be achieved through a single, well-perceived intervention and should be considered in traditional planning. One such example is the proposal by The Big U, of designing berms with salt tolerant trees that also function as waterfront civic spaces for the communities (The Big U, n.d.). A design-driven resilience approach can lead to such innovations by maximizing utilization of resources. This is an especially crucial aspect to consider for small communities with limited capability for flood resilience initiatives.

3.3 Collaborative process in Rebuild by Design
Phasing and partnership structures, as well as limitations on opportunities in the collaborative process, were identified using documentation available from Rebuild by Design. Four (4) phases comprised the competition:

Talent: In this phase, scholars and experts from around the world were sought to share their expertise. This was matched with local experts in the Superstorm Sandy affected region, who knew the specific and significant details about the area. This marriage between local and international expertise ensured that only the best recommendations were provided to build resiliency.

Research: This phase allowed for thorough research to gather a deep understanding of the region’s vulnerabilities, risks and opportunities. In addition to acquiring scientific data about the climatic patterns, ecological and geographical conditions, the team members, assisted by experts, made site visits to the Sandy-affected areas in order to hear first-hand about the problems that the local residents prioritized.

Design: In this phase, informed by the interdisciplinary and collaborative research, the team members devised implementable solutions with support from local communities and government. Various workshops with community members were held throughout this process in order to make sure that local aspirations and values were reflected in the plans put forward.

Implementation: Finally, in the implementation phase, government and community stakeholders came together to work as a team to help build the projects.

Table 1 compares the traditional government planning process with the Resilient planning process: Lessons from the resiliency competitions were derived to understand how successful community outreach may be conducted.

The community outreach recommendations from the Rebuild by Design competition are not only innovative but they also shed light on the fact that the resilience planning process encompasses much more than the usual limited engagement with community stakeholders. Community residents were engaged at every step of the process throughout the research,
design and implementation phases. This ensured that their values were reflected and their aspirations accounted for. Moreover, this empowered them to make decisions that affected their regions, fostering a sense of belonging and ownership. The mechanisms applied in bringing community members together were innovative. Instead of the usual informative presentations alienating participants, facilitating workshops that included design explorations, such as model-making, allowed residents to participate in redesigning their communities to adjust to climate change. These fun interactive methods educate the community, catch the public attention, and effectively communicate complex science and related messages. Table 2 shares some of the successful community outreach techniques applied by the winning team members of Rebuild by Design competition.

### Table 1: Comparison of traditional planning process with resilient process derived from resilient design competitions.

<table>
<thead>
<tr>
<th>Traditional Process</th>
<th>Resilient Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited scope for interdisciplinary</td>
<td>Significant Interdisciplinary collaboration</td>
</tr>
<tr>
<td>Lack of an organized structure</td>
<td>Organized into an orderly structure</td>
</tr>
<tr>
<td>Not enough scope for collaborative</td>
<td>Significant time for research (with locals, academicians, local</td>
</tr>
<tr>
<td>research</td>
<td>organizations, industry experts and state officials) before getting into the</td>
</tr>
<tr>
<td></td>
<td>design of solutions</td>
</tr>
<tr>
<td>Not enough provisions for long term</td>
<td>Plans for short term problems with long term vision</td>
</tr>
<tr>
<td>Most recommendations are reaction-</td>
<td>Recommendations are resilience-driven</td>
</tr>
<tr>
<td>oriented</td>
<td></td>
</tr>
<tr>
<td>Gender and economic issues not prioritized</td>
<td>Included advisory staff in gender and economic equity issues to ensure equitable</td>
</tr>
<tr>
<td></td>
<td>planning.</td>
</tr>
<tr>
<td>Confined within the municipality</td>
<td>Inter-municipality collaboration to address flooding issues that affect several</td>
</tr>
<tr>
<td></td>
<td>regions together.</td>
</tr>
<tr>
<td>Reliance on past storm data to predict</td>
<td>Planning for unforeseen projected climate trends.</td>
</tr>
<tr>
<td>future events</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: Tools used by the Rebuild by Design teams to facilitate collaboration (prepared by studying the finalists’ report). Adapted from Rebuild by Design Competition book. Retrieved from [http://www.rebuildbydesign.org/resources/book](http://www.rebuildbydesign.org/resources/book)

<table>
<thead>
<tr>
<th>Aspect of Research</th>
<th>Tools used in process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding residents’ perception of</td>
<td>Hand-sketches made by community residents during drawing exercises</td>
</tr>
<tr>
<td>‘Resilience’</td>
<td></td>
</tr>
<tr>
<td>Understanding community residents’</td>
<td>Series of interactive Interchangeable models that community residents were</td>
</tr>
<tr>
<td>aspirations regarding the design solutions</td>
<td>encouraged to design</td>
</tr>
<tr>
<td>Gaining feedback from engaged stakeholders</td>
<td>Workshops, meetings, Research colloquium; Web-based surveys, Design charrettes</td>
</tr>
<tr>
<td>Getting the stakeholders involved</td>
<td>Public events with interactive installations, displays &amp; research related activities</td>
</tr>
<tr>
<td>Waterfront design details.</td>
<td>“Build your own waterfront activity”-Foam models of berms, flood walls, and public</td>
</tr>
<tr>
<td></td>
<td>amenities given to community residents to let them design</td>
</tr>
<tr>
<td>Identification of shared values of</td>
<td>CrowdGauge Tool coupled with online game-like interface used to understand what</td>
</tr>
<tr>
<td>community</td>
<td>aspects in their community residents value the most (e.g. clean air, safe roads,</td>
</tr>
<tr>
<td></td>
<td>community parks, etc.)</td>
</tr>
</tbody>
</table>

### 3.4 Proposed collaboration model

Figure 3 shows a proposed collaboration structure adapted from the *Rebuild by Design Hurricane Sandy* competition. The important collaborators in each phase that crucially shaped the resilience design process are indicated. The diagram was derived by inferring from public resources made available by Rebuild by Design and the list of collaborators included are not
exclusive. Rather, the list gives an idea of the kind of experts that should be sought to enable a community-led resilience design process.

A similar structure for collaboration in Pennsylvania riverine communities may involve getting important stakeholders like PEMA, DEP, municipality staff, local experts and community members actively involved through collaborative research and design phases, in order to overcome the lack of coordination and communication in the system. Adopting the collaboration model from the resilience competition and engaging the relevant stakeholders can lead to practical and equitable solutions for the community.

Figure 3: List of collaborators and collaboration structure in Rebuild by Design Hurricane Sandy competition

4.0 DISCUSSION AND FINDINGS

Using the knowledge derived from studying resilient competitions, recommendations are made to address a gap in the traditional planning processes in an attempt to add momentum to the resiliency of Pennsylvania’s riverine communities. Research and experience indicate that the top-down traditional planning process is yet to achieve community resiliency. The process must address vital elements of effective community engagement, inter-disciplinary collaboration and well-perceived planning with provisions for unforeseen challenges.

Problems, addressing unique challenges and their solutions, must be locally defined. Communities in Central Pennsylvania suffer from three types of flooding. The large-scale sustained flooding that occurs along main river stems, such as the Delaware or Susquehanna, are certainly of significant concern. But equally, or perhaps more troubling, is the localized flash flooding that affects the upper reaches of the rivers and their tributaries. Many of these waterways have not been accurately mapped for flood risk, and some smaller tributaries are missing from the maps completely. These primary and secondary types of flooding are increasing in magnitude and frequency, and often cause major property destruction or
fatalities. Moreover, increases in precipitation is causing flooding from unexpected sources, such as the stormwater infrastructure that is intended to mitigate and protect, and recent recurring flooding has affected properties that never flooded previously. River communities are becoming increasingly more vulnerable due to overworked storm water systems, runoff pollution, rising flood insurance costs and damaged infrastructure.

While resilience competitions like Rebuild by Design and Resilient by Design are focused towards the large-scale impacts of coastal flooding, riverine flooding and flooding from tributaries and stormwater are not as comprehensively researched. Adopting the four-phase model of the resilience competitions would ensure that:

- An interdisciplinary team of experts would be engaged to assist with identifying and addressing the resilience issues in Pennsylvania’s riverine communities during the Talent phase.
- A better understanding of region and values would guide the process through the Collaborative Research phase.
- Feedbacks from community members and relevant experts would lead to comprehensive and informed solutions through the Collaborative Design phase.
- Funding mechanism and sources would be identified early in the process through the Implementation phase.

4.1 Obstacles in adapting the ‘resilience’ way

Referring to the definitions of ‘resilience’ discussed previously, resilience can either mean adapting to a stress and bouncing back to its pre-disturbance state or emerge into a different, stronger state. This leaves a profound dilemma when faced with decision-making for riverine communities. There is a need for decision support to inform responsible outcomes. A problem arises due to the fact that different types of floods and stormwater control fall under different jurisdiction. Flooding from tributaries are managed by the Department of Environmental Protection (DEP) while FEMA manages larger-scale floods. This segregation in the system was an impediment in implementing the winning projects of the Rebuild by Design competitions. Pennsylvania communities face similar flood resilience obstacles. Learning from Rebuild by Design, active steps can be taken to assure that problems are addressed and feedback is heard by maintaining regular updates with local leaders and relevant authorities (Grannis, 2016). As evident from this case, siloed responsibilities an create a profound lack of coordination. Integrating the relevant systems into a coordinated whole would prevent superfluous solutions and enable maximum resource utilization.

Top-down traditional planning approaches are yet to achieve community resiliency because they do not address vital elements such as effective community engagement, interdisciplinary collaboration and a well-perceived planning process with provisions for unforeseen challenges. While coastal flooding receives much attention - giving rise to massive scale competitions like Rebuild by Design which are producing real-life projects that are getting implemented - riverine communities are yet to benefit from that momentum. It is vital to apply these resilient principles when planning in flood-prone riverine areas. Some of the recommendations suggested can be enacted if proactive action is taken; Others require changes at a policy-level. Regardless, it is crucial to equip the riverine communities with vital knowledge and access to information regarding flooding, to involve them in the planning process, and to encourage them to participate in community-driven and informed action. Following the 4-phase resiliency design process informed by the Rebuild by Design competition can help make progress in an ordered manner while the collaboration model can help guide towards the kind of engagement necessary to build resilience. It is expected that the traditional planning approach could largely benefit from these suggestions.

CONCLUSION

The study of publications documenting recent resilient design competitions, such as the Rebuild by Design winning projects, has led a path to planning for resilience during a time when the concept of resilience is still being debated. By providing insights and sharing experiences, the competition teams have pioneered what it takes to successfully plan for...
coastal resilience. Riverine flooding, on the other hand, is not as largely researched. In recognition of this concern, the US government has led initiatives in the interest of hazard preparation, mitigation and adaptation. However, these initiatives are not always aligned with the resilience principles that scientists and experts around the world have recommended, including adequate local engagement. This research has been carried out in an attempt to bridge that gap; it aims to help lead the path to guide the vulnerable riverine communities of Pennsylvania towards a resilient future.

ACKNOWLEDGEMENTS

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REFERENCES


Magis, K. 2010. Community Resilience: An Indicator of Social Sustainability, Society & Natural Resources,


Total recall-ibration: teaching spatial thinking and critical design with virtual reality

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ABSTRACT: Virtual Reality (VR) is an immersive three-dimensional computer generated environment. The concept of VR was introduced in 1960s when helmet mounted display (HMD) devices was introduced to fighter pilots. The technology has improved since then to mature wearable VR devices. Outside of military use, VR can be found in the entertainment and gaming industry, and commonly accessible for home users utilizing entry level technology with smart phones and adapters such as Google Cardboard. The technology has crossed from entertainment to education and visualization. Tapped more frequently in design education, utilized for ideation inception through to logistical planning. The power of VR is in its ability to close the communication gap between designer and builder and users of space. Several previous studies have focused on how VR can improve construction scheduling and safety.

This tool can also be utilized to bridge from the conceptual and abstract; from teacher to student. VR allows environment designers to test concepts in 'virtual space' at 1:1 scale for themselves and for the critique of others – be they faculty, peers, internal, or reviewers. The utility of this tool comes from its ability to move communication from abstract visualization feedback to conversations held within a virtual representation of the space itself. This paper explores the role of VR in how students learn to design spaces and in how they communicate that space with fellow students, construction managers, and their faculty.

KEYWORDS: Virtual Reality (VR), design education, architecture, construction management.

INTRODUCTION

Virtual Reality (VR) is an immersive three dimensional computer generated environment. The concept of VR was introduced in 1960s when helmet mounted display (HMD) devices was introduced to fighter pilots (Furness, 1989). The technology has improved since then to mature wearable VR devices. Outside of military use, VR can be found in the entertainment (Total Recall 1990) and gaming industry (Dawood, N., Miller, G., Patacas, J., & Kassem, M. 2014.), and commonly accessible for home users utilizing entry level technology with smart phones and adapters such as Google Cardboard. The technology has crossed from entertainment to education (Messner, Yerrapathruni, Baratta, & Whisker, 2003) and visualization (Shen & Marks, 2015). It is being tapped more frequently in design education, utilized for ideation inception through to logistical planning. The power of VR is in its ability to close the communication gap between designer and builder and users of space. Several previous studies have focused on how VR can improve construction scheduling (Haymaker & Fischer, 2001) and safety (Chen, Golparvar-Fard, & Kleiner, 2013). This tool can also be utilized to bridge from the conceptual and abstract; from teacher to student. VR allows environment designers to test concepts in ‘virtual space’ at 1:1 scale for themselves and for the critique of others – be they faculty, peers, internal, or reviewers. The utility of this tool comes from its ability to move communication from abstract visualization feedback to conversations held within a virtual representation of the space itself.

1.0 BACKGROUND

In the 1990 movie Total Recall, action hero Arnold Shwarzenegger’s character dons a virtual reality headset to explore fantasy space, action plot aside, the film based on the 1966 short story by Philip K. Dick We Can Remember for You Wholesale (Dick 1995), explores the gap between the real and the imagined, the abstract and the visceral. At the heart of both stories, a series of questions align with the experience inherent in design, and design education; is what I have imagined possible? And, how will the reality be different than the imagined?
Designers work in the abstract, often at reduced scale to create ‘in-real-life’ – virtual reality (VR) offers a chance to move beyond the limit of scale to experience. The line between the imaginary and the reality is one in which designers and construction managers must dwell – conceiving of space, its construction, and planning its logistics before it is made physical. This inherently abstract process has spawned the profession of architect, construction manager, renderer, and draftsman/woman. Architects do not in fact build the buildings they design; they draw them – ‘imagine them’ – and tasked with explaining them in such detail that others can construct them. The education of a student in these abstract processes is, in itself, is a further extension of this abstraction – they emulate the process without actually taking part in it. In part, this is the reason behind the strict standards for training and on site experience outside of the classroom and in design firms and construction sites.

For students of both architectural design and construction management their work in the studio or class environment is rarely at a scale approaching 1:1 construction. VR offers a chance for design education to leap into a digital manifestation of a design idea, test that idea at the experiential and performative scale in a natural, palpable, and interactive way (Fonseca et al. 2013 and Erdoğan Ford, 2017). How will VR effect designers? How will VR engage young design and construction students? What might be best calibrated for this use in their education? Finally, what answers will student find to the same questions posed in the root of design posed be so many designers before them – *Is this design the way I imagined it to be?*

2.0 METHODS
Using an existing university VR Lab, HTC Vive Virtual Reality setup with Revit and Rhino three-dimension modeling software students were instructed on the use of the VR interface to review two models one a digital model of an existing building on campus, the second a digital model of their own design. Students were asked to generate verbal feedback in the moment, record peer feedback and fill out a post-session assessment. This assessment was collected and in turn generated an in class discussion. Selections from this discussion and the feedback forms are provided later in this paper.

2.1 Technology resources and VR lab
Technology to run the modeling software and the VR program and space includes:
- A VR-ready computer: Generally specified as a ‘gaming laptop’ or PC, the computer requires processor and video card hardware able to operate the VR software simultaneously with various modeling programs
- A VR head set unit: HTC Vive was used for this experiment. HTC Vive package comes with a pair of VR goggles, 2 controllers (i.e. hand-held devices), and 2 base stations. Goggles are used to show the virtual world to individual users, while controllers allow them to move and interact with objects in the VE. Base stations are needed to track the location of users in the immersive room-scale.
- SteamVR: Software that allows VR to run with the HTC Vive head set
- IrisVR: Software that allows 3D Revit models to be used in virtual walk-throughs. Additionally, Iris VR allows for in model markups, drawing, and annotation which can be screen captured for later use.
- Minodesk VR Plugin for McNeel Rhinoceros 3D Modeling to be viewed in VR
- Extra large mounted flat screen television connected to broadcast VR output from the headset to the monitor (An optional piece of equipment)

Testing utilized a VR space setup with a 3.5 meter x 3.5 meter x 2.5 meter space with head mounted VR goggles and hand controls tracked via infrared sensors – these are common with setups with hardware from Oculus rift and HTC Vive, this particular study utilized HTC Vive. Alongside this installation for the active VR user is a desk and desktop computer running the 3D modeling software (in this case Autodesk REVIT) and vr plugins, additionally for an a large mobile television setup broadcasts the ‘view from the goggles’ in real time. The space is in a
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flexible tech space co-located near IT services in a library group study area. These conditions noted here, as they proved fortuitous during the VR sessions.

2.2 Computer models
Student reviewed two types of models the first type was a model created from existing plans of an actual building on campus, the second was a hypothetical design proposal made by the student or another student (Figure 1). In both model types creation of the digital model was completed in advance of the VR design review.

Most projects in the study were presented as Autodesk REVIT models viewed through IrisVR plugin, but a minority of projects are also small designs produced in McNeel Rhinoceros 3D through MiniDesk VR– both programs have VR plugin software enabling the project to be opened and viewed in VR space. Software support and interface REVIT based projects are considerably more advanced and engage the systems and layers of REVIT more readily – thus these projects could engage students across majors (architecture and construction management) at a higher order of conversation.

Figure 1. Basic ‘cabin’ student model used in VR (image from the Author 2018)

2.3 Subjects
Two constituencies of students reviewed these models CM students and Architecture students. Students participating in the study varied across students between 2nd through 4th year undergraduates and 1st year graduate students.

Figure 2. Instructor in Virtual space and physical space (image from the Author 2018)

2.4 Procedure
Students were introduced to the VR setup in groups of between 2 to 12 students. Basic interface and safety were reviewed in a instructor-led demonstrations of the system and
physical interface – an optional large TV monitor was helpful in displaying the visuals seen inside the VR headgear to the observers in the class. Computer support staff were on hand for troubleshooting and to ensure proper system operation. After introduction students would take turns individually utilizing the VR setup to explore, assess and offer verbal assessment of the model during the live walkthrough. Students were allowed to explore the space freely. While each student was individually in the VR space classmates would provide guidance, take notes, and prepare for their own exploration. Depending on group size and the students own comfort level with the software students would experience the VR environment for between five to fifteen minutes in the VR space. Students were given the option to return to the VR lab outside of class time for further exploration.

Upon exiting the VR space students were tasked with relaying their findings verbally to their peers for notes and feedback.

Following the session in addition to the design critique of each project each student provided a one page general assessment of their experience providing written feedback to given prompts:

Perception + Navigation
1) Did you feel oriented / disoriented during the VR walkthrough?
2) What was the biggest surprise or difference between the actual space and the virtual space?
3) Having viewed the model what can you identify that would benefit the most from changes?

Details, Mapping + Planning
4) What role did outside students play for your walkthrough?
5) What helped the most to navigate through the space for review? Outside assistance, digital modeling, reviewing plans, familiarity with the design or existing space?

Future Recommendations
6) What planning would you recommend to another person going into VR?
7) What types of details were more easily found in VR than in other formats?

This written feedback, collected from students both verbally during the VR simulation, after simulation in a ‘debriefing’ and through written responses. The feedback generated a post-VR session discussion in class on the experience featuring the prompts. This discussion and feedback provided initial findings, recommendations, and best practices for use by future instructors and classes; presented below.

3.0 FEEDBACK + FINDINGS

Young designers and young construction management students often struggle with creating reasonably scaled spaces at scale – it is not uncommon for students to work out hallways that are expansively large, or tightly squeezed. Similarly, issues of wayfinding, exit corridors, handrail heights, and other code issues which can be observed plainly in construction can be a challenge to visualize during design. These beginner design issues exist – the challenge is in the identification and resolution. While these issues are abstract in the studio virtual reality (VR) modeling at one-to-one scale utilizes a student’s own embodied experience and spatial awareness to speed self-identification, critique, and resolution of these issues. The issues described above would commonly be termed ‘coordination’ in professional practice, and would be fodder of many meetings between designers and construction management teams. Often the real-world implications of code are not experienced until a designer or construction student is working on site – could this experience be brought to the classroom? By pairing architecture and construction management students together utilizing virtual reality the two groups could not only test each other but vault improvements to their designs by following a ‘punchlist’ style check of the work – emulating a real-world relationship. In this experimental partnership, several questions are posed: What issues would come up most frequently? How would the
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learning space need to be adapted? How would VR improve or impede communication? What objectives are expected? What are the drawbacks? Are results more tangible than other models of critique?

After initial testing, several modifications to the learning space and procedures were made to enhance teaching objectives and student application of knowledge. After each session students were requested to fill out a feedback form recalling their experience, a improvements made in thier design and suggest improvements to the lab

3.1 Observation of student engagement

Each student’s design was built as a REVIT model ahead of viewing in VR – students were capable of inputting as much information, data, modeling specifics as needed. Projects varied from high detailed to bare-bones digital manifestations of physical models.

Models were then loaded into VR space for students to first walk through their own design to make notes for future adaptations and then to give tours to other students of the design as a narrated walkthrough presentation. Initially these presentations mirrored a similar method utilized in class for a peer reviewed desk critique.

As students were introduced to VR space students went through several stages:
- Energetic engagement and adoption
  - Initial excitement and novelty
  - Wide-reaching exploration
- Detail orientation
  - Detailed observation
- Prompted review
  - Self-analysis
  - Create design improvements

During initial self-guided walkthroughs of their own designs, students are initially ‘wowed’ by the novelty of the technology and the empowerment of being in their own designed space. This ‘wow’ factor brought a large audience to the initial testing of the VR lab, when utilizing the VR lab was given as a voluntary topic over 90% of students expressed interest in seeing their design in VR.

Novelty and excitement drives the first moments of a VR experience, students are consumed by fully exploring the extent of their space, initially through vaults of super-heroic climbing, zooming in and out, and transiting through the space. This experience while enthralling for the designer as they explore their creation is difficult to critique, or follow via external monitor.

After an energetic exploration of space the novelty of VR can start to wane. At this point students tended slow their exploration focused on detailed areas of the overall design. Most critiques and adopted changes came from studying stair details, lobby entryways, multistory space, and railings. These more detailed observations provided the most useful time to prompt feedback and design critique through careful close up study of specific design elements both in the VR goggles and externally through monitors.

Most of these initial observations come through a self-analysis or self-identified critique of spaces either preforming as intended or not as intended. Ares of design malfunction are more easily identified in VR as the underdevelopment or over complexity of the design can be immediately experienced 1:1. Common self-flagged issues include elements such as handrail collisions, awkwardly scaled spaces, circulation overruns, or collision and headspace issues all of which speedily identified.

Self-evaluation led to discussion of design development and solutions to both enable the utility of the space and clarity of the conceptual spatial ideas. In studio-type reviews where these
issues are viewed through several representations – plan, section, perspective – and this abstraction can lead to uncertainty in the design. In an abstract setting a discussion may feel as it is preferencing either utility or concept in a zero sum game. In VR clashes between utility or lack of clear design concept are seen simultaneously together in familiar 1:1 3D space – thus the use and idea support of each other at scale giving both weight and relevance to improve design of both issues.

After each VR session, students filled out a feedback form to reflect on the experience and relate observations regarding their own design adaptations as well as improvements to the interface. The vast majority of feedback centered around four common issues: scale, circulation, collision detection, and a surprisingly specific facet of student focus was on code complaint stair railings.

Virtual reality tools will allow us as architects and designers to create buildings and products intuitively in 3D space so, we can check our designs and walk our professor and clients through our projects. This sensation of being inside a building makes VR an incredibly powerful tool for communicating design intent. Clients often don't have the ability to understand spatial relationships and scale simply by looking at a 2D plan or 3D model. VR can evoke a visceral response in exact the same way that physical architecture can.

Yasaman M. graduate architecture student

3.2 Scale
Scale was the most common issue reported – *not knowing how big something ‘felt’ in context as opposed to knowing how large it measures* seemed to be a particular utility. In fact, when a group of guest practicing architects were invited to test VR they gave similar feedback. Typically students know the height that they are designing to, but perceiving scale in context can be difficult even when designing with a site that within visitation distance. This issue is increasingly more important designers work on sites from which they are physically displaced. Fifty feet can impose a different presence in a rural landscape, an urban neighborhood, or a city center – the emotion of this scale is often an abstraction when dealt with in a model, be it digital or physical. When viewing through VR goggles a student’s natural viewing habits, perspective, and body scale are naturally utilized to digest the scale of the design at 1:1.

The VR lab... to give[s] a sense of actual scale and what the space created digitally actually looks like... you can control the sun settings in the model while using VR, I think that can become very useful in seeing how the sun and light activates a space. [Critiques] often talk about what could potentially be weird and awkward to live in, but with VR one can confidently say it is weird, or not, to be in that space because they have the actual scale and they believe they are actually in that space

Tom M. 2nd year architecture student

3.3 Circulation
The natural use of a student’s body to engage at their own scale can also extend to wayfinding. A common struggle for beginning designers is constructing comfortable clear way finding in a design. It is not uncommon for complex, overly narrow, overly expansive hallways to run rampant through early designers projects. The realization of a two foot or 15 foot wide hallway is often a concept which remains abstract to students. Experiencing wayfinding through their own eyes students quickly realize if a winding hallway is confusing, too long, or lacks clear signage or clarity of exit routes.

[We] used as a team building exercise, where multiple users can exist in the space and build upon one model or project in real time. One person can design a space and then another can walk around it and change it.

Helen P. 2nd year architecture student

3.4 Collisions
Interactions between buildings systems is a large benefit of construction management modeling. Often-mechanical systems and structural systems are designed, manufactured and adjusted separately, ‘collisions’ occur when one system is altered without proper coordination
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with another system resulting in the two designed to exist in the same space. Electrical conduit, HVAC ductwork, fire protection and plumbing are made up of rises, bends, and runs in highly three-dimensional twists — identifying areas of high congestion, or intersection is a key coordination focus for these students. Traditional 3D building information modeling (BIM) does have collision detection parameters; however, these are not fully effective. Reviewing these models in the computer show a finite field of view on screen, which can make detailed analysis frustrating. VR review allows students to complete a full visual inspection of the model in detail quickly while simultaneously building familiarity with the project. Students could locate and anticipate not only problem areas but also document and understand the collision of one system over another more quickly and clearly.

To put myself in a building that I had spent countless hours drawing in 3D only helped me realize how much more there is to learn in architecture.

Denis C. 3rd year architecture student

The biggest surprise is how the surveyed VR results came out for analysis quickly. Students can experience the surveyed space with accurate measurement[s], and it [can be seen] quickly compared to the traditional method … in which traditional method of field survey … takes [much longer] to complete.

Tran L. graduate construction management student

3.5 Railings

Of note, this particular element – the hand railing – was frequently a key focal point of peer and self-critique by students from both architecture and construction management backgrounds. Similar to building systems railings must be designed with full development through x-y-z axis in a complex spatial choreography. Railings are highly visible often-expressive design details, which must also meet rigorous building codes. A particularly challenging area of design is interior railing return at a stair landing – twisting over a large vertical distance in a short horizontal distance railing is often an area where a design is most challenged or requires a specialized detail. As with collision detection, many BIM programs have automated stair creation, which can implement standard practices automatically but struggles with specialized scenarios. The automatic nature of these programs has a twofold effect. First, since it is usually automated students are not practiced with stair design. Second, the automated plan and section drawings often do not show the design challenge clearly. Viewed three dimensionally railings and handrail detail issues are immediately recognizable in VR. The additional ability to markup drawings in model, drawing in three dimensions, allows students to start designing and implementing appropriate solutions immediately.

Figure 3. Typical presentation of Railing in two-dimensional documentation
4.0 RECOMMENDED BEST PRACTICES

In addition to the focus on specific design issues students gave feedback which lead to the establishment of a series of best practices to gain the most out of the experience. Terminology for this practices adopted pilot-styled vocabulary.

- VR training and familiarization session prior to design review
- Pilot and Co-Pilot ‘buddy system’ to remain task oriented during the walk through
- Flight Plan and design briefing ahead of VR session remain task oriented during the session
- Checklist or punchlist of key design elements and common issues
- Captured design stills / adjusted perspective views for analysis afterwards
- Debriefing to review the VR session and plan changes.

Before any work in the VR lab students paired in groups of a minimum of two people. This partner assisted in the next steps of procedures. The pilot working in the VR realm while the copilot would operate the hardware, software, provide support, reminders, capture imagery, and keep the pilot on task as well as operating the hardware while their partner was in the VR environment.
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Students benefited from having a brief VR session to become familiar with the program – while this was not necessary it did allow students to move through the ‘wow’ stage quickly to begin detailed design analysis, saving time overall.

Figure 6. Student’s view in Virtual space marking up model (left)

Figure 7. Student in physical space (right) reviewing work (images from the Author 2018)

Teams of two to three students in a pilot (in the VR headset) and copilot/navigator operating the computer responded with better feedback in post VR session discussions. Solo students tended to explore tangentially. Teams of students worked together to stay on task and recorded more materials for their post-session debriefing. Additionally students in co-pilot position stood ready to assist the VR Pilot if they became disoriented, entangled in the lab wires, or reach the limits of the VR lab sensors. This assistance made hesitant students more adventurous in adopting the technology. The co-pilots are also useful for recording data, such as screen captures, written descriptions, or vignettes from on screen for the pilot (who is unable to see or use objects outside of the simulation while the headset is in place).

Ahead of any loading of the VR experience students were notably more focused when they planned a specific goal oriented route ahead of time. Termed the flight plan this circulation route kept the team. This exercise meant that the team of students had to state the expected design issues – usually in terms of a checklist or vignette drawings, giving the students diagrams or verbiage to measure against when in the virtual space. The flight plans frequently met with adjustment during the session to take advantage of unexpected design issues requiring attention.

Key to each session was a debriefing, which followed the briefing and the collected information from the session. It is these sessions, and the subsequent feedback forms that evolved both the observations (above) and evolved the best practices for the VR lab sessions. Most importantly, these debriefings allowed for stocktaking of the design in both its conceptual...
effects and its design execution and detailing. The debriefing sessions allowed students to verbalize the experience in VR and test it against their peers experiences. Discussions ranged from the broad and conceptual to nuanced details. Common design issues such as out-of-scale elements or building systems collisions students addressed immediately and without guidance. Overall students reacted favorably to the experience and in general professed a desire to utilize VR design more frequently as a check in their design process either independently or as part of a design studio.

Drawbacks identified in the sessions focused on two limitations of the system. First, the mismatched and singular size of the experience was difficult to manage within the bounds of a class, as the pilot has an intensive experience while their classmates must wait their turn (only one user can use a VR setup at a time). The closed-loop of the VR experience means that the copilot must rely on verbal descriptions from the pilot. In the lab this was assisted by outputting the VR headset view to a large flatscreen monitor for the class to follow along, however the head movements, which are natural in the VR headset, can be abrupt and unsettling to view for an audience. Second, and more infrequent, some students were unable to use the system due to dizziness or a feeling of disembodiment using the googles – this sensation was not linked to a proclivity for motion sickness, as several motion-sick prone students were unaffected as well as the reverse. (In most cases the student affected could use the system and eliminate the sensation by using the headgear while seated in movable wheeled office chair).

As a final observation, the reader should note that VR tech is evolving quickly with new technology coming online during the testing of these initial groups of students, and even during the writing of this paper. This rapid expansion and evolution towards more collaborative and shared experiences being some of the latest additions to VR tech available, but occurring outside of the testing boundaries of this study.

CONCLUSION
Virtual Reality technology continues to increase its permeation of the design environment. As part of a educational system of tools VR can be a potent tools to bring the scalar qualities of architecture into manifested experiential form. The possibilities of this technology are exciting and the novelty of its adoption have led to a fierce interest in the tool – and it is a powerful tool. The closed system nature of the VR headset is perhaps its greatest strength and simultaneously its weakness, it is an almost overwhelming experience for the user in headset, which translates poorly for an on looking audience, limiting its use as a large scale class tool. The greatest utility lies in collapsing the distance (in time) for a student to experience their design in full scale. Where once students might take months or years of work at a firm to see a drawing become built reality (and this tool certainly does not replace that experience), a student’s model can be digitized and walked through – enabling both student and teacher to discuss previously abstract issues of scale in an non-abstract format. This in turn enables the teacher/student conversation to include a deeper discussion and understanding of issues of scale, experience, light, and construction. It also empowers students to be self-critical applying their own tactile knowledge of the world to their own work. VR is not a replacement of drawings, or models, but adds another tool to the designers toolbox to interrogate a design more thoroughly and in turn allows teachers and students of design and construction to ask the same questions with greater intent and shared vision – is this the way you imagined it? How can it be built? And most importantly, How can it be built better?

REFERENCES


The type chair: formal and economic optimization in full-scale 3d printing

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ABSTRACT: This paper discusses the implications of full-scale 3d printing when confronted with normative economic constraints in relation to desired formal outcomes. To explore this, we designed the Type Chair, which includes in its design, a cost and form optimization algorithm that ties the specifics of formal outcomes directly to cost. We describe the design of the chair and its accompanying algorithm, as well as the results we've gathered by employing this process. There is cutting edge, well documented work being done in the domain of 3d printing which suggests a potential paradigm shift for future architects and their approach toward design and construction. These processes embrace the notion that an architect's role is evolving away from the development of singular fixed objects and into the conceptualization of objects whose form changes based on the inputs and desires of a lay audience. The novelty of the approach in this project is the interrogation of how 3d printing processes may affect formal iteration and control in relation to normative market processes and forces. There is an ongoing revolution in the way objects are being conceived and made, and perhaps more importantly, an evolution in the expectations of a lay public whose daily engagement is now with devices and objects which have, as a primary ethos, the character of individual responsiveness. These discussions are important as we confront the potentials and limitations of full-scale 3d printing as a construction type, and how these emerging processes will affect architects and their changing role in the years to come.

KEYWORDS: Computation, digital design, post-digital, 3d Printing

INTRODUCTION

Although 3d printing has existed for several decades, its normative use as a full-scale construction method in architecture is still in its relative infancy. This paper discusses the implications of full-scale 3d printing when confronted with normative economic constraints in relation to desired formal outcomes. To explore this, we designed the Type Chair, whose form would be prohibitively difficult to build with any process other than 3d printing. Knowing that the normative market cost of full-scale 3d printing is often prohibitively expensive, we developed an algorithm using Rhino/Grasshopper/Python that iterates the chair within given economic constraints. In this paper we describe the Type Chair's design considerations along with the development of an optimization algorithm used to iterate the chair in relation to projected cost. There is cutting edge, well documented work being done in this domain which suggests a potential paradigm shift for future architects and their approach toward design and construction. These processes embrace the notion that an architect's role is evolving, away from the development of singular fixed objects, and into the conceptualization of objects whose form changes based on the inputs and desires of a lay audience. The novelty of the approach in this project is the interrogation of how 3d printing processes may affect formal iteration and control in relation to normative market processes and forces. There will no doubt already a revolution in the way objects are being conceived and made, and perhaps more importantly, an evolution in the expectations of a lay public whose daily engagement is now with devices and objects which have, as a primary ethos, the character of individual responsiveness; difference, not sameness, will typify the years ahead for spatial production. These discussions are important as we confront the potentials and limitations of full-scale 3d printing as a construction type, and how these emerging processes will affect architects and their changing role in the years to come.
We have structured the paper in five short sections. Section one is an abbreviated discussion about 3D printing processes and their cultural implications. Section two discusses the design and iteration of the *Type Chair* and many of the considerations and implications therein. Section three briefly discusses how the discourse in architecture begins to change based on the process of 3D printing. Section four addresses the considerations of normative economic constraints that arise when considering 3D printing as a construction method. The general spirit of this discussion centers on the disallowance of our attempt at affordability to weaken what we consider the formal and spatial strengths of the project. And finally, the last section discusses the iterative outcomes and what we’ve learned from these processes.

### 1.0 MACHINES OF DIFFERENCE

The general discourse that arises from the promises of new forms of making such as 3D printing are worth briefly discussing in order to provide some context for the work herein. As has been well documented, processes of digital making, such as 3D printing, help change the cultural expectations of objects. As a culture, we have relatively quickly emerged from a world of standardized production, are currently living in a world of configured production, and are in a rapidly evolving and expanding realm of parametrized production. That’s not to say that standardized production types don’t still exist, it’s simply to offer that processes of standardization are beginning to give way to newer processes made possible by digital software and production. The nature of these emerging processes alters the discourse about objects themselves, but also alters societal expectations, which will have a direct impact on the discipline of architecture and how we make buildings in the future.

In *The Alphabet and the Algorithm*, Mario Carpo outlines how the cultural expectation and recognition of objects emerges from the way the object is produced. According to his argument, the pre-industrial process of constructing numerous hand-crafted copies of objects left each one slightly visually different from the next. This meant that visual ‘similarity’, rather than ‘sameness’, was a primary way that people intuitively understood objects. The industrial age transformed this paradigm, allowing us to build as many identical copies as we desired. This evolved our visual expectations from that of ‘similarity’ to that of ‘sameness’. Contemporary digital tools such as CNC machines and 3D printers, in conjunction with parametric software, begin to force another paradigm shift characterized by visual difference from one object to the next. The parametric software is virtually a machine of difference within given sets of parameters, and the CNC machines and 3D printers are not particularly punitive when the thing printed or cut changes from one object to the next. If the promise of parameterized production is that objects become individualized to the people who desire them, one can imagine the implications of such a change in design thinking, production methods, and the economics of the made object.

Carpo’s argument establishes a theoretical benchmark from which we can begin a discussion of, in the case of this paper, the effects and implications of full-scale 3D printing. For instance, how is design transformed when full-scale 3D printing meets normative economic constraints? How do we discuss the litany of formal transformations within the objects themselves; does this revive typological questions and instantiate topological ones? Does the fact or promise of difference achieved through these processes transform the architect’s role? We are using the *Type Chair* to explore many of these questions and in this paper are focusing mainly on the maintenance of a formal language through digital iteration specifically related to economic considerations.

### 1.1 Design logic, formal language, resonance

The *Type Chair* is specifically designed as a provocation to the questions posed above. Within this project there were a few key questions that acted as design generators. First, how do we create objects that would be difficult if not impossible to produce with methods other than 3D printing? Second, how can we evaluate economic constraints and test the implications of aggressively moving in the direction of general affordability in this regard? Finally, what are the formal implications of a process that creates a litany of unique examples? (Figure 1)
Volumetric complexity was a primary ambition in the *Type Chair*. This complexity creates an object which would be extraordinarily difficult to build with other tools and methods. It also directly challenges the notions of object to object uniqueness in relation to comfort, structure, and affordability. To produce something with a simple surface and form would have meant creating an object that could have easily been produced another way. This avoids the challenges that are likely to emerge when dealing with digital tools that present an inherent promise of formal complexity and difference. We've built several projects invested in ideas of formal resonance - that is, recognizable forms distorted, fragmented, or otherwise altered and placed in a new context – and so were intrigued by how that way of thinking could be employed in this process.

The alphabet began to make sense as a DNA for the chair for several reasons. First, individual letters are forms in the world that we interact with every day; so much in fact that we take them for granted as forms in and of themselves. In the design disciplines these letters, as fonts, are part of our enculturation. We tend to gravitate toward certain fonts and away from others, we make judgements about our colleagues by the fonts they use, and as architects we look strangely at people who have used a serif font when a perfectly good sans serif font was available. However, it's likely that most people in the western world interact with letters and fonts in a primarily subconscious way. We could analogize the meaning of fonts to the meaning of the built environment for lay people. Most people pass by and through buildings without a second thought about their design or meaning; and thus, it is with the alphabet itself – this technology that has so greatly affected our everyday lives, exists beside us, compels us, and propels us, yet is virtually absent from our conscious minds. By using letters in varying fonts as the *Type Chair’s* DNA, we present the most familiar yet forgettable form into an unfamiliar context. This means that the edges, curves, shapes, of which we are so intuitively familiar, when scaled and intersected, become something new that carries with it meaning from its previous existence.

Next, the letters, especially in a nested configuration, offered us the important formal complexities described above that would be difficult to build without the use of a 3d printer. We knew that the Boolean Union of letter forms would create new hybrid shapes of solids and voids. These unexpected shapes become like a portmanteau that holds within it some slight possibility of a phonetic marriage that creates new meanings; in this case, non-literal meanings that offer formal resonance and familiarity. There’s something compelling in the notion that we can recognize the movement of certain lines in the chair that are familiar yet not immediately be able to read the chair as a literal text. (Figure 2)
The use of letters also acts as a play on the emergence of abstraction and automatic processes in art. As we discussed above, 3d printing and other emerging digital processes promise formal variation through parametric means. The alphabet itself is relatable to this way of making meaning; the rearrangement of set components (letters) into a vast array of meaningful configurations. The chair is metaphorical in this regard, as it embraces the world of abstraction, coding, and classification that the alphabet itself gives rise to. It perhaps becomes a playful way of giving the Alphabet Effect, proposed by Robert K. Logan and eventually the Toronto School, a visible and perhaps ironically literal form. But the Type Chair, along with all emerging processes of design and construction, also lives in a contemporary digital environment wherein all causality is lost upon lay users while their expectations and wishes for multifarious affects are granted. So, if as McLuhan suggests, the alphabet itself gave rise to mechanization, perhaps the use of letters in the Type Chair makes sense as a way of seeing 3d Printing as an heir to these processes.

Due to the complexity of the use of nested letters, and a desire to employ some sort of dependent variable, we designed the chair with a simple profile that became counterpoint to the complexity of the nest. We also needed something with relative thickness that would be able to visually support a tenuous nest of letters. A thin form in conjunction with the nested letters would have likely yielded structural issues at the joints, especially given the materials that can be effectively 3d printed at this time in normative consumer markets. A thin chair would have also risked a visual failure of sorts as there is a mystery that emerges from that which gets lost in shadows caused by the deep voids between the letters. Finally, we rounded the edges of the chair for comfort but also to help visually distort some of the letter shapes.

2.0 ECONOMICS OF THE EVERYDAY

There is currently incredible work being done in the realm of full-scale 3d printing. Ronald Rael and Virginia San Fratello, in their book Printing Architecture, provide recipes for printing with numerous materials and reveal some of the sensuous formal resultants. Neri Oxman and her colleagues at the MIT Media Lab have been developing 3d printing strategies with new materials and techniques that are transforming the way objects are made. Similarly, figures such as Achim Menges are invested in questions about new materiality in relation to emerging fabrication types. The project described in this paper is less interested in materiality at this stage, and more invested in questions of form, economics, and user controls that arise as
these new methods of making evolve. This cost/form/client relationship has a lot of fascinating implications for designers of 3d printed objects. First, it begins to tackle issues of formal uniqueness, as discussed in the first part of the paper, without assuming that there is no relationship between form and cost—and without assuming that users aren’t going to expect to be an integral part of design processes in the future.

3d printing costs are almost always directly related to printing time, which itself is directly related to the amount of material used in the chair and support material. Reducing construction cost while maintaining design quality became a major concern when developing the optimizing algorithm. What we found through the iteration of early Type Chair studies is that forms and edges buried within the chair’s interior were radically increasing the amount of material used for the final printed object. We discussed several ideas to rectify this, some of which were suggested by the 3d printing company itself. First, we could inset a second surface an inch or two off the chair’s outer surface, creating a bubble within the chair’s interior which would eliminate the extra lines within the body of the chair. This unfortunately would result in a form whose thin shell could be read immediately, eliminating much of the line and shadow play that makes the Type Chair compelling. We believed this was one of the great aesthetic attributes of the chair—the ability to see through portions of its complex surface, catching glimpses of fractured surfaces beyond.

Another strategy of course would be to convert the chair into a patterned surface entirely. This would be the least expensive option but was untenable due to an exaggeration of the issues mentioned above. We now understood that our task was to reduce line complexity where it would not be seen anyway; primarily in areas where fragments of letters existed within other letter extrusions. But the initial economic exercises themselves created numerous questions for us about ways we could generally test the economics of various formal options to find the underlying relationships between form and expense. So, we decided to iterate the chair design in relation to the following fundamental question: how do the economic implications of 3d printing become formal or spatial drivers in a project, without degrading the desired formal qualities? In other words, we knew that we could value engineer the form to lower the chair’s overall cost but determined that this was not a satisfactory way to approach design; especially with the formal promises that 3d printing suggests.

Two major area of consideration emerged from these foundational questions. First, how does one optimize process and form in order to achieve a desired aesthetic while simultaneously driving down cost? Next, but no less important, how might this optimization process evolve the aesthetic, and what implications does this have for architects in the years to come. Because the DNA of the chair consisted of font itself, many questions began to emerge with respect to the alternation of specific font types, sizes, and the inclusion/exclusion of specific letters as formal drivers that would each have cost implications. For instance, would certain fonts inherently cost more than others? Would serif fonts inherently cost more or less than sans serif fonts? Would the scale of the letters themselves affect the overall cost? These and many other questions became the central to the project.

3.0 OPTIMIZATION AND ITS CONTENTS
Once we understood the general implications outlined above, we began digital optimization efforts in Rhino/Grasshopper/Python that centered on issues of cost, structure, comfort, and form. While these four issues are linked in an inextricable way, the general value of each changes slightly dependent upon which part of the chair we’re considering. To accommodate this and create a more rigorous optimization tool, we divided the chair into six parts, each having their own programmatic requirements. The six divisions are Legs, Joints, Seat Bottom, Seat Top, Chair Back Face, and Chair Back Rear. This allows our algorithm to specifically define element densities (and potentially sizes) based on specific needs without having to manually perform these operations. At potentially tenuous areas, such as the Joints, where the legs meet the Seat Bottom, more structural capacity is required and therefore more assurance of letter density was needed. At the Seat Top and Chair Back Front more density
was also required for comfort but potentially a different density level than at the Joints; the allowance for this density creates a smoother, less striated surface. The Legs, Seat Bottom, and Chair Back Rear don’t require density for comfort or structure so could each employ different levels of sparsity if desired to save in overall material cost. (Figure 3)

![Simple Rounded Body Chair Parts – Programmatic Control](image)

**Figure 3:** Simple Shape Broken into Parts. Source: (Frank Jacobus, Jeff Quantz 2019)

Form, or the chair’s visual performance, was of vital importance, and the optimization algorithm allowed for varying level of controls in this regard. For instance, at the Chair Back Rear, the Seat Bottom, and the Legs there is a greater allowance for formal liberty than there is for the other parts chair. So, these areas have a greater capacity to deliver desired form, but also have a slightly increased capacity to affect overall costs. In other words, the user or designer can manipulate these areas more, but their manipulation has a direct cost result that is controllable.

For each test, the algorithm randomly chose a letter from the font family, converted it into a surface, rotated the surface, and then scaled it appropriately to the specific test. The algorithm then populated each chair part (Legs, Joints, etc.) with a point and assigned the manipulated surface to that point. Finally, the algorithm extruded the letter, split it using the outer shell of the chair, removed any geometry that fell outside the shell, and Boolean Unioned the remainder to the existing aggregation. The algorithm checked the volume of the resulting object and continued to run until the desired criteria of structure and aesthetics were met. Typically, the larger the letter, the fewer times the algorithm ran.

Our optimization algorithm embraces design rules set by economic constraints yet is equipped for a changing cultural environment that demands more lay person control within these constraints. These are the type of discussions that are likely to emerge as we evolve into designed environments wherein objects are not single repeatable entities, but rather are unique one-offs that emerge from a set of predefined rules unknown to the everyday consumer but whose forms are affected by them.

### 4.0 ITERATIVE ANSWERS

The original Type Chair was designed and sent in for pricing without any optimization algorithms in place. In order to iterate the design of the chair we would have to re-nest extruded letter forms, changing their sizes manually, and then re-boolean each outer chair profile out of the constructed nest. This process belied the promise of 3d printed objects, which fundamentally has to do with quickly delivered uniqueness from one object to the next. To truly embrace the processes we were dealing with, and to assume their eventuality within normative market economies, we created an algorithm that allowed for endless iterations that could easily be visually compared, priced, and reiterated based on transparent criteria. In Figure 4 we show the various iterations we’ve built to this point and how much print time is required for each.
Several patterns emerged from the compiled printing time data. First, the larger the letter, the faster the print time for the chair, thereby making it the least expensive option. We tested the same letters for each typeface with 1 inch and 6-inch-tall letters. The 1-inch letters took 43% longer to print than the 6” letters. In addition, and a bit ironically perhaps, the serif fonts printed 2% faster than the sans serif fonts. Comic Sans printed the fastest by 10%, which makes sense due to its cartoon quality. An unexpected result occurred while testing the letter ‘I’ across all fonts. The sans serif fonts of Helvetica and Futura typically printed faster due to the decreased surface area of the letters inherent in the stark font family. Focusing only on the letter ‘I’, the decreased surface area of the letter created an increased surface area in the chair, leading to a print time 45% greater than WingDings, the fastest in that category. We added WingDings as an anomaly font and found it useful both as a cost comparison mechanism but also as a formal aberration. We now have the algorithm workable enough to allow quick iteration and relatively immediate feedback regarding cost. Strategies like these will allow designers to build in their own value engineering mechanisms in ways that ensure that the spirit of the designed object is not lost.

**CONCLUSION**

Development of the *Type Chair*, and the algorithm used to produce its unique variants, was a foundational full-scale 3D printing experiment situated at the intersection of economics and form. This project considered how underlying, often hidden programmatic considerations for individual objects, must be addressed in relation to economic effects as we move toward parametrized models of object production. These optimization experiments should translate well to any material that one chooses to print with in the future due to the general linear relationship between printing time and cost.

3D printers should be thought of as machines of difference. The new construction techniques promised by these tools will begin to engender a world of objects that are unique one to the next. Though the discourse of 3D printing often centers on the democratization of design by lay users, the reality is that these consumers don’t want to assume the responsibility for the conception of these objects, nor do they want to bear the burden of the time it takes to invent, draw, and make them. What it does imply however, is that they will expect uniqueness in their object world; a world in which methods of customization will become commonplace, and the inability to customize will be unacceptable. Designers are vital in this parameterized world and
it will be up to us to determine not only the individual object aesthetic as in the past, but more importantly, the object language and rules. This is the path to the promised future of the appearance or perception of infinite choice and variety for consumers. Designers have an enormously important role to play in this emerging world. As this new way of making evolves, architects will not only have to design objects, but we will also have to understand their DNA and what that means for their potential variants. To design in a world of parameterized objects means to go beyond fixed, immobile form - to design the rules that affect real-time object transformation.

REFERENCES
Architect brought “much closer to the processes of making”

ENDDNOTES

ABSTRACT: Three decades strong, the Digital Turn is now mature enough to be read as a precedent rather than merely a tool for futuristic forms. Aesthetic fascination throughout the Digital Revolution has cycled through parametricism, cyberpunk, minimalism, and the more recent Vaporwave, New Aesthetic, and Postdigital. The philosophy of Object-Oriented Ontology shapes aesthetic theory and our understanding of the inner lives of things. The aggregation of these influences leads to a new self-consciousness among designers about leveraging digital tropes. In lieu of the road signs and duck buildings of Postmodernism, Digital Postmodernism embraces digital aesthetics and techniques—neon gradients, aggregation, feeds, pixels/voxels, and other ‘signs’ of the digital. Efforts to translate the aesthetics of computer imagery into physical space (and thus into practice) have emerged. Models and architectural follies produced in this vein suggest a material palette for bridging from representation to reality: architects seek to create physical versions of digital models, where the reading of space as being syntactically digital is the point. The implication for practice is thus a return to the linguistic concerns of Postmodernism—in lieu of disciplinary-centricity, however, Digital Postmodernism engages the public’s deep knowledge and familiarity with the tropes of digital space. The grounding of this architectural movement in popular perception suggests the possibility of bringing together architects and public, united in their desire to bridge the parallel worlds of virtual and physical space.

KEYWORDS: Digital Postmodernism, Postmodernism, New Aesthetic, Object-Oriented Ontology, Postdigital

INTRODUCTION
This paper explores the relationship between Postmodernism and emerging approaches to contemporary architecture as influenced by the Digital Revolution. It asks, and seeks to answer, how the recent succession of architectural fascinations—Postmodernism, Parametricism, and Digital Fabrication—shaped contemporary preoccupations with digital aesthetics in allied fields and popular culture. The research methodology looks at the work of young academics and practitioners, situating them within various influences including theories of philosophy, art, and popular culture. Collectively, the analysis of existing theoretical texts and recent theoretical and built projects establishes that today’s emerging voices share an interest in digital aesthetics that is both indicative of the larger cultural zeitgeist and a return to the aesthetics of popular culture.

1.0 AESTHETICS AFTER THE DIGITAL REVOLUTION
Architecture of the past three decades reflects both the fast pace of technological development and the economics that accompanied it. Just as parametricism heated up, capturing the public imagination with the celebrity of Frank Gehry and Zaha Hadid, the Great Recession not only halted many projects, but also scaled back what we as architects believed we can do. In art, design, and fashion, minimalism reigned, both because of its economic necessity and because sporting luxury goods during a time of economic hardship proved not a great look (Brooke 2018). A decade later, with unemployment down and earnings up, the design community is once again embracing luxury materials, but the futuristic, smooth swooping aesthetics of the Digital Revolution seem outdated. Three decades strong, the Digital is now mature enough to read as a precedent rather than merely a tool for fluid forms, thus creating a disciplinary question about what follows an aesthetic that supposes itself synonymous with the future.
Like architecture, allied creative fields have struggled with developing a new visual language. In film, popular science fiction became cyberpunk and then seemed to reach a design plateau, stalling out on a specific vision of dystopian techno-centricity (Konstantinou 2019). From the first 1982 incarnation of Blade Runner to the next in 2017, little has changed. The futuristic imagination has not been able to predict what extends beyond this vision.

Instead, contemporary image making has favoured a combination of nostalgia and techno-cool. Vaporwave, a term originally used to classify the sound of synthetic 80’s pop rock, expanded to define a visual culture of Lisa Frank pencil boxes and electric neon ski jackets (Tanner 2016). The recent rise of athleisure and streetwear brands has revived this aesthetic, with the emblematic Supreme fashion empire celebrating a look that seems simultaneously basic and loud: white sans serif text on a red background transforms every product into a billboard.

Gradients have dominated graphic design of the last few years, seeming to be the natural meeting point of 80’s sportswear and 8-bit digital aesthetics. Pantone named its Color of the Year as a gradient of two colors in 2016 and Areaware created a puzzle that immortalized a particularly prevalent pink to yellow fade. MOS Architects adopted this trend, updating its representation to include frontal axonometric drawings placed over gradient backgrounds, a form of representation of digital model space dubbed “screenshots” on their website.1 This meta tagging of an image which is in fact far more composed and labored over than the casual nature of the title suggests is as much a pointed rejection of the ubiquitous representation of photorealistic architectural rendering as it is an embrace of low resolution digital aesthetics. The “screenshot” goes so far as to imply that each project is developed through and lives perpetually in this highly refined digital state. When navigating from one project to the next, it is difficult to tell which is built and which is theoretical, but that is the point: every project, client or not, garners legitimacy from its careful presentation within a staged digital world of buildings unburdened by the requirements of codes, physics, weather, and construction crews—which is to say, reality.

In art, the New Aesthetic was defined not by a manifesto, but in a Tumblr thread of satellite images and pixel art (Birdle 2011). Because it takes form as a feed, “The New Aesthetic embraces an unusual creative technique: aggregation. It rejects the demands of the manifesto in favor of the indiscriminateness of the collection” (Bogost 2012). MOS Architects exemplifies this technique, both conceptually and formally. Michael Meredith and Hilary Sample’s recent book, An Unfinished ... Encyclopedia of ... Scale Figures without ... Architecture, (Meredith and Sample 2018) is masquerading as an encyclopedia but shares more in common with the structure of a tumblr feed or Pinterest board—it collects aesthetic objects as a set rather than assigning value to individual pieces. Their physical creations follow the same logic. Over the past decade, the duo has built up an aesthetic of aggregation: they developed a software that simulates physics by stacking blocks, Stack; they made physical installations that followed the same logic, On the Verge of Collapse and Rainbow Vomit; they have built a series of residential projects that aggregate like shapes (often extruded gabled house profiles), resulting in the framing of oddly shaped voids and courtyards, strange interior intersections, and a constant celebration of oblique views.

This new wave of production hatches out of a popular culture obsessed with the vernacular of digital forums: the ubiquity of drone photography and satellite view, the reality of constant surveillance via digital footprinting, and the rawness of nascent technologies such as photogrammetry (which sometimes allows the creation of accurate digital scans of real objects, but more often than not contains glitches and voids that inspire thrill through their simple inaccuracies).The clear distinction between intention and result in such a process creates the effect of “weird realism” (Harman, 2012), which, like the uncanny valley (a term coined by Masahiro Mori to convey the unsettling human reaction to a close simulacrum) becomes part of the public’s everyday experience in the consumption of video games, live-action films that
are in fact animated, and high-fidelity robots. Other digital tropes include neon, gradients, pixels and voxels, 8-bit net nostalgia, and primitive, simple geometries.

2.0 MAKING THE DIGITAL PHYSICAL
As in the art community, the emerging generation of architects are self-aware of their backgrounds as digital natives, accept technology as a default part of contemporary human existence, and are interested in mining digital vernaculars for novel potential. Just as their predecessors may have studied architecture on the Grand Tour, the new generation draws equal insight from webpage hierarchies, data streams, and algorithms. It follows then that the material palette of this generation contains both stones and pixels, structures of steel and code.

Unlike the Zcorp 3D printers, bondo, and paint readily stocked in the model shops of Morphosis, Zaha Hadid, and other parametricists, the physical models and creations of the new generation represent a shift in the treatment of the digital artifact—from smoothly plastic to self-conscious, reductive, and deliberately physical. In First Office’s Possible Table, a typical table is distorted using digital projection as to undermine its normative reading and use as a table, but is built in a typical material palette, thus bringing the digital act of distortion back into the physical world. Similarly, in the LADG’s The Kids Gets Out of the Picture, normative construction materials are stacked in a makeshift fashion and topped with a plaster surface reminiscent of a blanket atop a child’s fort. While the operation of formmaking is firmly rooted the aesthetic of digital collage, the installation itself hybridizes the found object of the off-the-shelf construction material with the digitally fabricated waffle structure of the blanket.

Postdigital architecture, as defined by T+E+A+M’s Ellie Abrons and Adam Fure, has laid claim to such blurring of boundaries between real and virtual:

- to think a postdigital architecture is to both flatten and peel apart the ontological difference: digital and physical collapse into overlapping realities while qualities of our tangible world, such as materiality and form, cleave. (Abrons and Fure 2017, 194)

In the design of an architectural installation, Living Picture, T+E+A+M demonstrates this effect. Primitive geometries (cones, prisms, logs) are populated with a graphic applique that recreates a historic tableau. The disconnect between form and image in this work suggests a privileging of the Digital. While the physical space is defined by platonic forms, the meat of the project is a digital rendering of a historical space that is then applied to physical objects of no specific formal significance.

In another blurring of the boundary between real and digital space, JE-LE’s Prom Picture creates an architectural installation that can only be fully understood in post-production. A classic, flat green screen backdrop is cut in a topographic pattern and folded to create oblique lines of viewing. In post-processing, the green is swapped for a variety of patterns symbolic of a formal dance (florals, sequins, jewels), transforming the classic couple’s photograph from the banality of prom to the limitless possibilities of digital space. The installation can thus be read as the physical incarnation of a Snapchat filter, a visual editorial captioning on top of an already lived experience.

3.0 DIGITAL POSTMODERNISM

3.1. In architecture
On a fundamental level, Postmodernist architecture was interested in elevating the banality of low culture—Robert Venturi and Denise Scott Brown sought to learn from the adult theme park of Las Vegas, complete with its strip malls and parking lots; Michael Graves became a household name because he sold his style of pop-cultural assemblage not only in the form of buildings, but also as household products on the shelves of big box stores; Postmodernism’s cousin, the Memphis Group, deliberately set out to undermine good taste—which had previously been synonymous with modernism.
The contemporary equivalent of Las Vegas signage is surely the visuals of the internet—memes, social media, online commerce. It makes sense then that the new crop of architects sees opportunity in celebrating and elevating these found materials. If Postmodernism took on the populist palette of billboards and strip malls, then Digital Postmodernism embraces the ubiquity of internet graphics and co-opts them as the building blocks of the new physical-digital hybrid.

Venturi’s argument for the value of commercial signage can be just as easily swapped out for digital signage:

I have alluded to the reasons why honky-tonk elements in our architecture and townscape are here to stay, especially in the important short-term view, and why such a fate should be acceptable. Pop Art has demonstrated that these commonplace elements are often the main sources of the occasional variety and vitality of our cities, and that it is not their banality or vulgarity as elements which make for the banality or vulgarity of the whole scene, but rather their contextual relationships of space and scale. (Venturi 1966).

It follows that a Digital Postmodernism might attempt to redefine the banality or vulgarity of digital tropes by repositioning them contextually against the backdrop of the real world.

While recent architectural movements have originated in the academy, the theoretical text and temporary installation are not enough to cement an idea’s place in the profession. MVRDV’s recently completed The Imprint, a windowless night club and theme park building in Seoul, then plays an important role in demonstrating the adoption of Digital Postmodernism into full-scale, permanent construction. The building’s façade combines the inverse relief of a Rachel Whiteread sculpture with the surreal quality of a warped digital model frozen in space and time.

In mitigating the building’s programmatic requirement to keep out daylight, MVRDV borrowed the windows of neighboring buildings as a kind of digital line work, then "draped" the geometry onto the volume as a series of grooved articulations (MVRDV 2018). The result is a façade skewed by lines, like an AutoCAD hatch gone awry. A giant golden circle is even projected onto the volume and made physical with metal cladding that drips from elevation to ground plane and down a flight of stairs. To occupy the resulting urban space is to set foot in a world that seeks to not only overlap graphics with space, but also to announce the digital syntax of said graphics. The project description on the firm’s website affirms this intention by describing the building through a series of software operations. That the building contains a theme park only furthers its dialectic with Postmodernism.

In this framework, theorists and architects that advocate for a strong placed-based architecture (e.g. Juhani Pallasmaa or Kenneth Frampton) may offer a voice of Digital-Modernism equivalent to the place that Late-Modernists had for Post-Modernism.

3.2. In allied fields
In allied fields, notions of the Digital Postmodernism have not yet been widely adopted. However, the term may apply to a contemporary literary scene defined by the emergence of diary-like realism in fiction, with authors like Karl Ove Knausgård and Rachel Cusk creating memoir work that more closely resembles a daily LiveJournal blog than a personal diary (Mariusz 2017). A modern update on the epistolary novel, it is an isolated projection of self for the isolated consumption of many others. The "digital" part of Digital Postmodernism suggests an external intervention, a filtering through a digital lens (Gibbons 2018). Digital Postmodernism is thus characterized by the depiction of a meta-self, an understanding of a self that has already been filtered through various cultural media. A thing becomes not only itself, but also an encapsulation of what the culture already assumes that self to be.

CONCLUSION
Some have posited that while the progenitors of the Digital championed form, and the second generation translated those forms into construction (digital fabrication), the next wave of architects will leverage data to shape future practice (Marble 2018). Within corporate practice, data has certainly been championed as a tool for both project management through BIM and
project evaluation through the measuring of performance and usage, but this largely reduces architecture to a profession of technicians.

On the other end of the spectrum, the New Aesthetic suggests a relationship with Object-Oriented Ontology (OOO), a philosophy that imagines all things are of equal importance and that things, as much as beings, have inner lives:

The New Aesthetic is a visible eruption of the mutual empathy between us and a class of new objects that are native to the 21st century. It consists of visual artifacts we make to help us imagine the inner lives of our digital objects and also of the visual representations produced by our digital objects as a kind of pigeon language between their inaccessible inner lives and ours. (Borenstein 2012)

In architecture, Mark Foster Gage posits that OOO reaffirms the importance of architecture for its own sake and rich in complexity, rather than as a reductive mechanism for solving functional problems (Gage 2015, 95). Gage is not interested in defining a formal movement so much as convincing the architect that form, like everything else, has value.

For an emerging cohort of architects, neither problem-solving nor OOO is enough. This group is not defined by a manifesto or doctrine, but can begin to be aggregated under a shared operation of blurring digital and physical boundaries where the reading of space as being syntactically digital is the point.

In lieu of disciplinary-centricity, Digital Postmodernism engages the public’s deep knowledge and familiarity with the tropes of digital interaction. The grounding of Digital Postmodernism in popular perception suggests the possibility of bringing together architecture and public, united in their desire to bridge the parallel worlds. Postmodernism allowed for economics and culture to blend: “Postmodernism calls attention to the reality that in the age of commodified culture, art has to be produced within the capitalist market; therefore, culture and industry always intertwine” (Tanner 2016, 32). In the same vein, Digital Postmodernism posits an inextricable link between contemporary culture and digital space.

REFERENCES
DESIGN THINKING


ENDNOTES

\[1\] www.mos.nyc

\[2\] In addition to publishing Learning from Las Vegas in 1972, Robert Venturi and Denise Scott Brown put together the exhibition Signs of Life: Symbols in the American City in the Renwick Gallery of the National Collection of Fine Arts, Washington, D.C. for the Smithsonian in 1976. The exhibit included three sections: signs and symbols in the home, on the commercial strip, and on the street.
Eileen Gray, systems thinker

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ABSTRACT: I propose to show how Eileen Gray is an exemplar of Systems Thinking, and in so doing articulate how Systems Thinking can and should be integral to design on multiple levels from the conceptual/aesthetic to the pragmatic. After years of near-obscurity, Eileen Gray (1878-1976) has secured her place as a thinker and designer who contributed significantly to Modernism at its inception. Scholars Peter Adam, Caroline Constant, Wilfried Wang and Jennifer Goff have detailed the depth of her knowledge and the sophistication of her working processes and innovation, both in the decorative arts/interiors and in her architecture—with the consensus that Eileen Gray had an unusually detailed and dynamic way of thinking about climate and site, functionality in daily life, and materiality and material processes—above and beyond many of her contemporaries. Systems Thinking—which emerged a half-century ago as a fundamental framework for environmental and economic sciences—enacts the notion that objects, forces, ideas, and especially people—interact and are mutually influenced in both somewhat predictable but startlingly dynamic ways. In architecture, we tend to attach the notion of systems to either the technical or the holistic/societal, but more clarity is needed about how it impacts the act of design itself, at the moment when multiple and competing interests are made manifest in matter and form. By outlining how Gray brought a kind of "operational thinking" to multiple aspects of her work, I will demonstrate through logical argumentation how she exemplifies Systems Thinking as enacted in design. A corollary motivation for this thesis is to take Eileen Gray out of relative—albeit admiring—isolation and place her in a framework that can further emphasize the nature of her contribution. Enriching the discourse on the design-specific implications of Systems Thinking also offers a potent bridge between theory and practice.

KEYWORDS: Eileen Gray, Systems Thinking, design, empathy, operational

INTRODUCTION

Systems thinking presents a lens to recognize and see how our built world exists within social, environmental and business realities, which are changing at a rate that traditional architecture can no longer support (Miller). As a practicing architect and academic I am an advocate of Systems Thinking, which emerged a half-century ago as a fundamental underpinning of environmental and economic sciences. "Systems Thinking is the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of the underlying structure," (Richmond 1994, 6). While not without criticisms and caveats, Systems Thinking enacts the notion that objects, forces, ideas, and especially people—interact and are mutually influenced in both somewhat predictable but startlingly dynamic ways. While whole conferences have been devoted to Systems Thinking in architecture (i.e. ARCC 2017), the papers tend towards building science-type research—a creditable arena where increased understanding of flows and trade-offs is most pressing—but which leaves not only a gap in the discourse on the broader implications of Systems Thinking, but also the absence of a potent bridge between theory and practice.

I propose through logical argumentation to show how Eileen Gray is an exemplar of Systems Thinking, and in so doing articulate how Systems Thinking can and should be integral to design on multiple levels from the conceptual/aesthetic to the pragmatic. As part of book research on innovation and the home, I have done archival research on Eileen Gray to understand her working processes and thinking beyond what is available in other publications—highlighted by the occasion to examine the finally-nearly-restored E1027 in Cap Martin, France. Thinking about how Systems Thinking manifests in a designer’s work requires unpacking how and why
one makes thousands of decisions during the design-to-realization process while weighing considerations and trade-offs based on both sound and murky motivations. It also requires a more thoughtful analysis of what Systems Thinking actually means in the design arena.

1.0 BACKGROUND

1.1 Why Eileen Gray
After years of near-obscurity, Eileen Gray (1878-1976) has secured her place as a thinker and designer who contributed significantly to Modernism at its inception. Scholars Peter Gray, Caroline Constant, Wilfried Wang and Jennifer Goff have detailed the depth of her knowledge and the sophistication of her working processes and innovation, both in the decorative arts/interiors and architecture—as well as her often unacknowledged influence on others. While the specifics may vary, the consensus is that Eileen Gray had an unusually detailed and dynamic way of thinking about climate and site, functionality in daily life, and materiality and material processes—above and beyond many of her contemporaries. Her “outsider” status as a woman of independent wealth and tremendous drive, enabled her to enact ideas in unparalleled ways that inspire us to this day. Relative to the Modernist “canon” that centers around Le Corbusier, Walter Gropius, Mies Van der Rohe, et al., Eileen Gray nonetheless continues to be regarded in relative isolation, much like Carlo Scarpa, Hans Scharoun and even Alvar Aalto—the “Other Modernists” of Colin St. John Wilson (St. John Wilson 1995). While often revered, their contribution is seen as “unique” and thereby kept at the periphery of transmitted knowledge. A second motivation for this thesis, therefore, is to take Eileen Gray out of relative—albeit admiring—isolation and place her in a framework that can further emphasize the nature of her contribution.

1.2 Why systems thinking
For me, the choice of Systems Thinking as a framework emerges as much from professional practice as from the theoretical/academic. As projects face higher demands in cost, performance, and environmental impact, it is clear that design and construction need to be rethought through a much deeper operational and logistical lens. Most of us have expertise in things like structural systems, which at the most basic level consists of all the components that hold a building together and convey its vertical and lateral forces to the ground, including its foundations, walls, roofs, columns, and beams, as well as the mechanisms that join them. Considerations such as embodied energy or life-cycle analysis, however, move us beyond just physical systems into a realm where the role and interaction of factors like energy, human resources and psychology, waste, logistics, economics and equity must be integrally considered. Although some issues may ultimately be resolved through innovations such as smart materials or digitally-printed cities, getting there requires returning to first principles—to the biology, chemistry and physics of materials and forces in the environment, and to the reappraisal of core human—and non-human—needs. Increasingly, answers of substantive consequence can be divined only through Systems Thinking, because each decision is a result of many factors from the concrete to the ethereal—which in turn affect a web of consequences. Such real-world conditions are forcing designers to approach their profession with an experimental frame of mind, and with a willingness to re-assess and retool as needed.

1.3 Systems thinking, expanded—and simplified
The need to address issues like sustainability more deeply in architecture has pushed some theorists and practitioners to harness the language and concepts Systems Thinking. Kiel Moe, in his remarkable book *Convergence* argues that:

> …buildings, and their architects, would be more powerful if they targeted complex, adaptive feedback loops that reinforce the ambitions and unconsidered capacities of buildings and their contingent system (Moe 2013, 7).

Moe urges us to imagine the systems potentials in many more aspects of buildings and materials than we do currently, with the potential of solving more problems with fewer means. For many, though, Kiel Moe is an expert in a language that remains elusive. It’s not just Moe, either—looking through a variety of literatures it is clear that Systems Thinking is simple to understand as a generality, but slippery to communicate in how it manifests in actuality. It is
possible that Moe is that he’s making his language more complicated than it needs to be—and maybe other Systems Thinkers do as well. On the subject of wood, for instance, one could boil his argument down to the point that it is a product of abundant free energy which simultaneously has structural, insulative and mass properties (as well as aesthetic and symbolic)—so why not use it for all of the above? In Systems Thinking-speak, it means that one gets many “alignments”, or mutually reinforcing benefits out of the one material that one can then “leverage” for a win-win or “positive feedback loop”, for the net result of an attractive, smaller-ecological-footprint building that relies on fewer fossil-fuel or mechanically-driven components. Moe is able to arrive at this thought because he is simultaneously able to pull “out”—to think about energy flows from a global or even extra-terrestrial perspective—and to pull “in” to think about its implications at the human interface. This kind of multi-scalar thinking is consistent with Barry Richmond’s thought that:

…people embracing Systems Thinking position themselves such that they can see both the forest and the trees (one eye on each)….structurally…both the generic and the specific … behaviorally…both the pattern and the event. (Richmond 1994, 7)

The idea is simultaneously revelatory and entirely commonsensical. In the same vein, Richmond goes on to highlight Operational Thinking—which he feels represents the “unique essence of Systems Thinking”—and which he defines simply as “getting down to the physics”—following what is actually going on in a particular condition,” and, “getting a fix on the underlying operational reality.” (Richmond 1994, 6) From this perspective, internalizing Systems Thinking starts to seem quite manageable.

Another commonsensical property of Systems Thinking is called “perspective” by some, “empathy” by others (Cabrera & Cabrera 2015)—which is to say that one has to be able to see from an “other’s” point of view to understand what forces might be drivers from their vantage point as opposed to one’s own. According to Human Interaction Designer, Seung Chan Lim:

Empathy is an explanatory principle for our potential to experience an event, where we feel as if we are embodying and/or understanding the experience of the other, and its related meanings from the context and vantage point of that other. (Lim 2013, 70)

Why this ultimately matters in Systems Thinking was unexpectedly clarified for me in an article about Wealth of Nations philosopher Adam Smith:

When two or more parties are in conflict, we must empathetically evaluate each of them. Only after having done so can we determine to what extent each has behaved properly toward the other. (Frazer 2010)

In other words, demands inherently compete, so navigating knowledgeably and adjudicating fairly amongst them is critical for achieving a “positive feedback loop” outcome. While applying this to interpersonal relationships may seem obvious, equally important in Systems Thinking is the idea that, “We are capable of realizing our empathy in relation to non-human beings, even inanimate objects.” (Lim 2013, 81) In a truly Systems Thinking mindset, we need with equanimity to be able to consider the point of view of a river, a factory, a healthcare regimen, and so on—what does each one need? What can each one give or take for the better of the whole?

2.0 EILEEN GRAY, SYSTEMS THINKER

2.1 Eileen Gray background

Operational Thinking and empathy as essential characteristics of Systems Thinking provide a useful entre into the consideration of Eileen Gray. I will discuss how these characteristics manifest in Gray’s observations of, and design responses to what emerged from the following: material; daily living; climate and site; and fabrication and construction. While one could argue that other designers have used similar approaches and achieved comparable ends, several unusual elements of Gray’s background reinforce this narrative aside from her tremendous native talent and intelligence. Her rigorous work and experimentation as an artist and artisan; her self-imposed isolation and the concomitant necessity of an inventive self-reliance; and her willingness to step across gender and class boundaries—were all factors in bringing about a more through-going Systems Thinking frame of mind. Most of my evidence relies on the
extensive scholarship of others, with some modest evidence about her work processes from my own ongoing research.

Eileen Gray’s life story is quite extraordinary, and impossible to do justice to in a paper that is not even entirely about her. An Irishwoman born in 1878 to a noblewoman and bohemian artist father, Gray fled her likely lot in life in 1901 by landing herself in Paris—a buzzing milieu of new and often scandalous ideas, though the art education she received was staunchly classical, and corralled by her gender and class. A serious student but not entirely satisfied with just art, she pursued an extra-curricular discovery of lacquering that became a full-fledged apprenticeship and partnership with Sugawara, an ex-pat Japanese lacquer artisan. By the eve of WWI in 1914 at the age of 36, she had received considerable acclaim for an extraordinary series of lacquer screens and furniture pieces. After four years of war that included ambulance-driving, relief work, and finally retreating to London, Gray returned to a Paris markedly changed by both devastating losses of friends and places, but gains of new attitudes and freedoms. (Goff 2015)

The several years before 1926—when construction began on the iconic E1027 house—were remarkably productive for Gray. Featured at the 1923 Salon des Artistes Decorateurs, Gray gained notice not only from the public but from the likes of Pierre Chareau, Mallet-Stevens, members of De Stijl. Taking on lover and collaborator Jean Badovici, Gray found both a public venue for her ideas through his influential publication L’Architecture Vivante as well as a means to gain an architectural training of sorts, informally facilitated by Badovici’s friendship with Le Corbusier. In the meantime, she had secured interior commissions in Paris and was variously maintaining workshops for producing her designs in lacquer, furniture and striking hand-made rugs, in addition to opening a retail Paris storefront called Jean Desert. By the time she started E1027 in Roquebrune, Cap Martin—where in ostensibly collaboration with Badovici and for him, she could play out design ideas that harnessed all her training and capacity into an extraordinary result (Figure 1, 2).

The decade-plus following was wonderful and terrible in equal measure for Gray—travel to Mexico, Peru and the U.S.; closing Jean Desert; designing numerous unbuilt houses and public buildings; leaving Badovici—and with him E1027; building herself the possibly even more remarkable Tempe e Paille while unbeknownst to her Le Corbusier was covering E1027 with garish, erotic murals; forced to leave the coast as WWII closed in to later return to nearly destroyed houses; painstakingly restoring Tempe e Paille only to have to turn around and sell it. With all the disruption and increasingly distance from the design community, Gray essentially disappeared from the public view for twenty-five years, even as she continued to work and create. Suddenly “re-discovered” in the 70’s with the record-breaking auction of one of her early lacquer screens, she was honored with six major shows worldwide in the last six years of her life, passing away in 1976 at the age of 98, while working on a celluloid screen. She destroyed many of her papers, but others were saved, and not long before she died Aram worked out licenses so that finally, her pieces could be mass-produced as she had always wanted(Goff 2015).

Figure 1: Restored exterior of E1027 (author)  
Figure 2: Restored interior of E1027 (author)
2.2 Gray's operational thinking and empathy via material

While designers may at times build their own work, for the most part it is the expectation of their training that they provide the ideas and instructions that others use to execute the actual work. Artists, on the other hand, typically execute their own work with the expectation that it is largely by their hand, and unique. As an artist/artisan, and in particular working in lacquer which is an arduous and exacting process, Gray became deeply familiar with the separate rigors of the repetitive as well as the unique. Lacquer can require as many as 40 layers applied and worked under exacting conditions, with the possibility of failure at any step. While virtually every lacquer piece Gray fabricated could be considered a tour-de-force, she regarded herself as often bumbling and having to start over. Nonetheless, “Eventually she mastered the medium to a perfection that assures her a place as one of the great lacquer artists in history,” (Adam 1987, 50). Both the repetitive nature of application as well as the arduous process of realizing unique colors and effects required the following of detailed steps and precise measurement, requiring a high level of Operational Thinking: “Her craftsman-like approach to everything she undertook speaks from every line she wrote down.” (Adam 1987, 53) This could equally be called empathy with the medium, as embodied in her willingness to accommodate to its rigors, though one might be tempted to shift the discussion to the lustrous, sensuous sense of the deeply layered materiality that she drew out of the material—empathically allowing the material its highest expression (Figure 3).

Gray also was deeply involved during the early part of her career in the design and fabrication of hand-knotted rugs. She went so far as travelling to North Africa to learn weaving and natural wool-dying techniques from Arab women,” (Goff 2015, 163) and “Gray (and collaborator Wyld) were probably the first to experiment with natural undyed wools used alongside dyed wools, uneven pile lengths, and juxtaposed plied and unplied yarns in the pile.” (Goff 2015, 164) She created a workshop in Paris to hire and train women, and again, “Gray was exceedingly precise in her instructions regarding the wool and the cost of wool to be used,” (Goff 2015, 164) and “Gray wrote….about the process of weaving, the workings of the loom and how to achieve a certain texture which illustrate an in-depth knowledge of technique.” (Goff 2015, 165) While this kind of Operational Thinking might be normal for any solid business undertaking, it was also about empathy, in seeking to elicit the most out the wool’s natural materiality (Figure 4). As one reviewer glowingly described “The tangled wools recall the mane of some captive beast. It is the complementary effect the artist wanted for the shimmering wood and sharp edges of her furniture.” (Goff 2015,164)
2.3 Gray’s operational thinking and empathy in daily living

“A house is not a machine to live in. It is the shell of man, his extension, his release, his spiritual emanation. Not only its visual harmony but its entire organization, all the terms of the work, combine to render it human in the most profound sense.” (Goff 2015, 263)

Gray is probably the most known not only for E1027 and its extraordinary siting, sophisticated organization and built-in cabinetry systems, but for the free-standing furniture that she designed as an integral aspect of the house. The adjustable steel tube bedside table and gateleg tea table (Figure 5) continue to be considered icons of Modern design. In each of such pieces, her Operational Thinking as well as multi-faceted problem-solving is evident. Like Marcel Breuer, Gray was intrigued by the design potential of steel tubing, but creating a static The tea table, for instance, slides together and folds compactly to store; it is light enough to move easily from indoors to out; has swiveling disk-shaped trays to support desserts that can be swung to arms-reach; the table end elongates so cups can be set down. Its surfaces are cork to prevent clinking noises that might disturb a sleeper or damage the cup itself. Inherent in her design was a critique of what she saw as the shortcomings of the approaches of architects such as Le Corbusier, who liked to claim thoughtfulness about storage but tended towards generic or standardized solutions. “she refused the modernist’s trust in the power of machine to transform man and his environment, instead believing in the need for emotion in all creation.” (Wang 2017, 15) The thinking-through—or Operational Thinking—of what needed to swing or move where and how to accommodate needs is one thing, but the transformational characteristics themselves elicits an interaction between human and object, creating an empathic relationship. As Caroline Constant articulates: “Gray derived her sense of design from the enabling powers of architecture vis-a-vis the human body. Gray rendered the subject an active agent in her environment…” (Constant 1994, 275)

E1027 gets some of its unique characteristics from the fact that it was small but not about providing just the minimum, such as in the social housing units that also preoccupied designers at the time—it was a compact house meant to support joyful living for an exuberant man, Badovici. Even in the kitchen, which was not so much Badovici’s realm but that of Louise, Gray’s lifelong housekeeper, Gray made a conscious decision to integrate what she learned of the Frankfurt Kitchen and Taylorism, but also to go further or otherwise ignore some of its decisions in favor of a more exuberant notion of living. “The kitchen, more than any other room in the house, demonstrates Gray’s rejection of the functional dogma of the avant-garde movement” (Goff 2015, 272) Without being much larger or lavish, the E1027 kitchen celebrates a strong connection to sunlight and the outdoors by working in retractable windows, and outdoor work space nearby, cistern overhead, easy but concealed access from the front entrance, drying racks placed in a sunny window niche, and varied storage components at useful heights and sizes (Figure 6). In effect, the kitchen is an exuberant negotiation between the outdoors sunlight and water, storage, preparation and serving needs, and the animated movements of the occupants. Though it is said that the kitchen didn’t really work as well as Gray had hoped, it is a clear if imperfect example of both empathetic and operational modes of thought, where multiple alignments are sought, negotiated and harnessed. (Goff 2015) On a side note, E1027 has been almost fully restored, but the kitchen remains incomplete—one looks forward to the day when it can be explored in its original form.

While any of the dozens of elegant built-in storage units with folding or swing-out tables or drawers, mirrors and lights could be used as case studies, one less-seen example that caught my eye was the hat “niche” near the entrance, which Gray has described: “Built into the wall of the stair to the left is the niche for hats, a half cylinder in transparent celluloid, with its shelves made of loose-knit twine nets so the dust cannot settle.” (Goff 2015, 270) One can imagine her puzzling through, where might hats go that might be wet or dusty, conveniently go to be ready at hand yet slightly hidden—and not create a clean-up nightmare, while being enchantingly being held by light twine...(Figure 7).
2.4 Gray's operational thinking and empathy towards climate

Gray’s diagrammed plan of E1027 is well-known. In addition to noting the house’s orientation relative to the town, the mountain upslope, the views to the sea, Gray carefully marks out the sun’s path as well as the movement and stasis patterns of the inhabitants, both owner(s) and housekeeper throughout the day. Shading and sunning were of equal concern given the hot weather on the one hand and difficulty of obtaining fuel for heating on the other. In contrast to Le Corbusier’s infamous failures to block the sun from overheating in some of his earlier buildings, which were later compensated by his famous but static brise soleil, Gray demonstrated a much more nuanced response to climate in its multiple modes and relationships to occupants.

Gray’s window shutter system on the north side of E1027 is also said to reflect a much more multi-faceted and operationally-aware response to the climate as well as other factors. It was also a response to an off-site debate between Le Corbusier’s dictum of horizontal “ribbon” windows for uninterrupted view, and Auguste Perret’s assertion that contrary to the anthropomorphism of vertical window, horizontal windows were “a transgression of the values deeply rooted in the culture and life of the interior.” (Constant, 274) Gray herself said that “a window without shutters is like an eye without eyelids” (Goff 2015, 256) Gray’s solution of a sliding shutter and folding window system supported a variety of configurations from closed window and closed shutter to open window, closed shutter, open window and shutter, and so on, such that one could freely mediate between amount of sunlight, amount of breeze and degree of privacy. While Baldovici held the patent, the drawings and working out were clearly by Gray, (Goff 2015) further exemplifying her operational and empathic thinking (Figures 8, 9).
2.5 Gray’s operational thinking and empathy in fabrication and construction

A common point made about Gray is how she generally got on with the workmen, while her partner/collaborator Badovici—who was inclined to show up sporadically and start ordering them about—was not. This seems remarkable given that Gray was still operating in an extremely sexist world where female architects were virtually unheard of, much less one that was trying extremely novel and risky ideas. It helped that “from early childhood on, Eileen hated the complacency and arrogance of her class” and that she apparently had “an inborn feeling of compassion and social justice” (Adam 1987, 14). At E1027, Gray worked side-by-side on a daily basis with the workmen for nearly three years, such that “having lived on the site in daily contact with the builder, she had gained a tremendous amount of practical experience about building.” (Adam 1987, 267) She also spoke to the fact that there was reciprocity: “The close collaboration with workmen trained her eye and helped her to eliminate superficial decorations, of which the period was fond.” (Adam, 1987) It seems clear that Gray’s experience as an artisan as well as a start-to-finish participant in building construction process gave her not only a deeper understanding of materiality, but also of the experience of the makers and builders themselves. She could not only have a much stronger dialogue about how something might be constructed, but also have an operational sense of the logistics and the effort required to get it done. This would immediately distinguish her from most other architects of the time, who might believe that they understood a detail or material, but would rarely have the experience or even the inclination to extend their understanding to considerations of or feedback from the people involved, particularly given the class attitudes of the time.

By the time she embarked on Tempe e Paille, she had enough experience to relish the challenge of the even-harder site perched on a hilltop on existing cisterns—helped by the fact that she had a loyal team of artisans to work with her. (Adam 1987) Again, one could argue that she was able—through the circumstances in which she existed—to observe with a deeper operational lens more empathetically and therefore, more successfully. In contemporary construction, gaps in this kind of operational understanding continue to be frequent sources of friction and litigation.

In other arenas, such as her furniture, she was quite conscientious to develop details that were not only logical and simple to operate from a user point of view, but also logical from the perspective of the fabricator as well as the materials involved. In part was likely a reaction to, or “lesson learned” from the extreme arduousness of her early lacquer pieces. In the case of the Transat Chair which Gray envisioned for inexpensive mass production, the bent-plate sliding connectors are particularly clever in their simplicity (Adam 1987) (Figure 10).
differentiates her furniture, for instance, from the likes of Mies Van der Rohe’s Barcelona chairs, whose crossing steel bars are reputed to take 7 days to weld together.

It should also be noted that as a business owner as much as an artisan or architect—in a metier where ambitions were high and business sense and profits were low—Gray could also see both sides of being paid for and having to pay for work. In my archival research, where I was looking for evidence of how she worked out technical details and questions of structure—in part to dispel notions that she relied on help from people like Badovici on such aspects—I was struck by how much time she clearly had to spend adding up columns of numbers, making detailed lists of materials and chemicals, discussing back and forth the fine points of a chromeing process or threading of a screw, and haggling over bills. While having to take care of virtually all aspects of both her daily life and her work yielded a tremendous body of operational knowledge and creative output, she was still constantly forced to expend her energies swimming upstream—but perhaps she was OK with that.

Figures 10, 11, 12: Details of Transat chair, light switch and wiring, mosquito netting cupboard (author)

CONCLUSION

Much of Eileen Gray’s process work was destroyed by circumstance or as a matter of course, but enough remains to create a sense of an accomplished multi-faced thinker and maker. In her surviving (restored or newly manufactured) works, the narratives of her thought process feel as if they are embodied in the product—a testament to the quality of thought that went into them. So far, among many sets of sketches, I have only found one set of a seriously rough early-stage drawings that hint at how hard she worked to evolve some of her projects from start to finish—typically more resolved stages of work were preserved. As an experienced architect, I can bring a deeper level of interpretation to such process work, but more archival work lies ahead. So far I have also relied primarily on other scholars to understand the working processes of her contemporaries, so more archival work is also required there. While this attempt to conjoin Eileen Gray and Systems Thinking cannot do full justice to either, perhaps a useful dialogue can be opened about how an empathetic and dynamic thought process can not only result in successful, beautiful design—but suggest a systematic and integrated approach to design challenges that lie ahead.

REFERENCES


Tensegrity cushions: formwork for cast-in-place concrete walls

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ABSTRACT: This article presents a tensile, fabric formwork for casting structural concrete walls that utilizes a tensegrity space-frame system. Based on analytical and scaled physical modeling, a series of full-scale proof-of-concept concrete casts demonstrate the methods, techniques, and sequence of construction along with the variation and tolerances achieved. Presented as an alternative to current cast-in-place concrete construction techniques, the tensegrity formwork provides a base logic for novel and emergent behavior in the final form while demanding comparably minimal material, equipment, and labor skill-sets. Empirical testing of the proof-of-concept casts document three points of control: the formwork system's ability to maintain industry standard coverage of structural steel; an acceptable tolerance on the location of structural connections; and, a reliable formula for estimating concrete volume. Further development of the assembly will include the testing of structural connections along with embedding programmatic and environmental design responses.

KEYWORDS: Concrete, Fabric Formwork, Tensegrity, Labor

INTRODUCTION
Steel has a tensile capacity of 60,000 pounds per square inch (psi), which is nearly double its compressive yield of 36,000 psi. These numbers are quite striking when measured against wood's 6k tension and 22k compression or concrete's meager 600psi in tension and 4k compressive strength. Buckminster Fuller exalted these tensile qualities in the structural concept of Tensegrity -- a coined phrase for tensional integrity. Tensegrity is a structural system that maximizes the resistance of forces through tension members and thus minimizing less efficient compressive members. Ideas of tensegrity are recognizable in many of the model explorations and built architectural work of Frei Otto. The breadth of Frei Otto's design research demonstrates the complex and diverse forms attainable through variations in tensegrity assemblies. Contributing to this area of research, a tensegrity system is adopted as an internal structure to a tensile, fabric formwork for cast-in-place concrete. This tensegrity system facilitates the construction of accurate and variable cast forms by comparably low-skilled labor, while minimizing the total material consumed by the formwork.

In this article, contemporary fabric formwork systems by Mark West are reviewed along with a survey of tensegrity systems by Frei Otto. Industry standards for structural concrete walls are assessed and selected along with techniques adopted from current fabric formwork research. A series of physical concept studies and small-scale structural models, problem solve design decisions for multiple full-scale proof-of-concepts concrete casts. Dissection of the full-scale cast structures documents the tolerances achieved and leads multiple iterations of testing through additional controlled casts. The research concludes with computational modeling that explores emergent behavior -- formal variations influenced by possible structural, programmatic, and environmental systems -- of the tensegrity formwork.

1.0 SURVEY OF CAST IN PLACE CONCRETE SYSTEMS
Concrete's stone-like beauty and potential for limitless form has driven the construction industry to challenge the methods with which we design, fabricate and deploy formwork. With each new advancement in formwork systems, concrete's weight of 150 lb/ft³ remains a dominant factor. Prior to curing, this static load of the concrete slurry is quite considerable -- most notably the accumulated outward pressure at lower levels of wall formwork (150lb/lnft x
A survey of contemporary cast-in-place concrete wall formwork systems compares how this high, yet brief, strain of the concrete slurry is mitigated differently when set against various other considerations; The time and labor’s skill required to deploy the formwork, the volume of materials consumed by the formwork, the sophistication of the equipment required, and ability to integrate building systems. To survey the impact that variation of the final form has on these factors, I have assembled the diagram below drawing from personal professional practice and construction experience with concrete, and through research on the topic.

Figure 1: Diagram Cast-in-Place Concrete systems. (Author 2018)

Contemporary solutions to these constraints have developed formwork either integral or sacrificial to the final cast form. Ubiquitous in construction today, concrete masonry units (CMU) and insulated concrete forms (ICF) (Diagram: Category 01) are modular units that are not removed after the casting of the concrete and therefore remain part of the final form. Their modularity and sizing allow for relatively low-skilled labor when constructing a uniform wall. Although when confronted with constructing highly-variable forms, these systems are limited by the unit size or the time and the laborer’s skill required to alter the individual units. It is important to note that the concrete finish of the CMU blocks is expressed in the final form. Whereas, the rigid insulation foam of the ICFs remain as the constructed wall’s finish -- not concrete.

Sacrificial or removable formwork systems -- whether wood boards, plywood sheathing, metal or plastic panels -- require an independent structural support system (Diagram: Category 02). These support systems include the vertical studs bracing the panels, the horizontal wales that bind the studs, and buttressing behind the wales locating the system on site. Some efficiency can be found in the reusing of the panels and subsequent supporting when constructing uniform and low variability forms. Although, when considering high-variability forms, the novelty of each member becomes excessive in the consumption of time and materials. In the past decade, Subtractive Digital Fabrication’s ability to manufacture high-variability with little to no excess time has opened the door to complex form-making and casting. Subtractive Digital Fabrication is burdened by requiring a very highly-skilled labor pool along with specialty equipment; such as, multi-axis computer numerically controlled (CNC) and plasma cutters. This equipment allows for off-site fabrication but adds additional expense to purchase and maintain.

More recently, Additive Digital Fabrication methods have moved the machine to the site and in-turn shed the necessity of formwork (Diagram: Category 03). With this nascent technology formwork is supplanted by either placing or dispensing the construction materials directly. Although full of potential, these methods have not produced the software or hardware to create...
both the cementitious wall and structural reinforcement required within it. Sophisticated equipment and highly skilled labor is mandatory.

For many of these reasons, Mark West pioneered contemporary investigations into fabric formwork as the founding director of the Center for Architectural Structures and Technology (C.A.S.T.) at the University of Manitoba. Although his work moved on to exploration into efficiencies in precast structural members, early work with columns and walls highlighted the benefits and struggles with intricate tensioning systems.

2.0 WEAVING A LOGIC OF ASSEMBLY

The American Construction Institute states a contractor is required to design, fabricate, and install the formwork. Through a comparison of Mark West's fabric-formed cast-in-place columns from the late 90's and his later experiments with precast thin shell vaults this paper will discuss the contribution that the design, fabrication, and installation of the formwork had on the cast work.

As the founding Director of the Centre for Architectural Structures and Technology (CAST) at the University of Manitoba, Mark West’s research dominates today’s discussion of tensile fabric-formed concrete. In his recently published The Fabric Formwork book, Mark West assembles two decades of concrete explorations. West's early success with site responsive cast-in-place concrete columns, highlight the speed and variability of tensile fabric formwork in comparison to contemporary systems that rely on steel, wood, or rigid foam paneling.

For discussion purposes, this paper identifies three key elements found in Mark West's formwork assemblies; the scaffolding, the rigging, and the fabric. The scaffolding is an initial structure that is temporarily erected to give support for the rigging. In turn, the rigging mediates the interstitial space between the scaffolding and the desired points of control of the fabric. The fabric, held by the rigging, is free to distend as the static load of the concrete slurry defines the surface and therefore volume for casting.

A comparison of Mark West’s approach to scaffolding in his cast-in-place columns to his precast shell vaults, the early column’s scaffolding demonstrated an ad-hoc nature in response to site. Constructed of wood and steel, the temporary scaffolding systems required extensive structural support as they were required to carry the load of the concrete slurry along with resisting bending due to the loading of the tensile rigging members. These constraints combined with site variability demanded on-site problem solving. As C.A.S.T.’s work moved off-site for the later precast structures, the scaffolding formwork was no longer needed to respond to the site constraints. This allowed for greater consistency of the cast form as the scaffolding became self-referential rigid frames.

Highlighted within the techniques utilized in the column work, Mark West’s elaborate rigging systems telegraphed ornamental details into the cast products. These cast articulations develop a distinct design language unique to the fabric formwork system. In the later precast work, the fabric surface was defined by plywood structural spines as the rigging was minimized to merely adding tension in the fabric surface. Like the consistency of the scaffolding, variation in the final form was limited due to the reuse of the plywood spines as the fabrics form controlling elements.

Focusing on flat-sheet work -- fabric that does not require extensive sewing or cutting prior to installation -- the Festival Plaza sound-sculpture column, which he cast in 1995, demonstrated an articulate two-layer fabric system -- an inner stretch-knit liner wrapped by a laced unyielding corset. This approach to the assembly allows details of the assembly beyond the initial surface to be telegraphed through to the final form. In contrast, the taunt pre-tensioned fabric of the direct-cast thin shelled vaults actively mitigated the expression of any details. Additional construction of “feather-boards” was undertaken at the moments of transition between the
tensile fabric and the plywood scaffolding to further minimize the articulation of the fabric formwork. Mark West mentions that he began his investigation by asking, “What actually needs to be controlled?”ix. When considering the column examples, the concern for ‘control’ plays out in the methods of assembling the scaffolding, rigging, and fabric. The final cast of these columns demonstrates a unique balance of intended and found form. Whereas, in the later spanning assemblies, his concern for control has moved to the final product, specifically focusing on the structurally efficient use of the concrete.

By re-examining this question of control, Phase One of this research identifies industry standards for construction of a structural concrete wall. Revised annually, construction standards aim at maintaining the life, safety and welfare of the public through the establishment of minimum construction standards. Aware that the act of construction is not perfect, many of these standards define acceptable tolerances -- these are, “permitted variation in one part of construction or in one section of the specification must not be construed as permitting violation of the more stringent requirements for any other part of the construction.” ACI 347 Formwork for Concrete.

2.1 Phase one: scaffolding
Phase One of this research continues Mark West’s use of scaffolding as a means to resist the tensile forces of the rigging and fabric formwork. The goal of this phase is to develop a logic of assembly for the rigging that allows for formal variation while maintaining accepted standards of construction. To this end, four key industry standards for above ground cast-in-place structural wall have been selected for assessment. Three of which address structural concerns; the minimum coverage for Steel Reinforcement (rebar), the allowable tolerance of Structural connectors (anchor-bolts), and the allowable variation in Structural form (plumb), whereas, the fourth identifies acceptable Surface Variation. Regarding the structural concerns, a minimum thickness of concrete must be maintained for sufficient transfer of forces between the concrete and rebar. An industry standard of 1-½” of concrete coverage is adopted for this researchx. When addressing the location of anchor bolts, ACI established a tolerance with which the construction must be executed. A dimension of + - ½” is seen as conservative in the industry and is set as the target for this research. The assessment of a structure’s Plumbness requires both a small-scale control -- no more than ½” variation over 10’ -- and a more comprehensive view stating a maximum 1” variation for the entire height.

Phase One of this research adopts the three structurally relevant industry standards but challenges the idea of allowable variation in the finish surfacexiv. When the concrete is understood to be rough or hidden from view -- Classified as B, C, and D surfaces -- a relatively high ¼” to 1” tolerance is acceptable for abrupt or gradual inconsistencies. In comparison, locations that are expected to be in the public view, Class A surfaces, demand a minimal variation of ⅛”. These categorizations suggest that only near-perfect surfaces are acceptable for public viewing; yet, we have seen with Mark West’s concrete columns that when fabric formwork is employed, the surface can take on highly variable and unique design vocabulary.

The logic of assembly for the Rigging is investigated through physical modeling. The diagram below notates the design research through initial Conceptual Models, followed by Scaled-Assembly test, and finishing with a full-scale Proof-of-Concept cast. Phase One concludes with an assessment of the methods, techniques, and sequences success.
2.2 Lab notes-

Initial Concept Models (See diagram: 01 Concept Models) explored various weaving systems to establish a systematic method of installation while allowing variation in the pattern. As diagrammed in plan and axon, when a Dovetail weave pattern is mirrored a complex spatial volume is defined. This technique began with a series of steel cables running the centerline of the proposed cast. Initially left loose, these centerlines ‘dovetail’ between vertical rigging triangulated in the scaffolding. This dovetail weaving between alternating sides, is mirrored with each vertical strata of centerlines. These opposing dovetail weaves establish structural bays within the future cavity of the cast.

In later Scaled-Assembly Tests, the location of the fabric in relation to the weave was refined through the installation of Offset Links at each of the centerlines’ dovetail connections (See diagram: 02 Scaled-Assembly Test). These Offset Links create a network of control points a defined distance from the internal tensioned structure. These points allow the fabric surface to be held by a secondary weave beyond the internal tensioned centerlines. The length of the offset allows for a direct control of the minimum coverage of concrete at each connection point.

In a full-scale Proof-of-Concept cast, 4000-lb of concrete was formed in four contiguous structural bays. The dovetail weave established nodes for the placement of #5 rebar vertically at a maximum of 24” on center. In addition, the Dovetail weave allowed for the placement of a 4” diameter void centered in each bay (See diagram: 03 Proof of Concept). At full scale, Mark West’s experimentation with surface materials inspired the selection of a woven PE geotextile for the fabric. This fabric telegraphs a consistent hatch pattern across the bulging surfaces. The perceived quality of the surface brings into question the skill of the labor typically required to construct a finished surface (class A). The use of a weave system decreased the requirements of on-site problem solving that were noted by Mark West regarding his early concrete columns.

Although the tensile formwork system did not fail, the strain is evident in the deflection of the scaffolding structural members (See diagram: 04 Challenges). With over an inch of deflection in the upper crossing members, the reliance on bending to resist the tensile forces of the rigging in the Scaffolding-based tensile formwork system does not optimize the structural efficiency of the formwork assembly and demonstrates an unacceptable lack of control of the anchor locations.

Phase One of this research did find success with a logic of assembly that paired a dovetail weaving pattern with a link offset. The Dovetail weave for the Rigging balanced a 3D spatial control of connections points using a set of communicable parametric relationships that are capable of variation. The Link Offsets established secondary external connections points that facilitates a controlled structural coverage of concrete for internal steel reinforcement.

Phase two of this research looks to Frei Otto’s explorations in Tensegrity to challenge the efficiency of a Scaffolding-base fabric formwork system.
2.3 Specifically high-low cable-net cushions
Graduating from the Technische Universitat in Charlottenburg in 1952, Frei Otto’s thesis and subsequent professional design work investigated maximizing the use of tension -- steel cables -- as the predominant structural members. This idea was in high contrast to ubiquitous structural systems that rely on compression (a column supporting a roof) or bending (a beam spanning between supports). Frei Otto’s work, specifically the Olympic Stadium in Munich (constructed 1967), demonstrated to the world that the volume of material required to construct a building can be greatly reduced with the increase of tension systems within the design. Frei Otto did not stumble upon these ideas.

Frei Otto’s design process tackled exploration, refinement, and testing through physically constructed models. Each model growing more complex and integrative of the materials and systems required. History loves to make note of the soap bubble models, as they represent the conceptual idea of structural forms, but it is the larger scale models, like that of the west grandstand roof of the Olympic stadium where measurements were taken, and the details matured. This method of investigation demonstrated the benefit of the architects understanding and critique of construction -- although scaled down -- as a critical design tool. Frei Otto models, regardless of scale, demanded the actual methods of construction as a means for insight into onsite problems. (Roland 1970)

Frei Otto’s investigation into Tension Structures can be classified into three areas, 1D Linear structures, 2D Surface Structures, or 3D Space Structures. Linear structures represent a direct tension between two points acting within a single plane. Surface Structures are the manipulation of a single surface stressed in one or more directions. Space Structures have internal members, arranged in three axis that define a volume within their assembly.

Linear structures easily identified as rope swings, a chandelier chain, or as complex as a suspension bridge. Surface structure take on forms such as domes, convex and concaves. These synclastic forms are created when a surface is arced in multiple axis towards the same direction. Anticlastic, or saddle-like, forms are created if those arcs are set in opposing orientations. As with many of Frei Otto's bubble experiments, these Surface Structures represent the most efficient use of material to structural define a skin. When anticlastic surfaces are constructed with a high degree of pre-tensioning, the structural efficiency of the form paired with a lightweight material allow for complete freedom in their orientation in space. Unlike Surface structures that require anchoring or resistance from external sources, the third type, Space Structures, are closed structural systems. When the multi-axis members of a Space Structure are ridged, we call the system a space-frame, when tension cables are the dominant elements, they are called Tensegrity systems.

Labeled Cushions, Frei Otto investigated a series of Space Structure installations where he encapsulated a cavity by facing two Surface Structures opposite of each other. The Mushrooms (constructed: 1959) relied on a compression ring to resist the internal tensile forces of two opposing conical surface structures. Advancing to more complex saddle-like surfaces, Frei Otto drew from his past success with what he defined ‘high-low’ surface like that at Cologne (1956). When these ‘high-low’ surfaces are mirrored to capture a volume, rather than a tent pole to resist the tension forces, a grid of compressive struts where incorporated. A Space Structure comprised of two opposing surface structures, the Congress Hall in Chicago (Yale University, Bogner and Moore, 1960) represented a physical manifestation of Frei Otto’s definition of Tensegrity, “Islands of compression, floating in a sea of tension”.

3.0 PHASE TWO: TENSEGRITY CUSHIONS
Acknowledged as the pure blasphemy when set against Frei Otto’s goal of lightweight construction, Phase Two of this research explores the logic of assembly Frei Otto’s high-low cable-net cushion tensegrity systems as an internal structure for cast-in-place concrete construction. Phase two builds on the use of Link Offsets as a means of controlling concrete coverage, while turning the dovetail weave inside-out through the use of the tensegrity system’s minimal floating compression members. The goal of this assembly systems is to
eliminate the requirements of the structurally inefficient scaffolding while establishing an easily communicable system that allows for a high degree of variability.

3.1 Lab notes-
A series of concept models explored the structural principles behind Frei Otto's High-Low cable net cushions. These scaled models identified a sequence of construction and opportunities for site designed variation. Temporary cables suspend a compression member in space allowing for the adjusting of individual cushion’s alignment. This ‘tuning’ of each structural bay allows for on-site engagement of the construction process as these nodes will become future locations for structural, programmatic, or environmental connections.

A full-scale proof-of-concept tested the ability of a series of Tensegrity Cushions to stack vertically between #5 rebar set at 16” on center. Plumb was maintained as the #5 rebar are held in place much like the center pole of a circus tent, equal ties in equal yet opposite directions. Once tuned, industry standard tie wire replaced the temporary cables rigidly locating each floating compression member. Between the Plumbness and the integrity of the individual tensegrity bays, no scaffolding was required. Similar to Phase One’s Link offset, concrete coverage is maintained by extending the floating compression member beyond the internal tensegrity frame. A woven PE-geotextile is held in place as a secondary weave of steel tie-wire connects the cushion nodes.

Figure 3: Diagrams and Photos of Tensegrity Cushions Design Process. (Author 2018)

Once cast, the proof-of-concept was documented and dissected. Through various cross-sectional cuts an empirical assessment demonstrated the minimum rebar coverage was maintained.

After establishing the Tensegrity system would maintain plumb during the structurally intense casting process and that minimal structural clearances could be maintained, A series of Control Casts isolated the outer weave’s impact on concrete volume and the tolerances achievable with structural anchoring systems. An equation based on the structural bay width estimate an appropriate volume of concrete mix. This equation proved accurate at estimating volume of 10” structural bays in early material studies and with 12”, 16” and 24” structural bays in full scale proof-of-concept casts.

These Control Casts allowed for measurements pre and post casting of the anchoring systems. In multiple cast a total of 16 anchor location were document achieving a tolerance of +/- ⅛”, well within the acceptable range.

Through the Control Casts, the increased static pressure of the concrete slurry at the lowest bays dictated the secondary-weave pattern’s reinforcement of the PE-geotextile fabric.
Investigation into emergent behavior of these tensegrity cushions through computational modeling allows for speculative studies of the systems response to site, programmatic, and environmental demands while maintaining the established sequence of construction and maintaining of the defined industry standards. By defining internal relationships of the tensegrity system, a parametric logic is established that allows the individual bay to respond to internal neighboring bays and external site, programmatic, and environmental demands. Like other complex systems, clearly established relationships in the base unit have the potential to develop unique emergent behavior in their responses.

Figure 4: Diagram comparing current and proposed cast-in-place concrete systems. (Author 2018)

CONCLUSION
Eugene Viollet-le-Duc’s dissection of why Greek artisans did not use arches notes the desire by the elite to maintain a caste system. Held by the sculptor, the art and knowledge of construction was removed from the subjugated, on-site labor. The removal of craftsmanship from the labor class dehumanized their work, in turn, removing their opportunity for pride and status\textsuperscript{16}. A century later, Eladio Dieste’s paramount work in brick structural form, idealizes the enriching possibilities of knowledge springing for the ground-up. Eladio notes the satisfaction his workers and the community take in the richness of the work executed\textsuperscript{17}. Between these examples we witness how the dominant method of construction employed in a region can regulate the dissemination of intellectual and economic prosperity, along with exerting direct impact on individual self-worth within a society. In today’s fervor for computational design and digital fabrication, it is easy to see Dieste’s concerns regarding the “tyranny of the drawing board” translate into “tyranny of the abyss of model space” as the act of construction has decreasing less influence in design. How do we utilize the tools at our fingertips, while not removing the knowledge and pride of the act of construction? The research presented cycles between the investigation of low-tech construction assemblies and computational testing of variations with the intent of establishing a logic of construction assessable to low-skilled labor while facilitating complex variability.

This research proposes a tensile, fabric formwork for casting structural concrete walls that utilizes a tensegrity space-frame system as an alternative to contemporary cast-in-place construction systems. An initial survey of cast-in-place concrete construction systems -- comparing the time and labor’s skill required to deploy the formwork, the volume of materials consumed by the formwork, the sophistication of the equipment required, and ability to integrate building systems -- established baselines for assessment. This survey was paired with research on Mark West’s fabric formwork to identify the role of scaffolding, rigging, and
fabric in the cast form. Furthering Mark West’s scaffolding-based systems, through scaled assembly and full-scale proof-of-concept casts, Phase One developed a unique approach to tensile assembly by incorporating a Dovetail Weave technique and controlled Link Offsets. Phase two of this research, began with a study of Frei Otto’s variations of tensegrity systems, where the logic of his High-Low Cable-net Cushions was adopted to challenge the structural inefficiency of bending in Phase one’s scaffolding. Again, through scaled assembly models, the methods, techniques, and sequences were explored, revised and executed in full-scale proof-of-concept concrete casts. These casts were assessed for their ability to maintain: industry standard coverage of structural steel; an acceptable tolerance on the location of structural connections; and, a reliable formula for estimating concrete volume. Through computational modeling, the logic of the assembly system explored additional formal variations. The success of the proof-of-concept casts demonstrate an opportunity for further research this complex systems design response to greater structural, programmatic, and environmental systems. With these industry standards met, although the Tensile Cushion units required a layered sequence of construction, once understood, relatively low-skilled labor has the potential to investigate and execute complex variations. In the vein of Eladio Dieste’s elevation of an assessible assembly, the proposed construction system has the potential to place design research into the hands of the working labor.

REFERENCES
ACI 347R-14. Guide to Formwork For Concrete. Farmington Hills, MI: American Concrete Institute
ASTM International, Standards and Publications. 2018
Forest Products Laboratory. 2010 Wood handbook. Madison, WI: U.S. Dept. of Agriculture.
National Ready Mix Concrete Association, As of June, 02, 2018, https://www.nrmca.org/

ENDNOTES
i (ASTM, 2018, Grade 60, Mild/Low Carbon Steel)
ii (Forest Products Laboratory. 1999. Coastal Douglas Fir)
iii National Ready Mix Concrete Association, 2018)
iv (Matter in the Floating World, 2011, 112) Ando, “…the potential for stone-like beauty without the geometrical limitation of stone itself."
(v (3D Printing and Buildings: A Technology Review and Future Outlook TAD, 2018)
vi (ACI 347-14. Formwork 26.11.1.1)
vi (West, 2016, 153)
vi (West, 2016, 248)
vi (West, 2016, 7)
ix (ACI 347-14. Formwork 26.11.1.1, Design Information) 2” coverage is required if the rebar is #5 or larger. 3” is required if the concrete is exposed to earth.
x (ACI 347-14. Formwork 26.11.1.1, Design Information. ACI Class A, B, C, and D)
x (West, 2016)
xii (Drew, 1976)
xiii (Roland, 1970)
xiv (Roland, 1970)
xv (Viollet-le-Duc, 1990)
xvi (Dieste, 1987)
Computational tools for designing shape-changing architectures

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ABSTRACT: Smart materials or systems are characterized by having built-in sensors and actuators, adjusting their properties in response to external stimulus. The rapid development of these technologies presents an immense opportunity for designers and architects to provide innovative and creative solutions for adaptive buildings. However, there are several challenges for the incorporation of smart materials in the toolbox of architects in design practice: The lack of an overlap in knowledge between material science fields and design practices; the addition of time as a condition that renders these materials inherently dynamic; and the general disconnect between material issues in typical design settings. This paper discusses the challenges for designing shape-changing architecture and examines the way in which computational tools or digital technologies can help overcome those limitations in design practice. Finally, we discuss an approach for designing shape changing architectures with the aid of digital technologies, highlighting the different considerations that must be taken into account.

KEYWORDS: Smart materials, shape-changing materials, responsive architecture, material-based design.

INTRODUCTION

In recent years, there has been an increasing interest in smart materials within design fields. The ability to design responsive and dynamic architectures that adapt to different climatic conditions is, with no doubt, an appealing idea. Furthermore, smart materials have already been declared as “the answer to 21st century technological needs”(Addington and Schodek 2012, 1). While these materials have long been part of the research agenda of material scientists and engineers with workshops on Smart Materials dating as far as 1988 (Smart Materials, Structures, and Mathematical Issues- US Research Army Workshop), smart materials have just recently started to permeate design research and practice.

There are multiple definitions of smart materials. Most authors agree that what characterizes smart materials is the ability to adjust their properties in response to a defined stimulus, as defined by (Kretzer 2016, 54) “Materials that can change their property in response to environmental conditions”, or similarly, in (Kretzer and Hovestadt 2014, 44) “can adjust their properties dynamically”. A comprehensive definition is provided by Ahmad (1988), who states that smart materials or systems are characterized by having intrinsic sensors, actuators and a control mechanism that allow them to sense a stimulus – a change in environmental conditions, for instance – and respond in a determined manner in a short time, as well as return back to their original state once the stimulus is removed. This definition highlights the intrinsic nature of both sensors and actuators in smart materials, while remarking that the response has to be controlled and occur in a short period of time.

Among the different types of smart materials, shape-changing materials have received particular attention from design-oriented studies due to their potential for constructing climate-responsive adaptive architectures (Fiorito et al. 2016; D. Wood et al. 2018; Correa et al. 2015). In shape-changing smart materials, a stimulus (i.e. heat, water) causes a strain in the material, thus changing its shape. Shape-changing materials are slowly being incorporated into design studies, not without challenges in the process such as, the lack of an overlap in knowledge between material science fields and design practices (Addington and Schodek 2012); the addition of time as a condition that renders these materials inherently dynamic (Kretzer and
To overcome the challenges mentioned above, researchers have used computational tools that link material properties, design considerations, and enabling manufacturing technologies. This paper discusses the challenges to designing shape-changing architecture and examines the way in which computational tools or digital technologies can help overcome such limitations in design practice. The following section summarizes the difficulties of incorporating shape-changing materials into architectural practice by providing a review of the literature on smart materials in design fields. The second section identifies several computational tools that can aid the design of shape changing materials, considering existing design-oriented studies on shape-changing materials. Finally, we discuss an approach for designing shape changing architectures with the aid of digital technologies, highlighting the different considerations that must be taken into account.

1.0 CHALLENGES IN DESIGNING FOR SHAPE CHANGE

Smart materials and more specifically, shape changing materials, present several advantages over traditional materials, particularly, in developing innovative and responsive architectures. Kretzer (2014) argues that there is a current need for architectural systems to become more responsive and adaptable to deal with unprecedented societal and environmental challenges. A main advantage of incorporating smart materials into architecture systems is that they can be used as both actuators and sensors, which places them, according to Addington (2010), on the middle ground between low tech and high-tech approaches. This is because even though smart materials are clearly sophisticated, they do not have any mechanical systems. In this sense, smart materials can be used to replace much more complex systems. Another advantage of using smart material relies on their ability to present more than one state, having an inherent dynamic nature. Identifying this characteristic, Mann (2009) makes a case for the use of smart materials due to their problem-solving abilities, particularly, for design problems with contradicting requirements.

The incorporation of shape changing materials into architecture practice presents several challenges. Shape changing smart materials cannot simply replace existing architectural technologies, due to their inherent dynamic nature that contrasts with the rigidity of traditional construction materials. In fact, one recurring theme found in the literature on smart materials is how the dynamic nature of shape-changing materials presents a challenge for architectural practice. This is because designers have traditionally aimed for concepts such as stability and solidity instead of dynamism when designing buildings and spaces. Kretzer (2014b) argues that architects should rethink environments as dynamic and soft, beyond the paradigms of longevity, stability and performance. In this sense, the dynamic nature of smart materials certainly challenges what architecture should evoke and transmit.

Furthermore, Addington and Schodek (2005) claim that conventional means of representation in architectural design privileges static materials, which becomes a problem for designing with dynamic smart materials. Conventional forms of representation – plans, sections and so on – can hardly incorporate the fourth dimension related to time, showing how these materials can transform when activated by a stimulus. Alternative modes of representation that convey the dynamism and transformation of shape changing materials are needed in the design process. For instance, Sung (2016), when describing her research on thermo bimetals argue: “The still images require extensive explanation (…). A 30-second video, on the other hand, explains it all” (Sung 2016, 106). Consequently, it is not only conventional ideas about what architecture should look like that need to change, but also the process of designing, to successfully incorporate shape-changing materials in architectural practice.

Another challenge for the incorporation of smart materials in design fields has to do with the lack of synthesized information on smart materials for non-experts in the field, such as designers and architects (Kretzer 2016). There is a need for constructing a common language...
between design fields and other areas of inquiry that are more closely related to smart materials such as material science and chemistry (Kretzer 2018). This common language could be gradually constructed with an experimental yet systematic approach to designing shape-changing architectures. The architect’s ability to synthesize information, as pointed out by (Kennedy 2012) can be seen as an advantage from this viewpoint, orchestrating technical considerations of innovative materials with spatial, structural and environmental aspects in the design of dynamic architectures.

The general detachment of material issues in design practice also constitutes a problem for designing with shape-changing materials. Addington (2010a) argues that conventional materials in architecture are usually treated as artifacts, or as things that have fixed and static attributes. In other words, materials are usually subordinated actors in design practice. This approach probably has its roots in the conceptual separation between the processes of design and fabrication that has dominated architecture since Renaissance. The problem with treating smart materials in the same way is that the dynamic nature of smart material is intrinsically connected to their properties, which requires designers to adopt a material-centered perspective to understand such properties and design with them. Furthermore, shape-changing materials can transform their configuration constructing dynamic architectures, and as such, they must be part of the conceptual definition of the design idea. These dynamic materials cannot be assigned to geometries as an after-thought but must be an integral part of the design process, predicting their transformation within the larger context of the architectural space.

To this point, we have argued that smart materials are dynamic by nature, and that this property presents challenges when we want to incorporate them in architectural design and practice. The conflict between the traditional static view and the required dynamic approach to design appears in multiple facets of architectural practice, mainly, in design representation. Then, we have stated that in order to design with shape changing materials, designers must be able to synthesize knowledge from different areas other than architecture. Finally, we have argued that shape-changing materials cannot be considered as subordinate or passive actors in designing dynamic structures, thus identifying the need for a material centered approach.

2.0 DIGITAL TECHNOLOGIES FOR DESIGNING WITH SHAPE-CHANGING MATERIALS

With the increasing integration of digital design and fabrication, architects and designers are becoming more involved in materialization technologies (Kolarevic 2003). Consequently, designers are regaining control over material processes in design with the emergence of a material-based design approaches that favors an experimental model of practice (R. Oxman 2012). This experimental model of practice is what Kennedy (2012) defines as a vertical integrated model, which emphasizes the rapid synthesis of new technologies. Digital technologies, by integrating design and fabrication, favor the emergence of such experimental models of practice that help introduce shape changing materials into architecture practice.

On the other hand, computation in architecture is increasingly becoming a medium for material exploration challenging the separation of the processes of design and making (Menges 2015). The development of digital technologies is also extending the mental process of design into the material realm (Gursoy 2016). As a result, designers are regaining their position as the orchestrators of materialization processes. This digitally-enabled material-based approach has the potential to encourage the design philosophy described by DeLanda (2001) in which materials are not passive property assigned to forms but active participants in the design process. Computation, we argue, can become the medium for exploring shape changing materials, in a framework where material properties, structure and form become strictly interdependent. This approach could help prevent smart materials to be “patched atop an existing structural or architectural system” (N. Oxman 2010, 83) and rather be innovatively designed to develop their full potential.
In short, we argue that digital technologies can help design for shape change, by providing a tool that integrates digital design and fabrication, promoting the emergence of a vertical model of practice. Furthermore, computational design technologies help designing with innovative materials because they can help enable the mediation between material properties, form and structure. Nevertheless, in shape-changing materials, material properties and design are not the only principles to consider. As mentioned before, shape-changing materials are inherently dynamic, which means that the concept of time and how materials transform in time must also be considered. In addition, the activation energy or what triggers the transformation is also a principle to consider. What follows now is a discussion of which computational design tools can be used in orchestrating this and other principles for designing shape-changing architectures.

A recent essay by Papadopoulou et al. (2017) argues that to program materials, designers need to consider three principles: material composition, activation energy, and transformation mechanics. These principles for programming materials provide a framework for designing shape-changing architectures. By placing design at the center of these three principles, we identify how computational tools can help dealing with the interdependencies between the described principles of material, energy and transformation. Figure 1 illustrates these three principles and identifies how computational tools can be used for this purpose. What follows is a discussion of the computational design strategies adopted for developing shape-morphing architecture in previous studies, from a design research perspective.

**Figure 1:** Computational tools for designing for shape change. Based in the principles proposed by Papadopoulou et al. (2017)

Material computation appears in the conceptual framework as a strategy that links material composition to design. In material-based design approaches, computation has allowed designers to integrate material properties with design at different scales, from the toolpath design of 3D printed objects for embedding shape-change into elements (Correa and Menges 2017) to the assembly logic of large scale objects conditioned by fiber orientation (D. Wood et al. 2018). This approach is often referred to as material computation, where design is conditioned, and emerges from, material properties and composition (Menges 2012). Physical computing allows researchers to quantify and measure shape change and understand how this behavior is strictly connected to design and material properties. This approach can also be seen in the work of Markopoulou (2015): The author presents a series of material explorations using physical computing to design responsive structures, using several shape-changing materials such as shape memory alloys and hydrogels.

Shape computation could be used as a strategy to predict and design the transformation mechanics of shape-changing architectures. The dynamic nature of shape-changing architectures requires the emergence of computational strategies to predict this behavior. The incorporation of dynamic concepts into digital theory is not without precedents: Liu and Lim (2006) introduce dynamic factors such as motion in digital tectonics. Shape computation entails defining shape operations, with a before and an after geometry. With this approach, the
‘after’ geometries could be the resulting geometry of the shape-transformation presented by the smart material. An approach for computing with shape transformation can be seen in the work of El-Dabaa and Abdelmohsen (2018), where the author proposes the use of motion grammars for characterizing and predicting the hygroscopic behavior of wood elements.

As mentioned before, one of the main advantages of using shape-changing smart materials is their ability to adapt to different environmental conditions. Design solutions could therefore be optimized for improving efficiency in buildings by including specific transformation mechanics that respond to defined activation energy. For instance, architecture skins or façade systems that change configuration in response to different environmental conditions, could be optimized to allow for sufficient daylight to enter buildings throughout the day. This responsive or dynamic optimization approach greatly differs from other types of optimization. In a static optimization approach, designs are optimized before construction, adjusting form and structure for improved performance. Through static optimization, designs can be adjusted only before materialization, therefore there is no dynamic adaptation of the building to the changing requirements of the environment. In a dynamic optimization approach, mechanical systems can adjust the building geometry to adapt to the environment, seen, for instance, in the design of a responsive skylight system, that adapts its form to maximize sunlight (Henriques, Duarte, and Leal 2012). The complexity of these systems that separate structure and the driving actuators becomes a major disadvantage of this approach (Kretzer 2016), as well as elevated fabrication and maintenance costs (Ball 1997). In other words, optimization strategies could be used to improve efficiency in buildings with shape-changing materials, designing for targeted transformation mechanics triggered by an activation energy.

Optimization strategies could also be used to find optimal material configurations for creating shape-changing actuators. For instance, Worre Foged & Pasold (2015) used an evolutionary search mechanism to find the adequate combination of materials and their bonding temperature for two materials in a bilayer configuration. The authors successfully applied the evolutionary search optimization technique in creating a composite material that reacts to temperature changes.

Simulation studies have been conducted in different stages of research involving shape-changing architectures. The literature includes simulation studies to predict shape morphing of kinetic solar skin designs using shape memory alloys – a shape-changing smart material – in the work of (Pesenti et al. 2015) and visual and thermal simulations to predict the performance of a dynamic shading device in its multiple configurations (Pesenti, Masera, and Fiorito 2015). However, computer simulation could also be used in predicting how different material compositions react to the material’s activation energy, as depicted in Figure 1. For instance, Abdelmohsen et al. (2018) studied the hygroscopic behavior of wood elements, developing a parametric model for predicting its shape-changing behavior considering different material properties such as fiber orientation and material thickness. A similar approach can be seen in the work of (D. M. Wood et al. 2016), where the authors use simulation tools for designing responsive timber structures, defining grain orientation and thickness as per targeted geometries in a multi-part system.

Overall, the computational tools identified above help orchestrate the interdependences between design, material composition, activation energy and transformation mechanics. There are several other computational tools that can be used in developing designs for shape-changing materials. However, the goal of this paper is not to provide a complete list of such strategies and approaches, but rather, to argue that digital technologies enable the development of material-centered design and fabrication systems that incorporate the described principles for programming shape-changing architectures.

3.0 DESIGNING SHAPE-CHANGING ARCHITECTURES

So far, this paper has focused on describing the challenges for designing shape-changing architectures, arguing that digital technologies can help designing with dynamic smart materials. The previous section outlined ways in which specific computational tools and
strategies such as material computation and simulation can help deal with the basic principles for programming shape change in materials. Nevertheless, it is important to remember that designing architectures – shape-changing or not – entails shaping the build environment for specific human activities, in response to defined environmental conditions. In order to design shape-changing architectures, design and fabrication systems must be developed considering specific function requirements and existing climate conditions. In other words, it is important to contextualize the design problem when proposing design methodologies for developing shape-changing architectures.

Andreoletti and Rzezonka (2016) highlight the importance of contextualizing smart or programmable materials in design practice. Contextualizing the design problem is an important first step in any systematic approach to design. Within a design system, Duarte (2018) describes this component as a formulation subsystem, that can interpret the design context, which includes user requirements and physical contextual information. Similarly, to design shape-changing architectures, the interaction of dynamic systems with the environment and the human experience become essential in the definition of the design problem. Contextualizing means considering functional requirements and contextual information such as climate conditions. When designing shape-changing architectures, function requirements would determine the degree of dynamism that the structures can have. For instance, in designing a shape-morphing skin, designers must establish the desired openness of the system, and how sensible the system should be to environmental changes. These design decisions derive from defining the functional requirements of the space. In addition, specific climate conditions define what activation energy will trigger the shape-change. For instance, in a hot and humid climate, the activation energy would likely be humidity and/or temperature, triggering a reaction in the shape-changing system. Functional requirements and climate conditions define a formulation process that specifies the requirements of the design but occurs prior to designing.

Figure 2 depicts a proposed approach for designing shape-changing architectures, with three components: formulation, design and fabrication. The first component, formulation, defines the functional requirements taking contextual information of the design problem into account. The design component is framed by the principles described in the previous section of material composition, transformation mechanics and activation energy. At this point, computational design tools play an important part in mediating the interdependencies of material and structure. The last component is the fabrication of design solutions, that can be enabled by different manufacturing technologies from automated production methods such as 3d printing to other more traditional manufacturing techniques. The enabling technologies for materializing shape-changing architectures are not discussed in the context of this paper, but it is important to define them as part of the approach.

The first component, formulation, is composed by two complementing processes: Defining the frame of transformation-the parameters of how the geometry will transform-, and the site-specific formulation process of how the system will react to the environment. The first process, the definition of the transformation frame is prescriptive, and should be defined by the functional requirements of use the space has. The second process situates the transformation mechanics in relation to a specific site with defined climate conditions. The thorough understanding of environmental conditions is especially important in the case of designing shape-changing architectures, because the activation energy might depend on specific climate conditions. There are other shape changing materials whose activation energy are not derived from shifting -outdoor- environmental conditions, such as electroactive polymers that change shape with high voltages (Kretzer and Rossi 2012). Nevertheless, the definition of how the system interacts with the environment is crucial in the formulation process as it defines how the system will perform through time.
The described approach illustrates the different considerations for designing shape-changing architectures. The subdivisions between the different stages of formulation, design and fabrication are merely conceptual, as these processes often become interdependent, particularly design and fabrication. Nevertheless, the idea is to identify which different components and considerations define the design and fabrication of shape-changing architectures, contextualizing these processes for tailored needs and a particular climate. Furthermore, this approach, at this point, is still theoretical. Further studies need to be carried out in order to validate and/or extend it within the context of designing with shape-changing smart materials.

CONCLUSION
Smart materials and specifically, shape changing materials have already been adopted in other areas of inquiry. The question yet to be answered is how architects can incorporate them into the built environment, to construct responsive and efficient buildings. The competence of architects in developing shape-changing architectures appears to lie in being able to articulate geometry, material properties, and fabrication strategies (Correa and Menges 2017). Discussing the challenges of designing with dynamic materials, we argue for the emergence of a computationally-enabled models of practice that can help overcome these challenges in design.

Kennedy (2012) argues that the implementation of new technologies in design requires new models of practice. The transfer of innovative shape-changing materials technologies from material science engineering to design practice will require the development of a new toolset for architects. Designing for shape-change entails not only a shift in the way we envision architecture spaces but also requires expanding our design-research methodologies. We argue that such design methodologies could rely on computational design tools, adopting a material-centered perspective. Providing an overview of methods and approaches in designing with shape-changing materials, this paper exemplifies how computational tools can help deal with the interdependencies between material, design and shape-transformation.

This paper also discusses an approach for designing with shape-changing materials that starts to systematize design and fabrication processes for dynamic architectures, identifying several parameters that should be considered in constructing such dynamic architectures. Different computational tools for dealing with the interdependencies of those parameters such as material composition and transformation mechanics have been identified. We also identified that design and fabrication processes for constructing shape-changing architectures are strictly conditioned by defined functional requirements and contextual information. This contextualization of the design problem becomes the first step in the approach proposed for designing dynamic architectures.
Shape-changing materials are emerging as a new device to design with in architecture that will ultimately lead to a new architectural language. A language that is dynamic and that questions current forms of representation, traditional forms of design, and changes the way we think about the built environment. This new language requires the development of new techniques and strategies for designing shape-changing architectures, that help deal with the dynamic nature of these new materials, and allow for mediating material properties, structures, transformation mechanics, within a specific context and for a specific fabrication logic. We argue that computationally-enabled design and fabrication frameworks could aid the process of building dynamic and efficient shape-changing architectures.

REFERENCES
———. 2010b. “Smart Materials and Sustainability.”


APPLIED HISTORY
Theseus’ paradox: history, authenticity and identity

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ABSTRACT: In the Life of Theseus, Plutarch observes: “The ship on which Theseus sailed with the youths and returned in safety, the thirty-oared galley, was preserved by the Athenians down to the time of Demetrius Phalereus. They took away the old timbers from time to time, and put new and sound ones in their places, so that the vessel became a standing illustration for the philosophers in the mooted question of growth, some declaring that it remained the same, others that it was not the same vessel.” (Plutarch, Perrin, 1914, V1, 49). Thereafter, the paradox sparked discussion regarding an object’s authenticity and identity. For Barthes (1974), the paradox presents form-permanence as a Structural argument. Walter Benjamin (1969) disagreed noting that “[t]he presence of the original is the prerequisite to the concept of authenticity.” When original producers are not available we can evaluate the relationship of contemporary design with historic modes of production through Material Culture. By privileging knowledge of what the spatial product is and how it was produced, the essay examines the role of History in addressing spatial authenticity. The essay uses Theseus’ Paradox as a theoretical framework to evaluate authenticity and identity. Architectural objects either continue or discontinue the aesthetic language of their context: as designers cite History to generate designs claiming contextual site sensitivity, it is important to evaluate the validity of this approach. Specifically, Theseus’ Ship is deconstructed using the philosophical arguments of atomism and essentialism. Atomism, a Positivist tool, determines elementary physical characteristics of a society’s spatial practice. Essentialism (Aristotle) focuses on the nature of the spatial product: what it has been, it is, and could be. Designers can use Theseus’ Paradox as a comparative framework to evaluate to what degree their proposal continues authentic modes of production rooted in historic spatial traditions and identity-based placemaking.

KEYWORDS: Theseus, History, Authenticity, Identity, Design

INTRODUCTION

Placemaking based on sociocultural traditions has greatly diminished because of two major challenges: The first is Modernism’s and Post-Modernism’s embrace of differentiation; the second is the phenomena of globalization. On one hand, the advent of Modernism’s willful rejection of the past and its spatial production traditions represented a major break with history and context. Practitioners, individually or as part of the organizations such as CIAM, embraced the idea of international fraternity that believed in Modernism’s meta-narrative promise of progress. While Post-Modernism provides a more democratic approach to design, including quoting the built past, most designers view this approach as kitsch or façadism. On the other hand, globalization, already a historic de facto process when one group conquered or traded with another, accelerated with each Revolution: Scientific, Industrial, and now, the Digital/Information. Globalization, driven by the logic of capital and its market-oriented forces, promotes an increasingly homogenized environmental aesthetic.

The above challenges to spatial identity have led some specialized spatial producers (i.e. architects, landscape architects, urban designers, and planners) to push back on the pervasive homogenized spatial production by employing a strategy of producing what they call an “authentic” spatial “identity.” This focus evokes the question: What makes a space, a place? As designers cite location and site-specific History to generate designs claiming sensitivity to palimpsest contextual spatial production, it is important to evaluate the validity of this approach. Can contemporary designers claim that historically rooted and contextually sensitive design is...
authentic, and hence preserves or augments place identity? If so, how do we determine if a
design is authentic? To answer these questions, the essay utilizes the Paradox of Theseus’
Ship.

The Paradox of Theseus’ Ship demonstrates that identity based on authenticity is one that
exhibits that essential nature of the object: not just how something looks —surface appearance—,
but also how is it made, and what is the purpose or “final cause.”(Aristotle, Barnes, 1995) of
an object. The essay will use the Paradox to explain how these questions inform and guide
design. First, the paper will recount the Paradox to illustrate the philosophical implications
regarding identity and authenticity. Second, the paper will explain and demonstrate how the
philosophical ideas of atomism and essentialism are appropriate tools to determine what is
authentic. Finally, using the previous discussions, the paper proposes an evaluation
methodology that identifies types of spatial production, by which designers can evaluate their
own design proposals within the context of spatial identity and authenticity.

1.0 THE PARADOX

1.1 Understanding the paradox

In the Life of Theseus, Plutarch makes a seemingly simple observation:

The ship on which Theseus sailed with the youths and returned in safety, the thirty-oared
galley, was preserved by the Athenians down to the time of Demetrius Phalereus. They
took away the old timbers from time to time, and put new and sound ones in their places,
so that the vessel became a standing illustration for the philosophers in the mooted
question of growth, some declaring that it remained the same, others that it was not the
same vessel. (Plutarch, Perrin, 1914, V1, 49).

Thereafter, the Paradox has sparked discussion regarding an object’s authenticity and identity.
The anecdote presents the reader with the description of an object: a sea-going ship
purportedly used by Theseus. Because of its historic importance, the “Athenians” decide to
preserve the ship at port, so that the then current and future generations of Athenians and
visitors, can experience the ship. Plutarch notes that the ship required maintenance, whereby
“old timbers” are replaced by “new and sound” timbers. Herein lies the paradox: if the object
has any part of it replaced, can it still be the same object. Can new components claim to have
the same authenticity as the original components? If we substitute the Ship with “site”
(regardless of scale), and ship components with spatial products, can a present day spatial
product claim to be authentic even employing the forms of its context? As Plutarch further
notes, the paradox serves as a standing illustration for what was then an already lengthy
debate about identity and authenticity. At the heart of the question is what makes an object
what it is, or in philosophical terms, its quiddity.¹

The paradox exhibits the intrinsic relationship between authenticity and identity. Plutarch’s
establishes that

1) there is an initial condition of production for the object —the Ship, hereafter S₀;
2) the Ship is composed of smaller parts, which configured together in a particular way are
understood as the object;
3) the object’s components were exchanged for similar (perhaps replicated) components
as maintenance required;
4) Plutarch asserts that the Ship “returned safely,” transforming the Ship from a sea-going
vessel to a monument.⁶ Therefore, the function of the Ship has changed.
5) the question of identity of the object arises after the replacement of ship parts.
6) when a part, or parts, of the Ship S₀ are replaced, each change may represent a new
Ship, hereafter S₁, or Ships S₂, S₃, and so on, but will never again be S₀.

If we exchange “Ship” for “project” located in a physical space, which we take as the initial
contextual condition (equivalent to S₀), we understand the application of the paradox to spatial
production. Spatial production, regardless of scale or object type (teapot, building, landscape,
or city plaza), incorporates the same assertions about process, components, authenticity, and
identity. Contemporary modes of spatial production based on historic factors, such as
aesthetics, materiality and traditions, claim to perpetuate genuine place identity. This is because designers quote existing historic and contextual spatial objects to justify their design as preserving or augmenting place identity. If the replacement of any part of the object renders the Ship inauthentic, then by extension, any object produced today, whether a building or a landscape, no matter how exact of a copy of its historic context would be similarly inauthentic. Yet, intuitively, design strategies such as “Critical Regionalism” (Frampton 1981, 1) feel as if they genuinely perpetuate a sense of place. In order to unravel the paradox to determine the validity of this approach we must define authenticity, identity, and essence.

1.2 Defining identity
All spaces, whether created by nature, or produced by humans, possess a potential identity based on their essentiality. In the case of human production, Henri Lefebvre observed that societies “secrete” space (Lefebvre 2011, 38), imbuing produced space and its objects with properties attributed to its producer. These properties include social, cultural, and political values, made manifest by the object’s appearance and function. Objects, mental or physical, generate an experience of space by their composition, configuration and qualities. Identity is a mental construct that describes an object (a thing) by the sum of its properties -its quiddity. All objects have an identity, even when the identity is a lack of singularity -as lack of uniqueness is in itself a property of the object. Moreover, identity allows cognizant living things to distinguish between one object and another, while simultaneously group objects together because of established criteria of commonality or sorting.

Furthermore, an object’s identity is generated not only by the properties confined by its physical boundaries, but also by its relationship with other objects. Theseus’ Ship, once a physically manifested object, occupied space, and in so doing, generated spatial relationships based on its existence. For example, the Eiffel Tower in Paris, France, would still be a tower if located anywhere else. Its location, however, at the northwest end of the Park Champ de Mars, with the Seine less than 100 meters away, is as much part of its identity as its iron materiality or its triangular prism form. The identity of the ship changed when its settings changed: from sea-going vessel to monument. Finally, identity requires a viewer, whose senses engage with the object, and whose interaction provides specific meaning. Hence, identity is heavily dependent on the value systems of producer and the individual’s or groups’ experience of that object.

1.3 Defining authenticity
Authenticity’s etymology derives from the Greek word authentikos, which in turn originated from the word authentes, composed of “autos (author, self) + ‘hentes’, (doer, being), from the Proto Indo-European ‘-sene’ to accomplish, achieve.”IV Authenticity is an essential quality that is possessed by an object because of the triadic relationship between maker (author), the process of making or spatial production (doing, achievement), and the produced object.

In The Human Condition (Arendt 1998, 139-148), Hannah Arendt outlines in “Work” the process by which humans who fabricate, or homo faber, imbue authority in the objects they produce. Drawing from Plato and Marx, she first notes that during fabrication it is necessary to transform Nature’s materials into objects. This transformation has two immediate object based results: a sense of permanence of the object (when not in use) and a sense of separation from the natural condition of its un-transformed raw component materials—a human process has rendered the object different from the materials whence they originate. Next, she argues homo faber destroys nature to produce objects, and such destruction confirms humans’ divinity, as producers—we become as gods through making. Arendt is then able to argue that this divine process of destruction of the natural state to produce the human-made object confers authorship over their products. We say an object is authentic when we perceive the engagement of human processes of extraction, destruction and production that together yield an object. Authenticity is a property of an object because it requires ideation (mental construction), a process that may or not be seen but is subsumed in the product, and an object that is the product of the previous two. For Arendt, without evidence of the metaphoric or literal maker’s hand in the production process of an object, or a lack of conceptualization (the idea of) making the object, there cannot be authenticity—as there is no authorship—as simply
reproduction by imitation. Years earlier, Walter Benjamin had also noted the inherent problems with reproduction of any original object.

In his seminal essay, “The Work of Art in the Age of Mechanical Reproduction” (Benjamin, Zohn, 1968) Benjamin takes up the task of defining authenticity. He begins by noting that “the most perfect reproduction of a work of art is lacking one element: its presence in time and space, its unique existence at the place where it happens to be.” (Benjamin, 220). This assertion is ever more relevant when we consider its implications regarding the built environment. After all, the greater question is can contemporary spatial production be considered authentic even when quoting its historic location and context. He further states “[t]he presence of the original is the prerequisite to the concept of authenticity.” He continues by defining

“[t]he authenticity of a thing is the essence of all that is transmissible from the beginning, ranging from its substantive duration to its testimony to the history which it has experienced. Since the historical testimony rests on the authenticity, the former, too, is jeopardized by reproduction when substantive duration ceases to matter. And what is really jeopardized when the historical testimony is affected is the authority of the object.”

(Benjamin, 221).

Finally, he introduces the concept of “aura” or the quality of uniqueness possessed by the original authored object. Detached from time and place, the tradition of making, and the uniqueness of the original, each reproduced object that replicates the original diminishes in its aura.

Common to the ideas of authenticity of Arendt and Benjamin, is the assertion that authenticity requires a) process, that is b) located in a specific time and place and, c) produced by a particularly maker. Any reproduction that does not match these conditions is considered inauthentic. On its face, this would mean that citing site historic context would be thus inauthentic design. Yet both, in noting the importance of the process, allow a way forward to produce space that does not diminish authenticity and hence the aura of place. Using their analyses it becomes clear that an attempt to reproduce the original object would be inauthentic, but producing another object, could be authentic. In other words, replication, that is attempting to copy the original form, results in a lack of authenticity as this new object is not produced by the original makers, nor at the original time and in the original place. Making a new object that shares atomic (formal and material) and essential qualities, however, could yield an authentic new object. It requires that the spatial producer understand and deploy knowledge of a place’s atomism and essentialism.

2.0 ATOMISM AND ESSENTIALISM

2.1. Understanding atomism

This paper argues that authenticity is an atomic and essential quality possessed by the object. First, it is important to define atomism. Centuries before Plutarch’s presentation of the paradox another philosopher, Heraclitus, had stated, “No man ever steps in the same river twice, for it is not the same river, and he is not the same man.” (Heraclitus, Barnes, 1982, 50). Heraclitus assertion implies two specific conditions for an object to be considered that object. First, an object is the perceived sum of its components: the river is the sum of all water molecules. Second, time is a descriptive and bounding property of an object. He notes that time has elapsed between the initial stepping event and any subsequent event. Considered together, he recognizes that the river is itself ever changing (as well as the person) because the component parts, such as the water molecules, are continuously re-arranging themselves, or replaced altogether. Yet, our common sense informs us that the river is still the same river, regardless if the component parts (and us) have changed. This is because we perceive the nature of the object at each individual moment of the existence and over time. The philosophical idea that describes the nature of things based on its components is called atomism.
In the 6th Century B.C.E., Leucippus and Democritus proposed atomism as an ontological approach to describe the components of the physical world. As the etymology suggests, they argued for an inductive construction of the physical world taking as the starting point, (ἄτομος) “a-tomos” or atoms, particles that cannot be further “cut” in any aspect. For Democritus and Leucippus, atoms exhibit a binary relationship with spatial occupation: one of being or not being—normally a void (Taylor 2010, 72-74). Space, in turn, was defined by the quantity (mass and volume), configuration (form), and their relative position of objects to each other.

Bertrand Russell (Russell 1988, 54) employed the construction of language to demonstrate Atomism’s capacity to transform generalized ideas into discrete, recognizable, and unitary concepts. Similarly, through atomic analysis, societies are distinguishable from each other not only by their rituals and value systems, but also by the fundamental material properties of the objects they produce. Material atomism, as an analytical approach, describes a society’s elementary (basic) spatial products. Material atomism analysis reveals the forms that are being identified, contested, reinterpreted, or abandoned altogether in spatial production. Material atomism is applicable at all scales of the physical world precisely because it determines the threshold at which point the product/object is recognized as elementary: an object whose further division results in at least two different objects with no individual-object specific identity. For example, if we speak of a Greek column, we may identify it as such because of its volutes or column fluting—all atomic identities. Should these components be removed, the object would still be a column, but it could not be identified as an elementary Greek column. Conversely, sub-atomic particles, fluting, marble, bases, can and do combine to form elementary objects, which in turn combine in varying quantities, to form increasingly complex objects with varying characteristics that exhibit the proprietary identity of its makers. It is these object qualities that permits them to be deconstructed as socio-culturally produced products.

Following Russell (32-33) spatial producers can employ a positivist approach when analyzing a spatial identity product. This approach, articulated by Auguste Comte, states “[t]he basic affirmations of positivism are (1) that all knowledge regarding matters of fact is based on the “positive” data of experience and (2) that beyond the realm of fact is that of pure logic and pure mathematics.” (Feigl, “Positivism”) In other words, designers may formulate empirically observed rules inherent to classify each spatial particle as a component of an object’s form, and then, proceed to develop criteria-based (sorting) component relationships whose configuration produce single identifiable spatial product or object.

2.2. The atomism of Theseus’ ship

In presenting the paradox, Plutarch notes that the debate centers on the identity of the Ship after its “timbers” are replaced during maintenance of the Ship. Hewn and shaped timbers are an atomic component of Theseus’ Ship. It is not accidental that Plutarch focuses on the timbers. Ponder the following: could the Ship S₀ be considered the same ship had it lost an oar, or all of its oars? Its sails? We could argue that we would still perceive the sail-less Ship as the Ship but lacking non elementary components. Conversely, can we call a Ship with no overall form of a Ship, the same Ship if its structural components have been removed? Probably not, as it could be something else, or at least an object in the process of becoming the Ship. Atomism permits the designer to investigate what are the necessary minimum components for an object to be that object. Roland Barthes notes this by writing

A frequent image: that of the ship Argo (luminous and white), each piece of which the Argonauts gradually replaced, so that they ended with an entirely new ship, without having to alter either its name or its form. This ship Argo is highly useful: it affords the allegory of an eminently structural object, created not by genius, inspiration, determination, evolution, but by two modest actions (which cannot be caught up in any mystique of creation): substitution (one part replaces another, as in a paradigm) and nomination (the name is in no way linked to the stability of the parts): by dint of combinations made within one and the same name, nothing is left of the origin: Argo is an object with no other cause than its name, with no other identity than its form. (Barthes, Howard, 1974, 46)

From one point of view, so long as the replacing components were identical to those replaced in materiality and form, the Ship continued to be S₀. If this were the case, in strict analogy, any design that adheres strictly to contextual component materiality and forms, regardless of the
historic period in which these are produced would have to be considered authentic. Similarly, if we were to produce the previously mentioned Greek column today, complete with all its atomic (elementary) components, why would we still hesitate to call it a Greek column, and instead label it a Greek style column? Several problems exist with this point of view: First, it is doubtful that as time passed, the same maker would produce the original object and the ensuing replacement parts. Second, contemporary spatial production does not have the lived experience of the historic context. Intuitively, we tend to consider this “pastiche” (the imitation of formal qualities) or “façadism” (in this case, a concern only for how something looks), because spatial production that relies exclusively on materiality and form is lacking the qualities possessed by the original context. Yet, not all contextually sensitive design is void of authority and identity placemaking qualities.

From the opposite point of view, the first time the Ship sailed was condition S0, and any replacement, regardless of its scale or location, meant that with each change the Ship was a different, such that with each replacement a new Ship emerged (S1, S2, S3…). We can reasonably expect that the Ship’s parts would have been replaced routinely during the command of Theseus himself, because of battle, sailing wear-and-tear, or even aesthetic preferences (e.g., rostrum colors). Seen exclusively from an atomistic components focus, this observation illustrates that the same Ship which left the port could not be the same Ship as the one that returned after its final voyage back to Athens. Hereafter, it is important to remember Arendt’s and Benjamin’s arguments. In the case of the former, Theseus and his crew are the maker and hence have authority to make, and in the latter, every event of the Ship –its history-, and therefore its component parts, strengthens the aura of the Ship as a whole, even when parts are replaced. This is could be why Plutarch points to the debate after the end of the Ship’s use at sea: so that Ship S0 must be understood as the final iteration that arrived back in port, no longer to be commanded by Theseus or his crew, to sail or engage in battle, but fully an object that embodies its historic experiences. This quandary suggests that atomism alone cannot solve the paradox; we must turn to another philosophical idea to arrive at quiddity of an object: essentialism.

2.3. Understanding essentialism

Object authenticity draws as much from its process of production and purpose as much as it does from its materiality and form. The primary purpose of Theseus’ Ship was to sail. Its makers were aware that the Ship would require periodic maintenance to continue to perform as a sailing ship. Because of this, it is easy to suppose that its makers purposely designed a Ship that could be maintained by replacement of parts. The process and purpose of an object are essential qualities. Where material atomism is useful in identifying and understanding the physical substance of spatial production, essentialism is applied in explaining the nature of the object.

Essentialism is a philosophical approach that seeks to go beyond the “appearances in order to discover the hidden causes of things,” (Ellis 2002, 24) and thus objects are defined by characteristics/properties that are bound in the very essence of the object. Essentialism requires first an affirmation of the object’s characteristics/properties and thus distinguishes those properties that are intrinsic and necessary for being the object and those which are accidental, the latter defined as a “property of an object .... it happens to have but that it could lack.”

Aristotle’s proposed four “cause” categories (Aristotle, Barnes, 1995, 315-446) that explain physical reality and the nature of things: material, formal, efficient and final. Of these, the first two parallel atomism’s definition of the elementary. Material cause, as the name suggests, explains the material content of the object; formal cause explains the shape of the object. With efficient cause, Aristotle attempted to describe qualities that are not necessarily exhibited at the surface of the object itself, but are imbued into the object during its production. These qualities include individual’s or groups’ socially constructed value systems operating during object production such as rituals, skillsets, aesthetics (value judgements of beauty), logistics.
(including location, tools and facilities) and temporality (duration and time frame). The purpose of the object, or final cause, is the designed purpose or function of the object. In this essay, the focus is on efficient and final causes.

2.4. Aristotle's causes

2.4.1. Efficient cause

For Aristotle, one of the explanations of the object's nature is the efficient cause or its production process. Efficient cause explores who produces the object, and how it is produced. Who may be a general category, for example, an ethnic, national, or other group, i.e. “the Greeks,” and can be further specified to an individual producer -i.e., Theseus. Who produces the object is then an essential property of the object itself -even anonymity of production is an identifiable property of the object (i.e., when we do not know or cannot know who made the object, when anonymity is a requirement of production, or when anyone can produce an object). Identifying who produces the object is limited only by the criteria that is established to generate a set based on common qualities or properties: such as profession, religious or hierarchical status, socio-cultural and political membership, etc. When analyzing a spatial product, such as ship, we might investigate who designed, built, blessed, and funded the object, noting that each of these producers had a specific role in the production process. We might further investigate requirements to participate in these roles, for example, to build a ship for the Athenian Navy, it might have been required to be an Athenian sailor.

Another aspect of efficient cause is how or the process of production. In essentialism, the object’s essential identity may embody the processes of production if deemed relevant by the individual maker or society as a whole. These processes include but are not limited rituals, traditions and their associated codes (rules) of execution. For example, it may be essential that the object be produced following specific manufacturing steps or associated rituals that may or may not be visible in the object itself; at specific periods of time, such as after offering ritual sacrifice to Athena (patron goddess of Athens); or with specific tools –particularly relevant when discussing human vs machine made. Codes and rituals of production may significantly overlap with the final cause (see below) designed purpose, as often how something is produced is part of why an object is produced.

It is important to recall that Arendt argues that the how of making is a fundamental part of authenticity because it necessarily incorporates socio-political value systems, including capital production contexts, codes, and working condition of the maker. Like production rituals, these characteristics may or may not be visible in the product itself, and overlap at times with other essentialist causes such as material. For example, a ship may be made of wood, such that its material cause is wood, but its efficient cause is that the wood must be from a particular forest associated with a sacred mountain.

2.4.2. Final cause

Aristotle describes final cause as the object’s telos (τέλος, end) or purpose. Purpose is further divided into two parts: what it should do, for example “a ship should float on water”; and what it can do (beyond its primary purpose) because of its inherent properties, such as materiality, shape, dimension, volume, color etc., for example, “a ship can be a monument.” The should is a desired intent, while can recognizes an object’s possibilities, but is lacking designer intent. Furthermore, as Benjamin noted, fundamental to the idea of what an object does, is an incorporated history of all previous actions, which taken as a sum, enable present and future actions of the object (hereafter, called functions). Observers must distinguish between passive (actions that happen to the object) and active functional properties of the object. In that sense, actions that happen to an object can be fundamental for describing the nature of an object, especially when these actions become emblematic of what an object must do when functioning to define it as a thing. These historic, present and future functions become the “signs” by which semiotic analyses ascribe various degrees of meaning and ultimately the collective memory inherent in the social contexts of spatially produced objects.
2.5. The essence of Theseus’ ship
Ship components are not then just elementary particles, but actually express a process and purpose for being. Theseus’ Ship could only be S₀ so long as it continued to carry out its purpose of sailing and during the time of his command. The moment the Ship docked for a final time, its purpose was no longer to sail, but rather to be a monument—its final cause had changed. Theseus’ sailing ship was different than Theseus’ monument ship. Once transformed, however, into a monument whose purpose was to be representative of Theseus and his adventures, it became necessary to maintain the ship to accomplish this purpose of being a monument. As long as the parts were replicated atomically, the Ship would continue to be considered authentic as a monument. In applying this theoretical framework to a site, a design that looks to its historic context to derive identity, will find its authenticity originates not only from the form and materiality of the site (recall the above example of the Eiffel Tower), but also from the essential how and why the spatial context was built. It is through the incorporation of the context into the new object’s being, that the spatial product emanates identity.

2.6. The role of context
Contextual site sensitivity begins with a positivist approach: while analyzing a place—and hence describing its space-time contexts must be identified and sorted (listing of qualities). Next, the History of the site gives spatial objects meaning: what have the objects been, what are they now, and what could they be properties themselves of site. Equally important, context must be understood as an intrinsic property. This context is necessary to establish the limits of being of the object itself: it is like this, but not like that. In his essay, “Building Dwelling Thinking,” Heidegger reifies an object’s identity through its context, stating “Accordingly, spaces receive their being from locations and not from ‘space’.” (Heidegger, Hofstadter, 2013, 152). The Ship is not merely a ship, but that Ship, and it embodies all its properties of space, time, materiality, form and essence of its context.

3.0 EVALUATING CONTEMPORARY SPATIAL PRODUCTION

3.1. Evaluation framework
As an empiric, positivist exercise, contemporary spatial producers should first deconstruct site context, that is take the whole of the site, and identify its spatial components. Just as one would describe each component of Theseus’ Ship, its “timbers”, oars, keel, mast, sails, and so on, a spatial producer must describe and understand the components of a place. Next, it is necessary to derive a set of normative rules that address the atomic and essential qualities of the contextual objects. Key to the evaluation exercise is the ability to distil the essential nature of the contextual objects. Who, how, and for what purpose were contextual environments produced? Can a project continue the spatial quiddity of the environment, and how does it do this? If a designer chooses to only focus on the aesthetic or material properties of an object, they risk addressing only the most superficial of qualities. Instead, designers must focus on the causes of things, and determine what can actually be learned from the way and purpose of making of the historic context. We can argue that like Theseus’ Ship as a monument, the site’s contextual vocabulary must be maintained by replacement and/or aggregation of objects which follow what Aldo Rossi called the spirit—“Genius Loci”– of the place (Rossi 1999, 103). The built environment must be preserved or augmented by the very act of its use and continued development. If identity is the main design driver, then the parts, however, must obey the cause logic of the place, so that the product acquires the aura of the place.

3.2. Contemporary example
In fig.1 (below), Teodoro Gonzalez de Leon and Abraham Zabludovsky designed in the early 1990s the Banamex Central Headquarters in the heart of historic viceroyal Mexico City. The designers are aware of the historic context, but rather than simply imitate the site’s existing surroundings, they deconstructed spatial components. Like the adjacent 17th Century adjacent
building, cornice lines are continued from building to building, and employed to separate the ground floor from the higher floors. These lines, however, also address the nature of the contemporary use of materials such as concrete and its aggregate texture. Arches above the windows tie together both buildings’ façades with a common language. However, where the older building’s arches frame the window panes, Gonzalez and Zabludovsky use the arches to mark the façade plane of deep windows that produce natural shade.

Figure 1: Banamex Central Headquarters, Mexico City by Teodoro Gonzalez de Leon and Abraham Zabludovsky

CONCLUSION

The Paradox of Theseus’ Ship serves as a theoretical framework to evaluate the validity of spatial production that derives its materiality, form and function from the site’s historic context. In using the paradox to evaluate the validity of a contemporary spatial production approach of emulating historic context, we must start with understanding the spatial component parts, as well as the efficient and final causes of place. Were the contextual objects designed and built for a specific purpose, in a specific way, during a specific time? Were these contextual objects, designed to be unique in their context –such as a Cathedral, or to belong to the identity of a larger community –e.g. a village house? Were contextual objects meant to be ephemeral, or last as long as possible, and hence it is in the nature of the object to be maintained after its initial production? What were the constructed systems of values that led to the production of an object, or a series of objects to produce a place?

The choice to push back against the challenges of Modernist and Post-Modernist goals of spatial differentiation, and globalization’s increasing influence, can and should lead to the strengthening of place identity, and hence placemaking. Yet, spatial producers, particularly designers, who fail to account for the value systems of those who produced objects rooted in the specificity of time, the intrinsic process of making, and the purpose of the original built environment, risk simulating identity due to a lack of authenticity. It is therefore recommended
that designers utilize atomic spatial components and a place’s essential qualities as design generators that preserve and augment the identity in an authentic manner.

REFERENCES

ENDNOTES

i “Quiddity”: Merriam-Webster "whatever makes something the type that it is: essence.” https://www.merriam-webster.com/dictionary/quiddity

ii Monument: a lasting evidence, reminder, or example of someone or something notable or great. https://www.merriam-webster.com/dictionary/monument

iii Plutarch himself never declares where he stands.


v Italics mine.


vii That is atoms that have spatial location and physical existence.


ix https://plato.stanford.edu/entries/essential-accidental/


xi Image originally appeared in Pinterest, modified by paper author. https://i.pinimg.com/originals/50/8c/8f/508c8f8c0d03642e7ebe73e197a2bfe6.jpg
The aesthetics of infrastructure: reflections on the scale models of the TVA

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ABSTRACT: Recognizing the importance of aesthetics in the contemporary discussion on infrastructure design, this paper looks to the work of Tennessee Valley Authority (TVA) as a historical case study that successfully merged a strong aesthetic agenda within an infrastructure project. The structures of the TVA have been extensively published in architectural journals and popular magazines for their innovation in dam design, modern appearance and ability to incorporate humanist values within a large-scale infrastructure project. Often discussed through the grand vision of the Chief Architect, Roland A. Wank, less attention has been focused on the specific project methods utilized in the collaboration of the architects and engineers of the TVA. With research collected from the National Archive at Atlanta, this paper explores the role that scale models play in the design process of the TVA during the design and construction of Norris Dam. For architects, the scale model is an important tool for the testing and communicating a project’s design intentions. However as is common in the world of architecture, the model is more than a utilitarian tool, often gaining the status of an aesthetic object that exists in its own right outside of the project for which it was intended to describe. While the production and reception of architecture models comes with its own extensive history and theorization, this paper looks specifically at the models that were built for a large-scale infrastructure as the site in which an aesthetic project that could be initiated by the architect is adopted within the working process of a large collaborative design team.

KEYWORDS: Architecture, Infrastructure, Aesthetics, Representation

INTRODUCTION

In 2017, the American Society of Civil Engineers “Infrastructure Report Card” scored the United States overall infrastructure a grade of D+. The overall score reflects that the infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of serious concern with strong risk of failure.”

(American Society of Civil Engineers 2017)

The report calls attention to the large quantity of projects that will be required to maintain the current infrastructure in place, as well as to improve the quality of design for the health and well-being of future generations.

The topic of infrastructure design has also been gaining attention in the architecture community as exemplified by international competitions for signature landscape urbanism projects such as the Highline, Freshkills Park and Downsview Park, bridge designs coming out of offices like OMA, Michael Maltzan and Santiago Calatrava, and even academic design speculation from smaller practices such as Urban Lab, Lateral Office, and The Office for Political Innovation. The buzzing of design activity by architects within the field of infrastructure combined with the national crisis of the state of contemporary infrastructure as declared by the ASCE appears to provide an opportune moment for architectural speculation to engage a ‘real-world’ design problem.

Recognizing the importance of aesthetics in the contemporary discussion on infrastructure design, this paper looks to the work of Tennessee Valley Authority (TVA) as a historical case study that successfully merged a strong aesthetic agenda within an infrastructure project. The Tennessee Valley Authority Act, signed in 1933, formed the TVA and initiated one of the largest infrastructure programs in the United States.
infrastructure projects in the history of the United States. The TVA projects transformed the terrain of the Tennessee Valley and surrounding region through the construction of hydroelectric dams along the Tennessee River system. The dams themselves were designed to produce hydroelectric power, control soil erosion, improve land productivity and increase recreational opportunities. The initial 16 dams were designed and constructed by a team of architects and engineers between 1933 and 1944.

The structures of the TVA have been extensively published in architectural journals and popular magazines for their innovation in dam design, modern appearance and ability to incorporate humanist values within a large-scale infrastructure project. The structures have also been praised for the ability to exemplify a harmonious union between architecture and engineering, demonstrating both aesthetic sensibility and technological performance. Often discussed through the grand vision of the Chief Architect, Roland A. Wank, less attention has been focused on the specific project methods utilized in the collaboration of the architects and engineers of the TVA.

This paper explores the role that scale models play in the design process of the Tennessee Valley Authority during the design and construction of Norris Dam. For architects, the scale model is an important tool for the testing and communicating a project’s design intentions. However as is common in the world of architecture, the model is more than a utilitarian tool, often gaining the status of an aesthetic object that exists in its own right outside of the project for which it was intended to describe. While the production and reception of architecture models comes with its own extensive history and theorization, this paper looks specifically at the models that were built for a large-scale infrastructure as the site in which an aesthetic project that could be initiated by the architect is adopted within the working process of a large collaborative design team.

1.0 THE NORRIS PROJECT
Beginning as early as 1911, the site of Norris Dam was examined as a potential location for hydro-power. The Norris Dam site is located on the Clinch River a tributary of the Tennessee River. In 1922, a formal study was conducted by the US Army Corp of Engineers of the Tennessee River Valley which recommended a series of dams along the Tennessee River and its tributaries, including one at the future site of Norris Dam then referred to as the Cove Creek site. Interest in the Cove Creek site continued to grow and in 1928 the US Army Corp of Engineers developed a report and design proposal titled “Report on Cove Creek Dam Site and Recommendation for Design of Dam, Powerhouse, Barge-lift and Spillway.” The design included a 220-ft tall barge-lift, that would be the first of its kind in the United States, and powerhouse at the center of the design and placed the spillway apart from the main structure to the east. The architecture of this original proposal included a series of archways for scale and ornament along the powerhouse and spillway. (The Norris Project 1940)

A series of the discussions and debates, many led by Senator George Norris, surrounding the dam projects continued into the early 1930’s until shortly after the inauguration of President Roosevelt in 1933. President Roosevelt proposed legislation to form “a corporation clothed with power of government but possessed of the flexibility and initiative of a private enterprise,” (The Norris Project 1940, 11) called the Tennessee Valley Authority (TVA). In May of 1933 the TVA Act was signed and the Cove Creek project, renamed the Norris Project in honor of Senator Norris, was authorized to begin construction. (The Norris Project 1940)

The Norris Project was simultaneously under both design and construction throughout its entire development, from the construction start in October 1933 to the opening of the dam in 1936. The team at the TVA, under the direction of Chairman, A.E. Morgan, began the project by hiring the Bureau of Reclamation to conduct engineering and drafting services for the dam. The Bureau of Reclamation conducted a feasibility study of the dam with four different structural types: a concrete straight gravity dam, a concrete round-head buttress, a rolled-earth fill, and a rock-filled. The study analyzed the required siting, layout and height of the dam as
described through a series of preliminary drawings. Following the study, the Bureau recommended a concrete straight gravity-type dam (Fig. 1) as it would provide the lowest overall cost of construction.1 (The Norris Project 1940)

On the heels of the Bureau’s study the TVA hired Roland A. Wank to become the Chief Architect for the dam under the Division of Land Planning and Housing. Wank is well known for pursuing a modern aesthetic in the design of Norris Dam, through the insistence on the removal of ornament and careful composition of the dam elements of the spillway, powerhouse, and roadway. Most noticeably, as can be seen by comparing the design by the Bureau of Reclamation (Fig. 1) to the final dam design (Fig. 2), the original design by the Bureau suggests exposed penstocks along the front face of the dam and vertical windows along the powerhouse which differ from the final design with the penstocks hidden in the mass of the dam wall and the horizontal ribbon windows of the powerhouse.

2.0 HYDRAULIC MODELS

With the general massing and layout of the Norris Project defined, in 1934 the TVA with the Bureau of Reclamation designed and constructed an interactive hydraulic scale-model to test the engineering and architectural character of the dam design. The first photograph in Technical Memorandum 406 published by the Department of Interior Bureau of Reclamation in 1934 shows a completed model of Norris Dam scaled at 1:72 (Fig. 3). Evenly lit, shot frontally straight-on, the photograph shows a faithful replica of the project’s overtop curved spillway, simplified plate-girder roadway bridging across the top, and the austere volume of the powerhouse. Decorative elements such as scale vehicles and window locations participate with the out-of-scale elements needed for the model’s technical performance such as metal piping and a sandy river bed. Most notably the model in this photograph is very dry. There is not so much as a drop of water visible in this photograph. While this model was at its time, a state-of-the-art technological device for testing the hydraulic performance of the dam, seeing it as an object to introduce this technical report is a reminder of the aesthetic seduction that miniature forms such as the architectural model is capable. (Hydraulic Model Experiments 1934)
Even with today’s sophisticated computer models, the behavior of water flowing across a constantly changing river bed is notoriously difficult to predict. Furthermore, the effectiveness and feasibility of the solid concrete walls that the TVA sought to build to inhibit and control the rivers of the Tennessee Valley could not be guaranteed by scientific formulas alone (Protection Against Scour 1933). So, the Bureau of Reclamation design team utilized a physical model to test the form and appearance of the dam and to help predict the effects of water flowing through it. While this was not the first time a dam or engineering work had been studied through physical model, the process, documentation and artifact provide a compelling narrative of the potentials for the techniques of architecture representation to participate in the aesthetic production of engineering research.

The Bureau of Reclamation was formed in 1902 to administer irrigation projects in the arid regions of the Western United States, and their Colorado Agricultural Experiment Station in Fort Collins had only been building hydraulic models like this since 1930 (Hydraulic Laboratory Techniques 1980). The entire process of the Norris Dam model’s construction, fluid and aesthetic testing and the resulting recommendations are painstakingly detailed in their Technical Memorandum No. 406, “Memorandum to the Chief Designing Engineer. Subject: The Hydraulic Model Experiments for the Design of Norris Dam” by Charles W. Thomas in 1934 which served as a primary source for this reflection.

The report uses drawings and photographs of the laboratory, model and dam to move the reader back and forth between the scales of both the TVA project of building a dam and the laboratory project of building a model. This oscillation between the work of representation and the built form is commonplace in architecture, and it is notable to see this similar balance of the importance of the final built work of engineering (the dam) with the attention paid to processes and procedures of the representation as carried out by the bureau. (Hydraulic Model Experiments 1934)

The space of the laboratory is first described through a series of four photographs that depict an idyllic rural setting and exterior structure that looks quite familiar like an archetypal pitched roof house. We then are presented with the supply reservoir—it’s only hint at what might be
happening inside. And finally, an interior photograph is revealed complete with the piping, ductwork and machinery that one would expect of scientific laboratory.

The laboratory building is then described in architectural plans and section with the model of Norris Dam located within “Calibration Tank X.” As a planning document, we can see the complex arrangement of pipes and equipment that direct water to the study subjects. As an aesthetic artifact, we also are given a full picture of the project of the model and the laboratory within which it is housed. With the knowledge that water flows downhill, the building cascades down a hillside with the holding reservoir above the weir box which can then be diverted into either of the small testing channels or the large Calibration Tank X, with the floor dropping another full story. Another TVA project, the Wheeler Dam is noted on the drawings in the one smaller testing channels. All of this complexity however is neatly captured with an even pitched roof, and regularly spaced double hung windows. The celebration of this technical ingenuity is left for the pages of government memorandums, and not aesthetic conceits of architectural form.

The report then briefly describes the plans and site for the final design of the dam before changing scale again to the drawings and details of the 1:72 scale model. The same format of construction drawings and documentary photography depict the model as both a performative device as well as an aesthetic creation. The model was constructed of steel, wood and masonite, and as noted in the report, “the entire model was carefully finished and painted with extra bright aluminum paint” (Hydraulic Model Experiments 1934, 12). Reading the drawings provided, one finds that while architectural features are kept to scale, the “plumbing” around and through structure is carried out with conventional pipes and fittings. This is because of the siting of the model within the Calibration Tank creates a necessarily different relationship between the dam and the reservoir then would occur in the hills of Tennessee. Also, the velocity, volume, and pressure of water does not have such a tidy scalar relationship to the model as the scaling of architectural forms would have

Regardless, with a single model, the designers were able to study many things that the report divides into three categories: Spillway Studies, Auxiliary Passages and Architectural Studies. While the Architectural Studies are given notably less ink than the other two categories, that they are included at all in such a technical study reads like a victory for design and aesthetics. Before looking at the results of these studies, it is important to note that as with the documentation of the Laboratory building, the drawings and photographs describing the model amount to a form a knowledge sharing that place importance on the production of a technical and architectural model as not only applicable for Norris Dam, but they were meant to serve also as a “model” for future dams and their designers.

The Spillway and Auxiliary Passage studies form the majority of this report as they study the shape of the spillway apron, stilling pools, and the openings through which the water exits the dam. (Fig. 4) Like in any building, joints and openings are a critical concern for the designers of dams. Not only must the joints within a massive concrete wall be carefully engineered, additionally the joints in which the man-made structure meets its earthen context are important moments in which the apparent heaviness of construction must respond to intricate conditions. The wall of the dam meeting the wall of the canyon in the vertical plane is one of these moments. Of equal importance is the way in which the horizontal surface of spillway’s stilling pool transitions into the natural rocks and mud of the riverbed on which it is constructed. This must be designed to dissipate energy in the water and alleviate the potential for scouring of the river bed adjacent to the concrete spillway.

Scouring is the hydraulic phenomenon in which the water flowing around an impediment or barrier has the tendency to erode the riverbed on the downstream side of that barrier and hence compromise the ground on which that barrier relies on for support. (Protection Against Scour 1933) One can imagine the catastrophic effects on a dam if the ground below it begins to disappear downriver. Despite formulas and proofs utilized to optimize the shape of the spillway in the design phase, physical testing is still necessary to confirm these assumptions.
And the lab technicians document countless iterations of these tests examining different shapes, transitions, water quantities, and patterns of operation. All the while, the technicians pay careful attention to the character of the water flowing over the surfaces and leaving the controlled conditions of the stilling chamber.

Only once a degree of confidence can be imparted on the hydraulic engineering of the structure, does the report discuss the Architectural Studies, and it does so in slightly less detail than hydraulic tests. While only the roadway bridge over the spillway was studied architecturally, it is still treated with the same seriousness as the engineering concerns. The same documentary language and photographic process was used to try to establish a verifiable conclusion for aesthetic decision-making by means of comparison. (Hydraulic Model Experiments 1934)

**Figure 4:** Bureau of Reclamation hydraulic model spillway studies. (Bureau of Reclamation 1934, Plate 68)

The roadway bridge had three structural options to be studied for aesthetic impacts: A through truss, a pony truss, and plate-girders. The through truss and pony truss were both steel framed options with exposed steel members that were deemed to be out of proportion with the rest of the concrete dam. However, using steel pates in the plate-girder system gives the appearance of a monolithic roadway, that is “much more in keeping with the other features of the dam and adds greatly to the appearance of the structure.” (Hydraulic Model Experiments 1934, 183) Beyond aesthetics, the engineers note that changing the pier structures to accommodate this is actually beneficial to the flow of water over the bridge.

It’s difficult to determine when in the process of Hydraulic Testing that the Architectural tests were performed. Sometimes the photos of the model show the plate-girder bridge, sometimes they show no bridge, and sometimes the through truss is visible. The bridge piers are drawn in the construction drawings of the model but not the roadway. This indicates that the architectural studies were intended from the beginning, and the model was constructed to be modified both technically and aesthetically. Decorating the roadway with scale models of cars and trucks as in the final model shots, the bridge is able to effortlessly find its way into the
testing, and its presentation in the report show a receptiveness of engineering practices toward the production of an aesthetic project.

3.0 THE STRUCTURAL MODEL SHOP OF THE TVA

The concurrent design and construction of the Norris Project raised many challenges that required real-time study of the architecture, hydraulic design, structure, and constructability. To aid in many of these complex studies the TVA built Structural Model Shop at the Norris site with trained engineers and model-makers to make scale-models and mock-ups of various project elements at Norris, as well as other ongoing TVA projects. In a 1938 pamphlet of the TVA Structural Model Shop, director H. L. von Hohenleiten describes the breadth and usefulness of the Model Shop’s services, suggesting that other departments with the United States government may also want to employ the shop’s skills. The pamphlet categorizes the work of the model shop into 5 model categories: architectural models, topographic models, construction models, electrical models and special models. At the front of the pamphlet Hohenleiten describes the engineering discipline’s recent adaptation of this “new medium” and its ability to provide an effective way to study complex three-dimensional design problems. Hohenleiten continues to emphasize the practical benefits of using scale-models in the design process stating: “In many instances models have more than repaid their cost by providing a miniature picture that could bring a story home to the laymen where intricate blueprints had failed.” (The Structural Model Shop 1938, 1)

The five types of models that the shop produces are notable in that they were intended to study different aspects of the dams in detail. The architectural and topographic models were typically constructed at the smallest scale and encompassed the entire structure of the dam and proposed buildings. These models, as they are commonly used today, allowed the TVA Architects to “visualize all his problems before design drawings are completed.” (The Structural Model Shop 1938, 2) The pamphlet also notes that the architectural scale models are often produced with inter-changeable parts to test different design options. The topographic models in particular allowed the TVA team to understand the three-dimensionality of the dam interventions in connection with the surrounding landscape.

A finer level of detail is found in the second category called construction models. These models were used to understand the constructability of the projects, as well as the sequence of construction. The models were designed to be taken apart and reassembled to give the contractor a better understanding of the construction sequence. Some of the models were in addition designed to be taken apart in section, to produce a three-dimensional cross-section of the project. The models are made with a high-level of craft and precision allowing for them to both describe the constructability but also to highlight the architectural details of the design down to the concrete scoring patterns.

The last two model categories described in the pamphlet, electrical and ‘special’ models, undertake some of the more progressive and experimental aspects of the TVA designs. Lighting of the Norris Project became particularly important to Roland A. Wank, as he wanted the lighting to become part of the scenery and enhance the approach and appearance of the dam design. In a series of letters between Roland Wank and the Norris Dam the Office of the General Manager in 1938, two years after Norris Dam had opened to the public, Wank requested the addition of flood lights illuminating the face of the dam, as well as addition of light fixtures in the parking lot. Wank desired an even illumination of the visitor parking lot and the dam itself as not to blind the visitors on approach. (Roland A. Wank 1938) As part of the lighting study, the architect’s office designed a baffling system for the parking lot lights that would help distribute the light evenly. The design was tested in a series of models and installed as a full-scale mock-up on site. At this point the Structural Model Shop was acting as much as a fabrication service, producing full-scale pieces that could test the designs prior to full production. The pamphlet notes:

A lot of the research work is being done in connection with these models in order to establish not only the correct optical features, but also to determine the proper chemical and mechanical properties of paints and materials.” (The Structural Model Shop 1938, 6)
The electrical models suggest a true collaboration between the architects and the engineers as the aesthetic effects of the architect's office are refined and tested through the physical mock-ups.

The special models section of the pamphlet describes the Structural Model Shops ability to test a wide-range of design and visualization challenges through physical models. The two examples described in the pamphlet are both quite interesting and operate at different scales. The first special model described is a skeletal model of a draft-tube, a mechanical element that sits below the powerhouse. The draft-tube was built with a series of sectional flat sectional members that form a lattice or skeleton of the entire geometry. (Fig. 5) The model appears strikingly similar to digital lattice models generated by the computer to that architects commonly use to model complex surfaces still to this day. The pamphlet notes the difficulty of the team to visualize this complex geometry through drawing alone.

The other unique model to note in this section is a scale model of the crusher plant. (Fig. 6) The extremely large quantity of concrete utilized in the Norris project led the TVA to construct a local concrete plant for the Norris Project. Rock was quarried from the surrounding hills of the dam and transported to the concrete plant to be processed. In the design of the concrete plant, the model shop built this scale model that included the “mechanical elements like screens, chutes, and crushers” that could be easily reconfigured in the model “until an economical and mechanically correct layout could be developed.” (The Structural Model Shop 1938, 11) The reconfigurability of the model gives it a children's game-like quality with a series of primitive parts set within a light structural frame.

The extensive amount and variety of models constructed in the TVA Structural Model Shop are impressive and suggest a detailed level of study into all of the building components, but it also demonstrates an interesting space of collaboration between the architects and engineers. The model shop, where neither the Bureau of Reclamation or the Architect's office was necessarily physically present, was a moment where the ideas and strategies of both groups were brought together and tested in a controlled environment. The detail and precision of the models and mock-ups constructed suggest that they were used for both purposes throughout the design, aesthetic sensibility and refinement of performance.

CONCLUSION

After the dam’s completion, heavy rains in January of 1937 provided an opportunity for the TVA to test the performance of the constructed spillway against the results predicted by the Bureau of Reclamation's laboratory tests (Performance of Norris Stilling Basin 1938). A remarkably similar set of photographs to the hydraulic model photos of water flowing over the dam on an overcast day are produced looking closely at the characteristics of the water flow.
The photos are distinguishable from the laboratory photos only by the apparent scale of the water compared with the scale of the structure. The concrete of the dam also takes on more detail and patina than the physical model could ever depict. The design process from drawing, to model, to construction is complete, but the memory of the model and the artifacts of the process are engrained in the artifact and its operators.

As the need for the design of new infrastructure meets the demands of maintenance, resiliency and decommissioning of aging infrastructure, architects have new opportunities to inject aesthetic possibilities for design work that will otherwise be relegated to engineers, industrialists and politicians. The signature parks, iconic bridges, and academic speculation are a good start for maintaining a thread of the discipline of architecture’s attention toward infrastructure. However, there is much work to be done to inject design into the gaps in mindfulness that are ubiquitous in the extensive reaches of global infrastructure.

The models that are covered in this paper represent a collaborative and interdisciplinary tool to test both aesthetic and performative potentials of an enormous project. The model shops at work here established a neutral ground outside of the hands of the projects designers to give life to their ideas and drawings. The model’s physical presence, transmitted through photographs, made it seem possible to have an objective vision towards and aesthetic production.

Today’s professionals also operate in a digital modeling environment heralded for its potentials for seamless real-time collaboration. What needs to be questioned is the capacity for that type of model to promote new aesthetic possibilities that are capable of transcending the ambitions of any single stakeholder in the project. While the architects of the TVA had the momentum of the Modern Architecture movement to propel their aesthetic agenda for the Norris Dam, architects today, for better or worse, enjoy a much wider field of aesthetic possibilities from which to bring to the collaborative table. The model making practices of the TVA give promise to the notion that aesthetic imagination must complement the engineering of infrastructure if we are to thoughtfully address the infrastructural needs of today.

REFERENCES


ENDNOTES

1 Scholars, including Reyner Banham and Christine Macy, have suggested that Roland A. Wank and the TVA Architects critiqued and re-designed the Norris Dam design based off of the preliminary design proposed by the United States Army Corp of Engineers in 1929. However, the four preliminary dam studies developed by the Bureau of Reclamation in September 1933 from the Norris Project Technical Report suggest that the concrete gravity dam design was selected for its cost benefits prior to Roland A. Wank’s arrival to the TVA in October 1933. This timeline would suggest that the general composition of Norris Dam was already in place when Wank’s team began work at the TVA, shifting the common narrative of the dam’s design inception. This historical timeline merits further study.
Learning from performative mid-century enclosures: Kahn’s Weiss House

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ABSTRACT: Important features often accompanying mid-century modernism were solar control devices, included in work of leading architects as well as main street practitioners. Although the application of solar devices was largely intuitive, the Olgyay brothers published a book in 1957 called *Solar Control and Shading Devices* that related theory to projects utilizing mathematical and graphic analysis. Prior to this point published studies of solar design principles focused on generic massing strategies and did not relate solar design to specific architectural details or aesthetics. By uniting the art and science of architecture, and not utilizing examples that are primarily functional, the Olgyays sought to inspire other architects. This approach is similar to most contemporary case-study books that select examples from designers of high aesthetic reputation. After air-conditioning became standard in the US in the nineteen-fifties, use of overt solar design devices waned. When interest in solar design reinvigorated during the energy crisis of the seventies, the aesthetics of solar design were folky and peripheral to mainstream architectural culture. Interest in vernacular buildings accompanying the revival. Reprinted editions of Victor Olgyay’s *Design with Climate* and Reyner Banham’s *The Architecture of the Well-Tempered Environment* enjoyed cult status. It would take another couple of decades for interest in environmentally grounded architecture to return with a broader focus on materials and engineered systems. Despite the beautifully rendered book, *Lessons from Modernism: Environmental Design Strategies in Architecture, 1925-1970* published in 2014, there has been little recent historical research on mid-century solar design. Abandonment of valuable knowledge is consistent with a larger culture of obsolescence and fashion. Rapid movement from one style to another has complicated comparisons requiring extra effort to harvest fundamental knowledge. A corollary is a lack of critical attention to building projects that fall short of promised performance but are valuable for comparison. Shift to high-tech building products and systems have eclipsed the value of performance of older buildings where the shape of building elements is central to performance. This paper revisits examples of mid-century solar design that have evaded comprehensive history books and are largely unavailable to contemporary architects. At the center is a house designed by Louis Kahn and Anne Tyng in the late 1940’s for the Weiss family that exemplifies how modern design can support human needs through an innovative widow wall system that mediated light, privacy, ventilation and thermal comfort with integrated adjustable panels, horizontal louvers, and heating elements. Aspects of the system translated to sliding panels that control light and views at perimeter study carrels in Kahn’s Exeter Library, one of his later works.

KEYWORDS: Modernism, Performance, Solar Control, Privacy

1.0 INTRODUCTION

Louis Kahn is associated with a monumental approach to architecture that relied on fundamental shapes, symmetry, and use of heavy materials including brick and concrete. This is clearly visible in his later institutional work including the Salk Institute, Philips Exeter Academy Library and the Kimbell Art Museum. Works prior to the Yale Art Gallery addition, considered his first masterwork, are less well known. The obscurity of Kahn’s early work reflects numerous anonymous modernist works of the post-war era. A key characteristic of buildings of this era were designs that were responsive to the sun with strategic glazing strategies and solar shading devices. Kahn’s solar details are important because they combine...
performance with aesthetic acumen in a manner that is exceptional but underappreciated due to the focus of the visual aspect of his later works.

Buildings designed by Kahn in the period prior to the Yale Art Gallery warrant greater appreciation although their attributes are difficult to reduction to a fundamental parti. Among them, the Weiss House located in the outskirts of Philadelphia is exceptionally complex project representing qualities, despite small rooms typical of the era, that escape relevance to only one historic period. The house is site and program responsive, is expressive of structure, reflects Kahn’s interest in craft and material, and is responsive to local solar conditions. Most importantly, it includes an innovative window wall system that mediated different conditions by allowing alteration between passive and active control of light and views. The goal of this paper is to provide context for the window wall system while fostering greater appreciation for a complex design that is difficult to understand due to eccentricities.

1.1 Background
After graduating from the University of Pennsylvania in 1924, Kahn’s career as an architect included a series of employments and collaborations that led to little built work until the end of World War II. His greatest direct influences were Paul Cret, a French-American architect who practiced a streamlined classicism, and George Howe who collaborated with William Lescaze on the design of the Philadelphia Savings Fund Society tower. Howe, Kahn formed a partnership in 1941 and Oscar Stonorov joined in 1942 focused on addressing wartime housing challenges (Leslie 2005). The collaboration produced the Carver Court housing project in Coatesville, Pennsylvania completed in 1944. The stark forms and surfaces of the International Style, and the raised living quarters derived from Le Corbusier, can be seen in the Carver Court project as well as the use of wood cladding which Walter Gropius had used in earlier projects as an ode to regional influences (McCarter 2009).

Figure 1: Photo of Weiss Residence from the South. Source: (University of Pennsylvania Archives)

After Howe left the practice in 1942, Kahn and Stonorov continued to practice together until 1947. The two most notable projects to emerge out of the partnership were entries for the Hotel for 1944 competition and the Libbey-Owens Solar Home competition in 1947. Illustrations for both entries represent rational planning, particularly the revealed structure of hotel tower block, and the form of the solar housing proposal that responded to the sun. Kahn brought David Wisdom who would be a key contributor, and Anne Tyng with whom he had a strong working and romantic relationship to the practice. Both of them would remain with Kahn after his partnership with Stonorov dissolved and he became a sole practitioner. In the period after, Kahn designed housing and institutional buildings that reflected modern experimentations of the prior collaborations, and a separate inclination toward qualities of buildings that predated immediate trends. The output also reflected a futuristic oriented academic approach brought by Tyng who completed advanced studies at Harvard.
The Weiss House (Fig. 1) is the third house designed by Louis Kahn after he formed his solo practice. It represents various influences on Kahn and reveals how he work through them toward a clear personal philosophy and approach to design that would mark his mature period initiated with the Yale Art Gallery Addition. Although his later work represents a clear monumental impulse, his earlier work, while less clear, is in many ways more complex. The facades, which are significantly different on each elevation, reflect this complexity. They mediate conditions between the interior and exterior based on programmatic and environmental impacts. The primary facades also are dynamic, and operable, allowing occupants to tune the building toward their immediate experiential preferences.

1.2 Project description
The Weiss House rests at the crest of a gently sloping hill, thirty-five feet above Whitehall Road. In plan, the parti is comprised of three rectangles, each containing spaces with related function. An enclosed corridor connects two of the rectangular masses that house the main living functions. Because they share a common roof, the two living masses present the appearance of a singular volume in elevation. A covered walkway links the third volume that contains a garage to the largest mass. The garage pavilion is spaced slightly further away from the other volumes signaling a support role as a non-habited space. A stone chimney located at the center of the western volume corresponds with a large stone exterior fireplace approximately twenty-feet away from the building.

The approach to the house is from a drive that passes the house to the east. It wraps the house turning west and terminating in a pad to the north of the living quarters in front of the garage. An effect of the approach is to leave the landscape to the south and west of the house an open field into which a stone pad extends. A direct result of the approach is that primary entry is at the back of the house, opposite the living room and master bedroom, creating a sense of privacy and permitting unencumbered views at the primary exposures. An open walkway from the car pad parallels the covered walkway from the garage, with the former terminating at the formal entry door and vestibule between the living and sleeping wings. None of the four exterior doors of the main portion of the house is particularly prominent. For example, the southern door is located to the side of the living room in a recess between volumes.

Figure 2: Schematic Plan. Source: (University of Pennsylvania Archives)
Grouping different functions of the house and distinguishing them in similarly shaped, but different, proportioned volumes contrasts with Kahn’s latter approach of fitting nuanced program elements into singular volumes. A rectangular zone in plan connects the sleeping wing to the living wing within a clear rectangle that penetrates the bedroom volume in plan (Fig. 2) and extends into the living volume. It contains service, circulation, and specialized functions including a large fireplace with a depressed seating area. The sequestering of support spaces in the center zone, and the distinction between the garage and main part of the house, foreshadows Kahn’s served and service relationship that became a defining aspect of his later work (Gast 1998).

Instances of the building are traceable to Frank-Lloyd Wright, the Bauhaus and Le Corbusier. For example, irregularly shaped fireplace is a pivot point from which spaces extend, including to the exterior fireplace. A butterfly roof defines the cross-section of the building, an invention of Le Corbusier. The highpoint of the butterfly roof is parallel to the south elevation permitting high ceilings and maximum façade area on the south face of the building where the living room and main bedroom are located. At the north face of the building, the façade is lower than living side resulting in a low point that is off-center, and lower ceilings in the kitchen, dining space and auxiliary bedrooms. This project was not the first time Kahn was associated with a butterfly roof. In 1942 when Kahn was in partnership with Stonorov, an unrealized housing project for Washington, DC included a butterfly roof superimposed over pitched roof (McCarter 2009). After the Yale Art Gallery, Kahn’s residential projects had flat roofs.

1.3 Elevation character and materials
The nuanced elevations of the building reflect the interior functions in a more direct way than Kahn’s later more monumental works. For example, taller windows occur in the more public areas of the house, and favor views into the landscape away from the driveway. The most prominent part of the elevations apart from the roof, and associated trellises, are large sections of repetitive ganged glass units situated between robust trim that conceals structure. They appear in three locations, at the living room, master bedroom and guest bedrooms. The windows at the southern side of the living room are taller and include a louvered overhang at the middle that divides the lower panes of the window system at the living room in two, and corresponds in depth to the eave extension (Fig. 4).

A shallow field of stone exists between the bottom of the windows of the main bedroom, the maid’s room, and the guest room that doubled as a study (Fig. 5). Clearstory windows at the south side of the central corridor provide additional privacy. The end elevations are punctuated by smaller openings on the east side where restrooms, reflecting the general orientation of the building toward the high points of the butterfly roof. The western end of the main structure has

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Figure 3: Axonometric drawing of the house. Source: (Author 2018)
a thin framed glazed section that supports a visual connection between the fireplaces. The majority of the building is clad in wide wood boards vertically oriented with the exception of strategically used stone. End walls of the living masses from which the butterfly roof is evident are clad in stone where not glazed. Their thickness evident at the ends where the meet the main elevations. The modulation of the lager windows are regular in width and made of exposed timber framing which runs in line with the windows.

Figure 4: Drawing of south elevation. Source: (Author 2018)

Figure 5: Drawing of north elevation. Source: (Author 2018)

1.4 Window system and details
In anticipation of Kahn’s use of heavy materials later in his career, the primary wood window system appears substantial despite large glass lights centered at five-foot-four-inch intervals horizontally. Despite material robustness, an overall effect of lightness exists on the main facades due to the juxtaposition of the wood framing to the adjacent to stone. The outer face of flat vertical window casings are approximately seven inches wide, a dimension matched at the top and bottom rails. With the exception of one section, each of the vertical sections of the primary window system is composed of three different layers, an outer fixed insect screen, operable glazed sashes, and operable inner and outer sashes. The function of the sections resembles a double-hung window although one of the sashes is glazed and the other plywood infilled. Another difference is that the sashes slide past each other (Fig. 6). The result is that window sections can be opened at the top or bottom, and can have a solid panel at either the top or bottom. A subtle nuance between the sections is that some of the glazed units are in the outer plane, some in the inner plane, and visa-versa.

In section, the windows conceal the structure embedded in them. The robust window and panel frames are deep, two-and-a-half wide and almost two-inches deep. They are set in a similarly robust hardwood frame and casings that conceals a parallel pair of heavy wood six-inch deep studs that support the roof. Notches in the frames receive the sliding wood panels biased toward the exterior. The insect screen is set in a frame inserted into the flat outer trim in-line with the outermost face of the window trim. Correspondingly, a four-by-six spans between the studs horizontal below the roof.

Horizontal solar control elements are located at the large living room windows at the mid-point between the upper and lower sashes. The exterior louvers extend thirty-six inches out and contain three angled wood strips to form louver blades. A result is shading from the southern sun at the lower portion of the window assembly by the shading device, and upper portion from the eave. The exterior louver corresponds with a two-foot deep interior shelf assembly of the same depth. It includes lighting elements that wash the ceiling and radiant heating imbedded in plaster concealed by a wood panel and trim. The result is a highly tunable system that provides optimal light under different external conditions and interior desires (Fig. 7).
Figure 6: Detailed sections of living room. Source: (University of Pennsylvania)

Kahn is famous for clear identification of structure, use of infill to contrast with the structure, and highly resolved detailing. An emphasis on legibility of the frame contrasts with a solid bearing wall and heaths what Kenneth Frampton in his essay Reflections on the Scope of the Tectonic described as stereotomic, often possessing a tactile quality (Cava and Frampton 2005). The notion of the tectonic relates to frame and infill construction that is lighter and embodies tension between components. Kahn’s use of material, particularly the heavy rusticated walls in the Weiss project, would have been unusual for the period and contrasts with the weightlessness of many early modern structures. The balance of the Weiss House contains a reading of structure through the window frames with the exposed roof beams in the larger spaces. Kahn resists a loss of legibility and time that occurs in stud walls by obsessing in the details of the window system and casework.

1.5 Solar control and user control
Overt solar control devices were a notable part of mid-century design until the ascension of air-conditioning in America during the post-war period. Shading had been incorporated in pre-modern vernacular architecture such as the shaded porch and breezeway of the dog-trot house in the American Gulf region, and the overhangs of early modern houses such as those built by the Greene brothers of Pasadena. However, Le Corbusier’s invention, and promotion, of the brise-soleil instilled overt shading devices as an expressive component of mid-century modernism. The earliest examples of the utilization of shading devices derived from Corbusier’s visions were in South America during World War II when building in the United States was limited due to the diversion of resources toward the war effort. After the war, building resumed with modernism as the defining aesthetic largely due to its visual encapsulation of progress through technology, an important component of the victory.

Modernist architects were motivated to adopt shading strategies largely due to the promises of better heath and comfort through rational architecture. They were influenced by Le Corbusier’s visionary work, and modern South American architecture. Many of the South American examples were introduced to an American audience in a 1949 Progressive Architecture article written by Richard Neutra. In addition to reporting on South American
advances, Neutra was a leader in incorporating solar shading into his designs including adjustable vertical louvers for the Kaufman House (1947) in Palm Springs. Another factor playing into solar shading was fact that North American homes and commercial buildings were not typically air-conditioned before and after the war. Solar shading was a way to maintain comfort near glazed areas of non-conditioned buildings where breezes were not adequate.

The best example of scholarship on shading of the post-war era is Victor and Aladar Olgyay’s 1957 book titled *Solar Control and Shading Devices*. The first half of the book is dedicated to explaining the Olgyay’s techniques for understanding how location relates the amount of sun available at different times including during the day and across the years. They relate the sun to local temperature, the sun’s potential to heat different orientation of building, and the effectiveness of different types of shading relative to the different conditions. The second part of the book provides case studies of modern buildings that exemplify many of the techniques. What distinguishes the book from most case studies is that the Olgyay’s connect the examples to the analysis presented earlier in their book. Among the building presented was the Radbil addition to the Philadelphia Psychological Hospital (1953) designed by Louis Kahn in Philadelphia. The prominent horizontal shading devices on the building are inconsistent with Kahn’s signature work, but not out of place among the other architectural works of the period presented by the Olgyays.

The hospital was not the first work by Kahn that included solar devices. Horizontal shading appears in Khan’s 1943 visionary proposal for an apartment building created for a city planning booklet titled, *You and Your Neighborhood*. The solid projections represent an extension of the floor plate and provide the primary articulation on the otherwise vertically oriented block. Another earlier project that included solar shading was Kahn and Stonorov’s 1946 proposal for a solar house competition that Anne Tyng contributed to after joining the office. She studied under Walter Gropius and Marcel Breuer at Harvard where she gained the technical rigor reflected in the house design. For example, extensive shading diagrams represented the impact of the suns influencing the building’s form. Louvered solar projections are evident mid-level up the façade at the three orientations with southern exposure.

Similar considerations factored into the Weiss massing that welcomes the southern sun with the highest glazing to solid wall ratio of all of the facades, and large extent of glass made possible by the butterfly roof. Overhangs are a natural extension of a sloped roof and are an integral part of traditional pitched roof, and more contemporary butterfly roofs. Solar shading is inherent in roofs with eaves provided glazing is close to the overhang. The louver system in the Weiss Residence is in the tallest glazing section and balance in the middle of the wall. Limits to fixed geometries are compensated for by movable panels that are adjustable under different solar conditions that particularly uncomfortable when the sun is low on the horizon.

Further control occurs in the building with integrated opaque panels that allows for tuning to user preferences under different scenarios similar to the visors in an automobile windshield. Views are also augmented by the panels that when situated lower, allow for privacy, light and views toward the trees and sky above. When in the lowered position, the panels provide allow for views toward the immediate landscape. The panels provide visual variety that signals the operative modes prompted from interior desires. Kahn’s interest in a tactile architecture recognized human agency in the architectural experience making architecture more than visual.

Comfort in architecture when acknowledged, typically points to thermal comfort which is physical and psychological. Thermal comfort is largely a factor of temperature, with humidity, air-movement, and radiant heat also playing a significant role. Physical comfort is largely considered objective and is represented in psychrometric charts that provide the basis for interior comfort standards that have been codified. Recognition of physiological differences, including gender, along with psychological comfort have gained greater credibility as different cultures have been studied revealing different reactions to environmental factors based on local experiences and tendencies. The Weiss Residence was built when most homes did not
have air-conditioning and the idea of environmental consistency was not expected. Mitigating immediate environment conditions with active and passive building elements offered a corollary to modifying clothing.

![Diagrams of possible window panel arrangement. Source: (Author 2018)](image)

**Figure 7:** Diagrams of possible window panel arrangement. Source: (Author 2018)

### 1.6 Privacy

Passive privacy control is integrated into the architecture of most well designed houses. However, active control occurs with furnishings such as curtains. The Weiss House integrated active privacy control in a manner that few architectural have. Control of access to our inners selves is a universal human concern affected by developments in environmental factors such as densification, and technological capabilities that allow institutions to collect and manage information about individuals. At the heart of the concept of privacy is according to philosopher Adam Moore.

A right to privacy can be understood as a right to maintain a certain level of control over the inner spheres of personal information and access to one’s own body, capacities, and powers. It is a right to limit public access to oneself and to information about oneself. Privacy and control is a necessary condition for healthy individuals and social relations. Without it intimacy, friendship, and love are difficult to cultivate. Similar to function of garments, the building blocks of buildings are important elements to maintaining privacy and control (Moore 2003).

In addition to enabling relationships Joseph Kupfer find privacy necessary for the existence of an autonomous self, free thinking and self-determination. It also, gives individuals room to make mistakes. (Kupfer 1987) Although access to light and openness has been identified as a fundamental objective of early modern architects who sought responses to pathologies associated with the modern city with openness to light, exemplified by the glass curtain wall, transparency runs counter to privacy and control. In private residences curtains, shades, and blinds impede flow of natural light into building interiors and views to the outside.

It is possible to develop a definition of privacy that operates between philosophy and sociology and law. In her book *Configuring the Networked Self*, Julie Cohen see privacy as part of a power relationship that allows for different levels of self-expression (and concedes that individual relations privacy depends on cultural conventions). Notions of self-expression and play are interchangeable in this context. When describing privacy in the context of a home, it “furnishes room for a critical, playful subjectivity to develop” (Cohen 2012). Kahn design preceded this analysis, but qualities of play and environmental control of woven into the enclosure of the Weiss Residence. Occupants could mediate the light and views, and change the aesthetic of the architecture as a form of play and expression.

The spirit of the arts and crafts movement pitted the individual against industry that threatened individuality and expression. Karsten Harries in his book *The Ethical Function of Architecture*
draws a line between John Ruskin and Louis Kahn. Ruskin sees self-alienation in the rationalization of the industrialization that has no time for architecture and decoration. Harries sees Kahn as a counter force to an entirely rational architecture. In this paradigm, symbolic representation, cultural continuity, and humanism are consistently present (Harries 1997). Artistic craft and acknowledgment of the humanity of the individual user was resonant in the Weiss Residence and carried through to Kahn’s later institutional work. The study bays at the perimeter of the Philips Exeter Academy Library in Andover, New Hampshire, have small movable shutters that allow the individual to modify lamination levels and views.

CONCLUSION
Louis Kahn’s career prior to the Yale Gallery of Art is formative and work includes characteristics of his later buildings, but lack resolution compatible with expectations of the monumental. However, associations with the monument has overshadowed exceptional qualities of Kahn’s less monumental work. Expectations most applicable to institutional commissions of cultural significance are less relevant when assessing residential architecture. Although the overall form of the Weiss House is less holistic than later work, the components are well integrated and the building rooted to the landscape in a manner that is consistent with Kahn’s concept of timeless. Anchored to the site with local stone and detailed with wood that represented craftsmanship.

Kahn’s experiment with panelized window system that allows for use control of sunlight began with the unbuilt Parasol House and realized with the Weiss House. The essence of the system was use soon after in the Pincus Annex to the Philadelphia Psychological Hospital and toward the end of Kahn’s career in Andover. In all cases, the system was confirmation of Kahn’s interest in placing the human activity at the center of his buildings and that control of light was a key component of setting the stage for experience. Light and views balanced with control of privacy another human need.

REFERENCES
Future of architectural hybridity: exploring the Bauhaus culture in Hajjar’s hybrid architecture

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ABSTRACT: The aim of this study is to explore the notion of stylistic hybridity in architecture by using shape grammar as a computational design methodology. The mid-twentieth-century architecture produced by William Hajjar is used as a case study for this exploration. Hajjar was a member of the architecture faculty at the Pennsylvania State University (Penn State), a practitioner in State College where the University Park campus is located, and an influential figure in the history of architecture in the area. The residential architecture he designed for and built in the area incorporates many of the shapes, rules, and features of both modern European architecture and traditional American architecture. Using computational methodology, this study offers an investigation into this hybridity phenomenon and explores the possibility of producing hybrid architectural designs for future uses. In the present study, shape grammars are used specifically to verify and describe the influence of Bauhaus/European modernism on Hajjar’s domestic architecture: rules from the grammar developed for his single-family houses in the State College area will be compared with rules from the grammar developed for the Gropius–Breuer partnership in the United States. The potential of shape grammar will be discussed as an effective complementary tool for architectural historians to use in a mathematically rigorous way to verify the formal and functional similarities between styles. In short, it is proposed that shape grammars be used broadly in detective work to verify or disprove hypotheses.

KEYWORDS: Modern architecture, Single-family house, William Hajjar, Walter Gropius, Shape Grammar

INTRODUCTION

In A Field Guide to American Houses, Virginia and Lee McAlester describe "modern" as a post–World War II architecture that abandoned historical precedents in favor of new variations in architectural composition (1984). The modern U.S. houses featured in their book include minimal traditional, ranch, split-level, contemporary, and shed-roofed styles. However, earlier in the twentieth century, Henry-Russell Hitchcock and Philip Johnson defined modern architecture in general in a different way: Their focus was the "International Style" in reference to three identifying features: volume instead of mass, a lack of ornamentation, and elements characterized by regularity and standardization (Hitchcock & Johnson 1966). They offered definitions related to the five points used by Le Corbusier as a basis for defining a new architecture. Rooted in Europe and transferred to and further developed in the United States, modern architecture later in the twentieth century was defined by scholars such as Kenneth Frampton, David Handlin, and William Curtis by principles close to those proposed by Hitchcock and Johnson (Wright 2008). A tendency to use simple rectangular volume (instead of mass) articulated by crisply cut openings, regularity, avoidance of architectural decoration, flat roofs, an open floor plan, and a free façade are the main characteristics.

In documenting examples of mid-twentieth-century architecture in U.S. college towns, the authors discovered that many of these houses, including those designed by William Hajjar in State College, PA, do not seem to fully fit in the existing mainstream categories of the period inasmuch as his houses are not built according to popular mid-century ranch, split-level, shed, or minimal traditional styles. Nor do they feature the characteristics or shapes of modern
architecture such as flat roofs, ribbon windows, or free facades, as first identified by Hitchcock and Johnson (1932) and later by other scholars such as Frampton and Curtis. Furthermore, these houses do not conform to traditional American styles such as colonial, revival, or Victorian styles. Instead, many simultaneously reflect traditional American styles together with forms associated with modernist ideologies, showing forms/shapes and rules associated with both. For example, some houses boast sloped roofs, partially open plans, large windows, and traditional balloon frames with local stone, wood, or brick cladding, and horizontal organizations in split-level arrangements.

To verify and describe the influences of modernism/Bauhaus internationalism on the work of Hajjar in State College, PA, this study offers an investigation of the faculty-practitioner's hybrid architecture by comparing and contrasting it with Gropius’s architecture, with a focus on single-family houses produced by the Gropius-Breuer partnership in the United States. Via computational design methodology, this comparison will provide information to serve as a basis for determining the nature of Hajjar’s single-family architectural language including by verifying and describing the influence of Gropius-Breuer’s architectural language.

1.0 NOTION OF HYBRIDITY

The notion of hybridity between modern architecture and traditional architecture, or the duality between modern and traditional, international and local, and designed and vernacular in architectural practice has already been addressed in the literature. Frampton (1983) drew on Alexander Tzonis’s “critical regionalism” in this context. Whereas the postmodern era’s modernism/International Style was criticized for its placelessness, critical regionalism was an approach to architecture that offered the possibility of both countering that placelessness and rejecting the whimsical ornamentation of postmodern architecture. With this duality in mind and in search of a definition of popular architecture—specifically in modern architecture—Devlin and Nasar (1989) conducted extensive research to compare “high style” versus “popular” architecture produced in the second half of the twentieth century. Later, Fernando Lara (2008) explored how modern architecture became popular in Brazil by borrowing local elements. The idea of “vernacular modernism” was also explored by scholars such as Maiken Umbach and Bernd Huppauf (2005), and more recently by Anthony King (2016). If critical regionalism calls for architects to use elements from local and vernacular architecture, vernacular modernism calls for elements of high modern architecture to be incorporated into local-vernacular architecture. However, Hajjar’s hybrid architecture, constitutes a mixture of both of these, thereby constituting one way to bridge modernist and popular architecture. In this paper two important questions centering on this duality/hybridity are explored: Can computational design methods verify this hybridity? Is shape grammar as a computational design methodology an accurate and adequate method for analyzing the ways in which architecture might reflect elements from multiple traditions?

2.0 METHODOLOGY

This paper is part of a larger research project that includes five steps: (1) tracing Hajjar’s life and practice to identify likely influences on his work; (2) developing a shape grammar for the houses he designed in State College; (3) identifying or developing grammars for some of his likely influences; (4) comparing Hajjar’s grammar to the grammars of such influences to determine the nature and extent of their impact on his work; and (5) identifying aspects of the social and technological context that may explain such influences—i.e., trends in regard to lifestyle and availability of materials and technologies. Whereas a previous paper (Hadighi & Duarte 2018) described Hajjar’s single-family architecture by developing a grammar of his work, the focus of the current paper is on highlighting hybridity in his architecture and on exploring the use of shape grammar as a computational methodology to analyze and design hybrid architecture. Future papers will focus on further methodological steps related to the notion of hybridity.

2.1. Shape Grammar

The history of shape grammars goes back to the early 1970s when Stiny and Gips (1972) published their first paper illustrating shape grammars for the original language of paintings.
Shape grammars in computation are defined as a class of production systems based on an initial shape (or a set of finite shapes) and transformational rules that can be applied to the original shape recursively (Stiny & Gips 1971). Based on the numbers and sequence of rules that can be applied to an initial shape, the grammar can produce an unlimited number of solutions. Since the 1970s, as a design computation method, the concept of shape grammar has been used in architectural analysis when a pattern in design characteristics or a stylistic repetition of shapes in architecture is evident. This method has been used to analyze examples of historical architecture, such as the Palladian Villas by Stiny & Mitchell (1978), Frank Lloyd Wright’s Prairie houses by Koning and Elzenenberg (1981), Bungalow houses by Downing & Flemming (1981), Queen Anne houses by Flemming (1987), and Alvaro Siza’s houses at Malagueira by Duarte (2005). More recently, shape grammar has been used in the production of a variety of designs especially within the idea of mass customization. An example is the generation of mass customized housing units in Malagueira, Portugal, based on Siza’s housing style (Duarte 2005). Given that Hajjar’s work, the present study’s focus, shows some evidence of shapes and transformation rules shared with multiple architectural traditions, the shape grammar methodology is appropriate for testing the hypothesis. For example, many of the houses designed by William Hajjar can be considered in reference to shapes and rules as follows: a wing (i.e., a garage), connected through a breezeway (the connector, usually the main entrance) to the main volume. This main volume in his early work is a simple shoe box, which regardless of size (short or long) and orientation (parallel with or perpendicular to the main road), usually has a low-pitched roof. The main volume sometimes comprises two stories: the bottom story is usually the main living area (living room, dining room, and kitchen), and the top story is usually the sleeping area. Depending on the orientation and slope of the site, the bottom story may be a garage whereas the main living spaces may be located in the wing, the latter of which consists of one or two stories.

3.0 A. WILLIAM HAJJAR

Abraham William Hajjar (1917-2000) was born on February 11, 1917, in Lawrence, MA, the youngest of a large immigrant Lebanese family. He initially pursued a career with the family business of grocery store. However, in 1936, he left the business to enroll at the Carnegie Institute of Technology (now Carnegie Mellon), graduating in 1940 with a professional architecture degree. For his graduate studies, he attended MIT, graduating with a master’s degree in 1941 (Hadighi et al. 2016). After graduation, he moved to Washington State to join the Department of Architecture at the State College of Washington in 1941. Five years later, he joined the Department of Architecture at the Pennsylvania State University (the Pennsylvania State College at the time) in State College, PA. While Hajjar was at Carnegie, the school’s pedagogical philosophy of design was dominated by the Beaux-Arts, similar to most of the architecture programs in the country. Yet, at Carnegie Tech in the late 1930s, some young faculty members assigned to teach freshman and sophomore studios leaned toward a modernist philosophy of design. Walter Gropius, founder of the Bauhaus School and one of the pioneering masters of modern architecture, was invited to deliver a lecture on March 11, 1938, when Hajjar was a sophomore. This was probably, the first interaction between Hajjar and Gropius.

When Hajjar attended MIT for his graduate studies in architecture, he became more familiar with modernism through proponents of modernism, such as his advisor, Lawrence Anderson. Anderson not only designed the first modernist building on an American campus (MIT Alumni Pool-1939), but he also tried to bring a modern outlook to MIT’s program in the late 1930s. Also, he advocated for Alvaro Aalto’s appointment as a research professor in architecture at the school in 1940. It is worth noting, too, that Aalto’s work, in addition to Jorn Utzon’s, was an example of the critical regionalism approach discussed by Frampton (1983). More importantly, it is likely that Hajjar was influenced by modernist ideas propagated by the German émigrés: He was at MIT when Gropius and Breuer were at Harvard, a time when students from the two schools attended lectures together and when Anderson would often invite Gropius, Breuer, and other outside critics to MIT to review the students’ work (Anderson 1992).
When Hajjar moved to State College with his family, he bought a house in an area close to the campus. The house was a simple traditional two-story building in the Georgian revival style with a four-square plan (Figure 2). To be different, and to make it easier for his family to recognize the house from other similar houses of the area, as he mentioned to his son, he painted the street face of the house in white—a design element that expresses his philosophy of improving traditional American architecture with integrating it with modern ideas/elements. In 1951–1952, after he had been at Penn State for a few years, he designed and built a house for his family, his first house in the area. At the time, most single-family residences in the area were in the Georgian revival, Colonial revival, Tudor, and Cape Cod styles, although ranch and split-level houses were also starting to appear. Hajjar’s first family house represents his main idea of volumetric design and interior planning: the house consists of a simple shoe box and a garage connected to the main house via a breezeway. From the exterior, Hajjar’s house is similar to other houses that had already been built in the area, especially given its cement blocks for the base, the wood cladding for the top part, and the sloped roof. However, there is no front porch and no entrance in the front façade. In fact, the front façade seems to be a side façade when compared to those of other houses in the area. Additionally, whereas most of the local Colonial revival houses in the area had a garage at the back of the building, the organization of the house is rotated in Hajjar’s design such that the garage appears at the front and the main entrance to the house is hidden in the breezeway. Many of these features appear in Hajjar’s later designs in the area.
Hajjar designed and built thirty-two single-family houses in State College, mostly in two neighborhoods close to the Penn State campus. Many of his houses blend into the traditional houses in the neighborhood in terms of exterior building materials, volume, and roof shape. However, Hajjar’s houses have an internal organizational structure that is both modern for the time and unique to his work. In the new College Heights neighborhood, located at the northwest side of the campus, most of the houses Hajjar designed are located on sloped sites. Taking advantage of the slope, he situated the entryway between the two main levels of the houses—a feature that can be read as an adaptation of the mid-century split-level effect. As explained in a previous paper by the authors (2018), there are similarities between Hajjar’s architecture and mid-century split-level houses, especially in terms of the section and façade. However, there are definitive differences in regard to the interior planning, the organization of the fenestration, and the slope of the roof. Hajjar’s interior planning leans toward the modernist open plan concept, especially in the public part of the house (living room, dining room, kitchen). There is also a clear division between the public part of the house where day-time activities take place, and the private part of the house where night-time and personal activities take place (bedrooms, bathrooms, and private living area). Typical mid-century split-level houses were organized so that the living room faced the street, whereas Hajjar’s designs are open with the kitchen facing the street and the living room at the back of the house.

In the plans, the entryway to Hajjar’s houses is on the main floor through the breezeway and generally in the middle open space, which could include a hall and a family/sitting room on the private floor. Hajjar’s typical plan can be read as a modern plan with an open space in the center, rooms organized on both sides, and service spaces, including the bathroom, staircase, and hallway, in the middle. However, it can also be read as a very traditional plan as used in the Georgian period and the Georgian Revival, i.e., a developed hall-parlor organization, or as a developed four-square design, similar to the plan of the first house Hajjar bought in the area.

Another typical mid-century plan that appears to have exerted an influence on Hajjar’s work, or at least on some of his designs, is the U-shape plan used in ranch-style houses (Figure 3). Hajjar kept the U-shape geometry with a garage, or a covered porch in some cases, attached to one wing. Although the geometry is the same, Hajjar’s spatial organization is more modern in comparison to the traditional plans: one wing for private activities/bedroom section, and the other wing for public/daytime activities, such as the living room and dining room, with service spaces in the center (Figure 4).
In general, given the spatial relationships in Hajjar’s houses, it is possible to identify five subtypes of floorplans (Figure 4): (1) tri-partite organization, where a breezeway connects the garage to the inhabitable space, the lower floor hosts the living areas, and the upper floor the sleeping area; (2) split-level organization, where the sleeping area is a half floor above the living area; (3) butterfly, where a cross-shape or U-shape organization prevails; (4) compact organization, where a square-shaped plan reflects Hajjar’s idea of a core area; and (5) linear organization, where two square-shaped plans forms a rectangular/linear plan.

Figure 5: Subtypes of Hajjar’s single-family houses in State College, PA.

3.1. Hajjar’s Hybrid Grammar

A detailed account of the development of a grammar for Hajjar’s single-family houses can be found in a previous paper by the authors (2018). However, in brief, the grammar was
developed based on the five subtypes described above. Figure 6 shows selected rules of the grammar. The grammar encompasses four phases or groups of rules:

1) Rules that capture the way in which Hajjar situated his houses on the lots (Rules 1 and 2);
2) Rules that describe the formal relationships between mass volumes (Rules 3–5);
3) Rules that describe the way in which the interior space is divided into smaller rooms or spaces (Rules 6–29); and
4) Rules that generate details such as the placement of closets and wall thickness.

The grammar can produce plans of all the houses designed by Hajjar in the State College area, and also new house plans based on Hajjar’s design philosophy, what we call Hajjar-inspired houses. Figure 7 shows solutions produced by the grammar, including plans of houses designed by Hajjar and a Hajjar-inspired plan.

Figure 6: Selected rules of Hajjar’s grammar.
Figure 7: From left to right: Euwema House, Ferrell House, Christ-Janer House, as well as a Hajjar-inspired house, all generated by the grammar.

Figure 8: Selected rules of Gropius-Breuer grammar.
As noted earlier, through his academic training at MIT, Hajjar learned about European modernist/Bauhaus principles from his advisor, Lawrence Anderson, and more importantly through the influence of Gropius and Breuer—all of which are evident in the houses he designed in the State College area. Using shape grammar, the authors compare Hajjar’s architecture in the State College area with single-family houses designed by the Gropius–Breuer partnership in the United States. In order to describe these influences through shape grammars, a grammar of Hajjar’s work should be compared with one of Gropius and Breuer’s work. A detailed account of the development of a grammar for single-family houses designed by the Gropius-Breuer partnership in the United States will be explored in a separate paper. Figure 8, however, shows selected rules of the Gropius-Breuer grammar. In brief, the grammar was developed with the same strategy as that used for the grammar of Hajjar’s work. In general, to compare grammars, they should be developed in the same way at the same level of detail. When this is the case, it is easiest to compare the grammars by determining which rules are adapted, deleted, changed, or added.

A comparison of the two grammars shows the rules that Hajjar borrowed or adapted from the grammar of Gropius–Breuer. There are two ways to test similarities between the rules of the two grammars: (1) compare step by step the derivation of a house designed by the Gropius–Breuer partnership and the derivation of a house by Hajjar, and (2) produce a Gropius–Breuer house through the grammar of Hajjar’s work and compare it with the original design.

Figure 10 shows a comparison of a step-by-step derivation of the James Ford House designed by the Gropius–Breuer partnership in 1939 and the Higdon Residence designed by Hajjar in 1955 (Figure 9). Higdon house is one of the few houses designed by Hajjar with a linear organization and a division between daytime and nighttime activities such that each is assigned to its own floor. It is also possible to produce the James Ford House using the Hajjar grammar. However, the part projected out that expands the dining area is unique to Gropius–Breuer design.

Figure 9: James Ford House designed by Gropius-Breuer in 1939 (left) and the Higdon Residence designed by Hajjar in 1955 (right).
4.0 DISCUSSION: FUTURE OF ARCHITECTURAL HYBRIDITY

As noted earlier, this paper is part of a larger study undertaken with the purpose of analyzing Hajjar’s hybrid single-family architecture by developing a grammar of his work and comparing and contrasting its shape rules with those of works of modernist and traditional American architecture. The proposed study will concentrate on using shape grammar to verify and describe the notion of hybridity in architecture by using Hajjar’s single-family houses in the...
Penn State area as a case study. Comparing the grammar of Hajjar’s work with the grammar of the Gropius—Breuer partnership’s work in the United States verifies that shape grammar as a computational design methodology can be a useful and effective method for verifying and describing such influences and, therefore, for identifying hybridity in architectural design. In fact, the authors with other scholars are collaborating on using this same method to analyze hybridity in mid-twentieth century architecture in another part of the world.

Since the postmodern era, many scholars have advocated for architectural hybridity, or as Frampton described it, critical regionalism, to promote a local adaptation of European modernism as an approach to counter the placelessness of European modernism. Being keeping with those who are looking for such a response, a grammar that can produce hybrid architecture would be an effective instrument for professionals in the building industry in an era in which the industry is seeking greater efficiency in producing higher-quality housing.

As part of the larger study, a computer program has been developed to produce Hajjar-inspired houses based on the grammar developed for his work in the State College area. The aim of developing the computer program was to facilitate the generation of designs and to eliminate human input while applying rules to generate houses. However, the program can be used to produce new hybrid designs based on Hajjar’s design philosophy. An appropriate future use of this computer program would be to further develop the program to mass-customize hybrid and efficient single-family houses. The authors of this paper, collaborating with other scholars, are in fact in the process of further developing Hajjar’s grammar and the associated computer program to help the building industry in the state of Pennsylvania to produce energy-efficient, low-cost, high-quality, customized single-family houses.

5.0 CONTRIBUTION
The proposed study will make a contribution to the field of architecture not only by presenting shape grammar as a tool for verifying and describing hybridity between modern and traditional architecture, but also by describing the work of Hajjar, a local architect who contributed to the stability and popularity of modern architecture in the United States. Further, it is our hope that the study will show the potential of shape grammar as a complementary tool that architectural historians can use to verify formal and functional similarities between styles in a rigorous way.

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REFERENCES
*Nexus Network Journal* 13, no. 1, 49-71.

Resistance.” In *The Anti-Aesthetic: Essays on Postmodern Culture*, edited by Hal 
Foster, 16-30. Seattle: Bay Press.

Hadighi, Mahyar, and Jose Duarte. 2018. “Adopting Moderns Architecture to a Local Context: 
A Grammar for Hajjar’s Hybrid Domestic Architecture.” *Proceedings of the eCAADe 2018: 
Computing for a Better Tomorrow*, Lodz, Poland, 515-524.

Hadighi, Mahyar, Ute Poerschke, Henry Pisciotta, Laurin Goad, David Goldberg, and Moses 
Hajjar.” *Proceedings of the Façade Tectonics World Congress*, Los Angeles, CA, 
473-482.

Norton & Company, Inc. Originally published under the title *The International Style: 
Architecture Since 1922*, Copyright 1932 by W.W. Norton & Company.

Vernacular Architecture.” In *Writing the Global City: Globalisation, Postcolonialism 

Planning B: Planning and Design* 10, 2, 155-177.

Houses.” *Environment and Planning B* 8, 295–323.

to Trace Alberti’s Influence on Portuguese Classical Architecture.” *Nexus Network 
Journal* 13, no. 1, 171-182.


Knopf.

An Intersection: water in Louis Kahn’s landscape

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ABSTRACT: This interlocutory research examines American Modernist architect Louis Kahn’s (1901-1974) works through the lens of landscape design. This research emphasizes the materiality and design instrumentally of water in Kahn’s designs that have significant landscape work and explores the reverberating relationship between architecture and landscape. From the late 1950s to his death in 1974, Khan produced his most important works, which include: the Salk Institute for Biological Studies (1959-65) in La Jolla, California; the Kimbell Art Museum (1966-72) in Fort Worth, Texas; and the National Assembly Building Complex (1962-83) in Dhaka, Bangladesh. All of these selected works with major waterscapes have been heavily influential in the architectural world. The key questions that the paper explores are: How does the water (waterscape) act as an intersection? What role does water play? How is water a cultural connector? These questions are explored via interviews, conversations, empirical and spatial studies of the selected sites, and archival scholarship that includes study of existing drawings and literature. This paper looks at water primarily as an intersectional element that not only acts as the interface of architecture and landscape, but also helps in creation of “contact zones” and a controlled topographic catalyst. Use of water also creates a link between the East and the West, the local and the global, colonial and native, Islamic and non-Islamic, as well as the seen and unseen, expanding to the perception of real and unreal. Holistically, my research creates a bridge between the larger discourse of different cultures, theory, and a cross practice of disciplines.

Key Words: Water, intersect (tional), Contact Zone, Topography, Landscape and Architecture.

INTRODUCTION
As much as landscape is a way of seeing, it is also a physical embodiment that is instigated by visual and other sensory mechanisms (Mitchell 2002). This interlocutory research examines American Modernist architect Louis Kahn’s (1901-1974) works through the lens of landscape design. It focuses on Kahn’s use of water and waterscape that does not operate in isolation but creates a visual and sensory, and ultimately a physical, embodiment that catalyzes the audience in engaging and imbibing in his designed built-environment. Landscape, which derives from the Greek verb Scopein, also means to “instrument for viewing.” Therefore, built-environment becomes a stage for viewing, where the users simultaneously are the actors. Distinctively known for his mastery with forms, Kahn’s designed landscapes are an integral part of architecture that has received only a little attention (architecture studies include Scully 1962;; Brownlee 1992; Brownlee and De Long 1997; Carter 2005). From the late 1950s to his death in 1974, Kahn implemented water and waterscapes in his most significant works: the Salk Institute for Biological Studies (1959-65) in La Jolla, California; the Kimbell Art Museum (1966-72) in Fort Worth, Texas; and the National Assembly Building Complex (1962-83) in Dhaka, Bangladesh. All of these projects have water as the kernel landscape element. The two key questions that this paper explores are: How does water in Kahn’s design act as a topographic material? How is water a cultural connector creating Kahn’s “contact zone” of different cultures and perhaps asymmetric power? Historian Kazi Khaleed Ashraf, in his essay titled “Taking Place: Landscape in the Architecture of Louis Kahn” (2007), departs from traditional form-driven architectural analysis to analyze Kahn’s approach to landscape. This paper takes Ashraf’s essay as a departure point, but also heavily relies on David Leatherbarrow’s Topographical Stories: Studies in Landscape and Architecture (2003). The research method includes interviews, talks, historical research from documentaries, videos,
and literature, empirical observations of the selected sites, archival research, and readings of existing drawings for further investigations. Robert Twombly writes that Kahn’s primary importance was the past and innate characteristics of material, color, water, light, and nature (Twombly 2003, 10). This paper examines a genealogy of Kahn’s topographical stance that through spatial use, materiality, and constructed design of water becomes the hinge between past and present. Water here is an intersectional landscape vis-à-vis topographical element that connects the East and the West; the local and the global; and acts as a link between the larger discourse of culture, theory, and practice. Consequently, these designs turn Kahn’s works into cultural contact zones. Holistically this paper views the term “intersectionality” from multiple perspectives and ultimately creates a thread between theory and praxis.

Water is a topographical element. The Oxford English Dictionary defines topography as the “arrangement of the natural and artificial physical features of an area.” Typically, the word topography means place description or physical configuration of a site. For the intention of landscape studies, the definition is more akin to what geographers call surface relief (Norberg-Schulz 1980). It situates both the landscape and the architecture in a space, creating a more complex and meaningful place. Historian David Leatherbarrow sees architecture and landscape as topographical arts. He writes: 

The task of landscape architecture and architecture, as topographical arts, is to provide the prosaic patterns of our lives with durable dimension and beautiful expression. (Leatherbarrow 2004, 1)

He further writes:

Topography gives to landscapes and buildings a kind of sense that differs from that conferred upon them through the intentions, controls and expectations of design and construction, a kind of sense like that of an event: engaging, intrinsic, and more often than not startling. (Leatherbarrow 2004, 256)

Leatherbarrow brings forth the relationship that has historically been seen between landscape and architecture, which were either distinctive or the same. He also brings forth a third option, which says that they are neither different nor alike, but simply similar to each other. Ashraf takes this relationship even further and offers a fourth possibility that

Architecture (as built work) is inscrutably intertwined with landscape, irrespective of whether they appear or are made to appear, distinctive or not, an interdependence or in-betweenness between two objective entities, that I describe as “landscape event.” The intertwining is continuous and unpredictable play of the various natural and constructed dynamics, and that is how a building yields to the environing world, and shared latency “rises to the visible” to make an event. (Ashraf 2007, 48)

Following Leatherbarrow, Ashraf claims, “Architecture is inherently a landscape event” (Ashraf 2007, 48). What, then, is the role of water as a topographical element that brings forth architecture as a “landscape event”? The following section will discuss several projects to explore the question, how is water as a landscape event related as a similar, dissimilar, entwined element or extension?

1.0 WATER AS A SURFACE RELIEF: SALK INSTITUTE, LA JOLLA, CALIFORNIA

Johannes Salk (1914–1995), an American medical researcher and virologist, was the founder of the Salk Institute for Biological Research. Salk credited Kahn for defining the shape of the site of the institute, which was considered the most beautiful property left in La Jolla that time. He universalizes the institute, turning it into a contact zone. According to Salk, Kahn’s designed master plan wrapped around the coastal canyon whose geometric peculiarities Salk compared with “cerebral convolutions” (Brownlee and De Long 1992, 330). According to Brownlee and De Long, Salk’s expectation from Kahn was a recombination of science and humanities to mend the rift between the “two cultures” (Brownlee and De Long 1992, 139). Kahn’s translation of Salk’s thoughts therefore coincided and was congruent with his own idea of “measurable” and “immeasurable.” Salk’s vision collapsed into Kahn’s design philosophy as a singular thought. These dualities also connect with the qualitative and quantitative, tangible and intangible phenomena of place and space. While architecture is quantitative and often designed with numbers and pragmatic issues, landscape remains as the qualitative part. According to Christian Norberg-Schultz, place is assigned with qualitative phenomena, and
architecture as an “event” of landscape takes place as a qualitative phenomenon. “Taking place” is usually understood in a quantitative way, and that is architecture (Norberg-Schulz 1980, 7) explicitly taking form in the spaces of the Salk Institute.

An image search of the Salk Institute on the internet or in books immediately tells us about its most popular space (Fig. 1). For as much as there are groves, gardens, and lawns at Salk, its main plaza area is the foremost spatial-piece that grabs the attention of visitors and users. There is a water channel running through this travertine plaza towards the westward infinity as if cutting through the cliffs and the canyon reaching towards the Pacific Ocean and sky. This thin water channel bisects the plaza. With lines of poplar trees, Kahn had a very specific central arcaded garden idea in his mind for this plaza (Brownlee and De Long 1997). The garden idea, however, was changed by another architect. Mexican architect Luis Barragan collaborated with him and offered his simple yet majestic ideas. He annulled Kahn’s previous garden scheme of lined trees and suggested, “there should be no garden”; rather, “it should be a plaza,” which was to become the “façade to the sky” (Wiseman 2007, 128, 130.) According to Barragan:

Lou [Louis Kahn] was thinking…and stated a very important thing—that the surface is a façade that rises to the sky and unites the two as if everything else has been hollowed out. The texture of the travertine plaza closely resembles the fair-faced concrete of the buildings. For this unity of materiality, Kahn’s architecture of Salk almost seems to be sculpted out from the topography just like a deep “surface relief.” The surface, like plastic, almost molds out from the ground, creating an architectural form that rises above.

While Barragan suggested a plain plaza, it was Kahn’s idea to insert a narrow channel of water running down the middle of the plaza to reduce its harshness (Wiseman 2007, 128–129). The narrow controlled stream cascades to a sculptural cistern at the western end through a water pond. This system of water channel, pools, and cisterns opened Kahn’s idea of “architecture of water,” where the water system lies in between the two laboratory buildings of Salk (Brownlee and De Long 1991, 332). This gesture was an isolation of nature or control of nature. “Architecture is what nature cannot make,” Kahn preached at Yale (Brownlee and De Long 1997, 150).

Nature cannot make anything that man makes. Man takes nature—the means of making a thing—and isolates its laws. (Kahn 1965, 305)

The thin slit of water trickles down the middle on the concrete plaza towards the infinite landscape of the Pacific and the sky. This situates the complex more to the site-context and makes the Salk Institute a part of the Pacific. Vision is thus also controlled to situate ourselves in a perceptual infinity. A visual sensation infiltrates into a conceptualized spatial and physical containment that is regulated by Kahn’s constructed landscape. Water becomes a device for a creating connection between sight and space, creating what Elizabeth Kreider-Reid calls a “visual vocabulary of perception,” where the users instantaneously learn to use vision to understand the space (Harris and Ruggles, 2007, 8).

This aspect of a channel of trickling water, which is primarily visual, transforms into more holistic sensations of sound, beauty, and the imagery of an infinite line to the sky. These qualitative aspects are present, diluting the quantitative measures of pure architecture and forms. The users from the laboratories and study rooms of the building, who were intended to enjoy the previously envisioned garden, now enjoy the plaza with the water channel, the pools, the cliff, and the Pacific.

Islamic landscape culture is rich with examples of such visual experience. Historians mention that Kahn was inspired by the water channels and fountains in Islamic architecture such as those of the medieval palace-city Alhambra, in Granada, the capital of Al-Andalus (present-day Spain) that was designed to spill over and irrigate the gardens (Wiseman 2007). The Nasrid Sultans (1230–1482) built the Alhambra palace complex, in fact, on a similar topography; it was atop a highland overlooking Granada. The oratories of these highland palaces gave opportunity for the sultans and elite members to have their view towards the lower areas and garden (Ruggles 2008). This “gaze” feature is a predominant phenomenon of Islamic architecture, which brings a possibility of an equal analogy to the Salk design concept.
where each laboratory building allows a gaze towards the central plaza and the Pacific, towards infinity.

Live gardens with water acquired the religious concept of Islamic paradise more at a later phase, particularly developed and predominantly observed in Mughal tomb architecture (Mughal era: 1526–1856) and associated with paradise gardens in India, which Kahn was familiar with. As per Quran, water is clearly an important element of Islam. It is often instrumentalized in Islamic architecture and landscape, symbolizing purity, landscape of heaven, of abundance and therefore richness. This is particularly so as Islam is a religion that germinated in an arid landscape area (Saudi Arabia) in the sixth century. Mughal tombs were set on Chahar-bagh, which had water channels similar to that of the Salk Institute (Ruggles 2008). With Kahn's concurrent work being executed in South Asia at that time, Kahn already had experience with Mughal garden architecture and landscape. These Mughal landscape experiences may have been influential for him and been the decisive factor for bringing the water channel at Salk. The channel closely resembles Mughal water systems, which were used for cooling, aesthetics pleasure, and irrigation purposes. This is also indicative of Kahn's predisposition to spiritual spaces, which we commonly see in religious institutions and edifices. It indicates and coincides with Kahn's intension of making Salk a monastic space.

With the implication of the water channel in Salk, Kahn essentially transpired an existential content of the site. Here, water dematerializes concrete, which becomes part of the landscape, just as a continuation of the sky. The complex becomes a microcosm in essence also turns into contact zone where two oppositional cultures meet and blends. In Salk, he “dematerializes the physical and finally touches the psyche” (interview of B. V. Doshi in Blackwood 1995). The view of the Salk Institute changes not only with seasonal and diurnal patterns; the slit of water also captures the reflection of the sky, which becomes the surface of Salk's plaza. Perhaps this was what he intended when Barragan said it was to be “the façade of the sky,” thereby conceding and intertwining with nature's rhythm and order. In this way, architecture also becomes a topographical art perpetually dependent on time. Architecture as a landscape event yields to the world and environment around; it becomes nature's narrative and ontological condition. Following Merleau-Ponty's conception of the “lived-body,” Ashraf considers this phenomenon as “lived-architecture,” where he conceptualizes architecture as an animate being. He elaborates:

In living, the body not only lives itself but also lives the environment, making the body what I would like to describe as landscaped subject. (Ashraf 2007, 51)

So, building becomes a landscape subject where users are invited to look and think beyond. Conversely, the landscape around becomes an extension of architecture. In fact, a building is a landscape. Architecture dissolves with users' experience. In Merleau-Ponty's words, it is “reciprocal insertion and intertwining…the limits of one is lost in the other” (quoted in Gallagher 1986, 165). The water channel creates an emblem of tranquility in architectural quality enhanced by water in the symmetrical vistas overlooking the Pacific.
With this design of the water-system, Kahn created an infinity that correlated with the distinctive quality of landscape, “extension” (Norberg-Schulz 1980, 32). This extension can be of different spatial properties and character and therefore depends on their very design and articulation. According to Norberg-Schulz, a flat plain surface is “general and infinite.” In Salk, the flat plaza’s water channel connects the complex to the infinite. Through the interaction of concrete surface and water, it creates a totality of space, which is a totality of the context. Variation of surface relief only fits to the different totality of sites.

Here, architecture becomes what Ashraf brings forth, a part and extension of the open area and landscape. It is neither separate nor the same, but only a part of the landscape is inscrutably intertwined with architecture. The water in Salk also recreates the space-extenuated natural qualities of the place, thereby granting the design its pertinence to “genius loci.” While the entity of waterscape is instrumental in creating the genius loci of Salk, Kahn’s waterscape can be seen through a similar or perhaps dissimilar lens in other projects. The design philosophy and use of water also situates Kahn’s design beyond the boundary of La Jolla or California, evocative of a design trajectory that comes from the East and particularly, in this case, the Islamic world. This sets Kahn and his design as a harbinger of cultural efficacy connecting the East and the West and, more specifically, the Muslim and non-Muslim worlds, modern and tradition and, consequently, the slit of water as an intersectional element. While Islamic Spain and Mughal India already represented paradigms of successful melting pots of different ethnicities, races, and religions, the Salk landscape became a palimpsest of multi-religious mingling, or perhaps a secular platform, as if those cultural ties from the past guide the modern landscape of the present. This establishes an essence of cultural osmosis and continuation. This is the concept of the translocality of space, where this particular design phenomenon exists in more than two spaces. Subsequently, this also brings the concept of chronotope, where time and space collapse into an element of the past used in modern language and support Kahn’s work being “timeless.” So where does the water idea come from? Is it of the East or of the West?

2.0 LANDSCAPE OF DECEPTION: KIMBELL ART MUSEUM, FORT WORTH, TEXAS

In the Kimbell Art Museum, the water is placed, not in the center, but at the side of the building. While natural light is the prime focus of the museum, which creates elegant spaces perfectly suited for displaying art, the aspect of water and green is no less important. To this end, gardens and landscaped areas have been introduced both outside and inside the museum. Particularly on the north and south sides leading to the western side entrance, which leads one to the main gallery level, there are gardens and groves of trees. Yet accessing the museum on foot compels a visitor to experience the two water bodies, which are almost symmetrically positioned on the western side, creating a Roman pristineness for the museum. Kahn designed the museum in a way that the experience can be gained on foot in a very indirect way. According to Wendy Lesser, Kahn designed it in such a way that one is unable to get in easily or see it without experiencing the constructed landscape environment; one has to see and hear the trickling water and walk on the gravel, imbibing and engaging through a process of preparation prior to entrance to the museum. According to Lesser, the Kimbell’s seeming straightforwardness is rather deceptive (Lesser n.d.). The trickling water, in addition to visual pleasure, offers one a transitional experience prior to entering the museum (Lesser 2017). The water also changes its rhythm: the water here cascades like a waterfall to a level down. This not only creates sound but also changes the view depending on the time of day and the changing sky colors. Hence, water is used as an opening experience to the gallery space, which again creates architecture as an animate being.

This landscape design of the nine-acre museum was done with a major contribution from Harriet Pattison, who worked for Philadelphia architect George Patton. She took the lead role of landscape design. The landscaped area has different level changes, as if the ground planes created with its level changes create a site-relief. Therefore, the landscape here creates a canvas for the museum. Harriet Pattison herself claims her contribution by saying
I soon took exception to Lou’s imposing plinth and eased his building into the site, persuading him to incorporate the paired porches at the garden entrance. In my mind, they were, “Kahn ambulatories,” an alternative way to experience his building. The ambiguous middle that tied the museum to nature and lent same dignity to live forms that sculpture had within. (quoted in Wiseman 2007, 226–227)

About her choice of traditional landscape elements, she further says:

I chose groves of trees and water—reflecting, tumbling, purling—to temper the climate, animate a featureless site, and attract the public. (quoted in Wiseman 2007, 227) With these elements: the garden then water, trees and then plinth, created a transition from the garden settling easing the building of galleries. In her mind, Pattison called these transitions, “Kahn Ambulatories,” an alternative way to experience Kahn’s building. (Wiseman 2007, 227)

Though not visually connected to the gallery spaces, the water bodies are experientially connected. They create a contiguity with inside and outside. The museum building itself is not isolated, but a part of the larger landscape palate. Nature expands beyond physicality. Looking at the plan (Fig.), we can also see the proportion of water, which is almost the same as the width of the repeated vaults. The waterscape emulates the longitudinal entity of the vaults and takes up another module of the same, which inherently justifies Ashraf’s observation on architecture as inscrutably intertwined with landscape, making Kimbell evidently an “event” of the surrounding landscape. The water becomes a transitional platform to the museum. On this record, Curtis also relates the water to Dhaka’s Assembly Building Complex, which creates a citadel atmosphere on a much smaller scale, where the citadel is devoted to culture and not the government (Wiseman 2007, 230–231). The water seems like a moat, as in the Dhaka Complex.

3.0 WATER AS IDENTITY: NATIONAL ASSEMBLY BUILDING COMPLEX, DHAKA, BANGLADESH

Dhaka’s Assembly Building Complex in Bangladesh is arguably Louis Kahn’s magnum opus of architecture that constructs the nation’s identity. Regardless of the programmatic differences, here too, his citadel idea is consistent and creates a continuum to his previous works. Kahn envisioned the National Assembly Building Complex both as a “Citadel of Assembly” and as a “Citadel of Institution of Man.” The Assembly retained its supremacy as the “Citadel of Institution” in the composition, set in the center as a crowning element among surrounding buildings, lakes, gardens, and plazas, and thus an emblem of Bengali identity, which is analogous with the symbolic use of water.

The Assembly Building Complex, as it exists today, is in the center of Dhaka city. The city is positioned at the confluence of two major rivers, the Buriganga and the Shitalakha, while the country itself is formed by the lower reaches of the Ganges (locally known as Padma River) and the Brahmaputra. Dhaka is centrally located on higher land. Dhaka's regional location meets with central rivers: the Meghna, the Brahmaputra, the Lakhya, and the Dhaleswari (Fig.), so Dhaka as the city and holistically the country has long roots and cultural ties to water. According to Kahn:

The two elements of nature most pervasive in the landscape of East Pakistan
(Bangladesh) are water and vegetation. They almost assert their presence. The examples of intelligent cooperation with these pervasive elements of water and vegetation in some of the best examples of Mughal Garden architecture has been great inspiration to me. (Ashraf and Haque 2002, 15–16)

However, as the Complex spanned two independence movements, Kahn had to work on meeting both Islamic value—which was the core reason for the Partition (1947), to have Pakistan as an Islamic country—and, on the other hand, Bangladesh as East Pakistan as a part of larger Bengal, which was already a fusion of sensibilities, including but not restricted to Sufi (unorthodox Islamic) and Hindu influences.vi Henry Wilcot, Kahn’s project manager for this project, cynically thinks it was perhaps a satirical response to West Pakistan, which was rather an arid land without water (author’s interview of Henry Wilcot, March 6, 2019).

To many historians, Kahn’s work in Dhaka with red and white contrast and water setting relates to its Mughal past.vii Therefore water, vegetation and the sculpting of horizontal plane became key premises for the architecture of Sherebanglanagar. (Ashraf and Haque 2002, 16)

They describe this gesture of water-based planning as “an image of a visionary Bengali City” (Ashraf and Haque 2002, 44) which today is a symbol of victory against and independence from Pakistan. viii Ashraf and Haque argue that the complete landscape of the Assembly Complex indicates a possible relation of the natural landscape of Bengal, meaning not just land and water but also how the culture is intertwined with it. The mere size and depth of water also allow small boats within, simulating the rural landscape of Bangladesh. Therefore, it’s not clear but seems plausible that, while designing the complex, Kahn was influenced and inspired by the region’s deltaic landscape and its longstanding influence on the culture, for which water is featured prominently in this design. His dexterity with water also seems to have evolved with significant confidence from the previous projects.

In this complex, the Assembly building itself appears to float on a constructed, moat-like lake. The other key buildings are placed by this artificial lake, thereby granting the entire site a sense of dynamic interplay with the lake and surrounding landscape. The lake takes a crescent form opposite the North Plaza area and is called “Crescent Lake,” which is often misinterpreted as an Islamic symbol, which was not Kahn’s intention. Accompanying the focus on water, there are other elements of the design that Kahn intended as nationally symbolic: the immense lawn, the basic geometric shapes, the gardens, and the open plazas. The water body is a major element of the complex landscape form which has taken a huge place in Bangladesh’s national identity, and which was much needed in that political paradigm.

Kahn initially got the aerial view of Bangladesh, which was primarily covered with water. He also visited Bangladesh in 1963 for the first time and experienced Dhaka from waterways on the Buriganga. Kahn’s early sketches of the Complex show a fascination with the deltaic landscape, as Ashraf and Haque iterate (Ashraf and Haque 36). Kahn asserted that in Bangladesh, one needs to think of “an architecture of the land” (Ashraf and Haque 2002, 36). According to Ashraf and Haque, he saw molding of the earth as the process of “dig and mound,” and “something that involves an excavation of the ground” that would “create an earth to provide both platforms and proto architectural shapes” (Ashraf and Haque 2002, 15). Like the rural huts in Bengal that are built on mounds, the Assembly Building was also built on a mound that was created with soil from the excavation of the artificial lake surrounding it (Ali 2006). For others, this is just atypical Kahn, who uses landscape elements like temporal form (author’s Interview of Shamsul Wares, Louis Kahn expert, Dhaka, Bangladesh. January 2019). However, it is now immensely crucial in the creation of a national identity of Bangladesh. However, Identity is a loaded word, particularly in the case of Bangladesh, which went through multiple rulers and paradigm shifts which historians often fail to notice. Therefore, the word identity demands acute probing on what it means. With the water as an essential element of rural Bangladesh, it creates identity. Its edge and relation to the built form also need exploration. There are several kinds of relation of the elevated Assembly Complex to water. One of them is the ghat.
The ghat as a cultural symbol fits perfectly in the semantic discourse for dissecting the Assembly Building Complex. The water encodes the cues of Bengali riverine imagery and cultural values, which are decoded by the people of Bangladesh. The water edge condition and ghats on the South Plaza side of the lake are monumental, creating a smooth interface between water and the red-brick plaza. The predominant river edge landscape itself is Zaminder Villas and Bagan baris (garden houses). According to Swati Chattopadhyay, these Bagan-Baris derived their architectural characteristics locally and were also overlaid with British aesthetic prerogative. With the designed gardens, the new landscape also bore resemblance to the pastoral and picturesque English landscape. For the British, these were more a pastiche of the past, fulfilling the nostalgia of the European colonizers (Chattopadhyay 2007). These villas evolved during the British colonial era and with time became a part of Bangladesh’s heritage and constructed identity (See, Hobsbawm and Ranger, 1-14). It also creates an asymmetric visual connection with the centered and more privileged Assembly building, which is elevated higher than the ghats’ plane and the rest of the complex, creating a power-space relation and affirming Michel Foucault and Michel de Certau’s teachings that institutions govern our modes of seeing and produce a subjectivity (Foucault 1984).

The edge of the water also has a low height wall around the lake, which helps people to sit and enjoy the ambiance. The centrally located Assembly Building acts as a focus and prime background without direct palpable connection with the water and indirect visual connection to the building, which sets the users of the Assembly Complex more visually empowered being in the higher level.

The border of the water landscape has a slanted edge (like a dam, which is also evident in Kahn’s Indian Institute of Management in Ahmedabad and water edge of many colonial buildings including Victoria Memorial of Kolkata) but doesn’t halt there. Kahn made a porous façade or large openings through which the water is seen and therefore visually gets connected, which Adnan Morshed calls “Urban Windows,” which work on a much larger scale (interview of Adnan Zillur Morshed in Tagore 2018). Ashraf writes that when Kahn makes those gigantic perforations, those cavernous spaces of shadows, he is surreptitiously “landscaping” the building (Ashraf 2007, 56). These openings are a landscape continuum where landscape enter visually and experientially inside the architecture. However, the Assembly being on the higher elevation further establishes the separatist relation of the colonizers and the native/vernacular, making it a semi-democratic place. However, both these emblematic forms—the colonial landscape and the citadel—allude to the bourgeois culture or societal elite position which acutely resembles upper-class and a non-democratic symbol, further questioning its democratic stature that Thorsten Botz-Bornstein (2016) has already questioned (he also relates Kahn’s work to Nordic architecture). However, perhaps the colonial relation is so deeply ingrained, that with water and the ghat it becomes a Bengali normative and essentially symbolic of Bengal’s landscape. Therefore, while the Complex is a national monument and may allude to the colonial power structure, it is accepted as a national monument precisely because of its effective association with the people (Rappaport 1990, 39). Yet, the Complex becomes a contact zone which is evocative of ancient Roman ruins, Medieval water castles, Mughal tombs, and British colonial landscape to the Bengali vernacular, leaving its meaning to the mind of the interpreters.

CONCLUSION
In Kahn’s words, “Architecture has to have the element of time.” He further notes, “Teak will fade away, but the spirituality will remain” (Khan 2003). Water is the element through which Kahn consistently merges his inherent coexisting binaries of poetic with inherent rationality, mystic sensibility with objective intentions and the new with the old (Louis 2017). But what is implicit in these examples is that these three sites become contact zones of different cultures, including apparent binary cultures like the East and the West, Islamic and non-Islamic, colonial and vernacular merely by the materiality and design instrumentality of water. These landscape act as contact zones, forming a modernist landscape where these become spaces in which opposite cultures meet, clash and grapple with each other, often in contexts of highly asymmetrical relations of power. The unique capacity of Kahn is to blend the past and the
present and the ancient with the modern, classical with contemporary sensibilities in connection to universal power and perceptual strata (Louis 2017). Filmmaker Sundaram Tagore, obsessed with Kahn’s work in Dhaka, says that they are futurist and ancient at the same time (Tagore 2018). Consequently, it is difficult to situate Kahn in any stylistic classification of modernism, classical, post-modernist, regionalist or critical-regionalist or transcultural. With his dexterity of material and unconventional universality and permissible multiple readings, they fall under many genres and no particular genre at the same time. Kahn unites the world with a single building in one a single site that becomes a sub-world creating a contact zone of past and present, traditional and modern, and East and West which constantly grappling with their very presence

REFERENCES
ANTi-History in design research: New applications and interpretations

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ABSTRACT: In the postcolonial era, contemporary poststructuralist paradigm shift has provided alternative views of the past as well, especially in terms of new interpretations of regional histories and understanding of cultural contexts. One fairly novel strategy in this respect is ANTi-History, which is an approach to the study of the past drawing on the actor-network theory (ANT). The objective is to offer diverse readings of the largely Euro-America centralized history writing by revealing accounts that have earlier been overlooked. Contrary to the negative connotation of ‘anti’, ANTi-History does not, however, negate the significance of history, but aims to pluralize historical narratives. The view is based on Foucauldian poststructuralism and comprehension of the present as it relates to the past. In other words, ANTi-History focuses on the present, while seeking alternate connotations and (de)constructions of past events, particularly in relation to sociopolitical actants and actions. This links ANTi-History to the concept of Applied History, according to which present-day problems can be solved by knowledge of the past. As to design research, substitute readings of history are particularly relevant in the postcolonial contexts, in which ‘place making’ as part of re-creating regional identities is the main concern and further related to Critical Regionalism. Hence, this paper examines the interrelationship between ANTi-History, Critical Regionalism, and decolonialization within the discourse on the design of built environment. To clarify ANTi-History as a theoretical framework in architectural research, a single-case study on the Jean-Marie Tjibaou Cultural Centre in New Caledonia is given as an example, in order to offer new interpretations of its architecture and design actions in one postcolonial context. Consequently, the paper argues that applications of this paradigm to precedent studies both in the education of architecture and in the practice-based research can be pertinent in the future praxis.

KEYWORDS: Actor-Network Theory, Applied History, Critical Regionalism, Transculturalism, Jean-Marie Tjibaou Cultural Centre

INTRODUCTION

Within the poststructuralist paradigm shift in the 1980s appeared many alternative theoretical agendas, such as the Actor-Network Theory (ANT) focusing on new interpretations and analyses of actions in various networks. Simultaneously appeared alternative ways of interpreting the past as well, based on Foucauldian discourse on the references to the past in order to comprehend the present, accompanied by the call for non-Euro-America-centralized worldviews. Among the many new trends evolved ANTi-History which aims to provide more pluralistic readings of history, especially in terms of regional histories and understanding of cultural contexts from the perspective of power relationships within various sub-groups of these sociopolitical networks, which is particularly relevant in postcolonial settings. As that has recently been the focus of Critical Regionalism, or more broadly that of interpreting transcultural architecture, too, we examine the interrelationship of the latter to ANTi-History as it relates to Applied History.

In order to regard ANTi-History as a methodological framework, it is necessary to briefly look at the Actor-Network Theory from which it stems and, in turn, is closely related to the sociology of science and knowledge as well as Science and Technology Studies (STS). This alone is a challenging task, as ANT has been subjected to criticism, controversies, misinterpretations
and deviations over a few decades, ever since it was established as a term by Bruno Latour, Michel Callon, and John Law in the early 1980s. Indeed, Latour himself has later stated that there “are four difficulties of the actor-network theory, that is the words ‘actor’, ‘network’ and ‘theory’ – without forgetting the hyphen” (Latour 1999, 15). Some even argue that ANT is not a theory at all (e.g., Feenberg 2002). Nevertheless, this paper maintains that the approach of ANT has potential in design research due to its aptitude of interpreting simultaneous actions that take place in any process, in any network. To put it very short, ANT deals with complex relationships of and associations between both human and non-human actants, to use Latour’s terminology, that are the source of an action. This is reminiscent of design processes which involve various sets of decisions within the complex parameters of a project brief and its actants, resulting in the ensuing design actions. It is important to note, however, that ANT as an analytical method is not an end itself, but instead a way to understand the workings of an expanding network. From the perspective of ANTi-History in design research, it is sufficient to say that it can thereby expand our comprehension of contemporary architecture by providing new interpretations of the past events and actions in analyzing architectural processes.

Another challenge is that ANT has rarely been applied to architectural research. In this respect, the work of Albena Yaneva is especially relevant because she has used ANT in analyzing design (e.g., Yaneva 2005, 2008, 2009a). Of particular interest is The Making of a Building: a pragmatist approach to architecture, which investigates the design of the extension for the Whitney Museum of American Art in New York City by the Office of Metropolitan Architecture (OMA) of Rem Koolhaas. Yaneva’s analyses of this interactive network/s of human and non-human actants are based on extensive and intensive contact with the OMA team throughout the design development in 2001-4, including observations on the role of model making, concept sketching, collective discussions, personal connections, changes in design, and so forth, with the goal of understanding the dynamic process of generating the evolving design proposal (which was never built). Although space limitations of this paper do not allow delving into the many aspects of Yaneva’s study, which resulted in a book of over two hundred pages, it serves as an inspiring precedent of ANT regarding the methodology of architectural research in the constructivist paradigm, even with its certain weaknesses in interpreting the consequences of the design solutions in architectural practice in general (see, e.g., Champy 2012).

As Yaneva puts it: “The ANT presumes that there is a basic uncertainty regarding the very nature of action, groups, objects and facts, to the extent that in order to produce an ‘explanation of …’ the researcher cannot rely on mobilizing pre-established definitions” (Yaneva 2009b, 14). This is exactly what Latour has emphasized in terms of a priori assumptions characterizing conventional scientific research, in addition to the limitations of the Cartesian division of object and subject, as opposing to the significance of a posteriori definitions in ANT (Latour 1999). There also are certain similarities to the phenomenological ‘thick descriptions’ defying the dualism of subject-object position and stressing the importance of subjective experiences in creating meanings. Accordingly, Yaneva goes on stating that the “term of ‘mediator’ points to the fact that a variety of non-humans take active part in design in the course of action that is overtaken by other agencies, this being the main postulate of ANT” and continues that in so doing a “mediator can transform, translate, distort, and modify meanings […] and] constitute, recreate and modify the social relationships established by design” (Yaneva 2009b, 118), which is discussed in this paper from three perspectives: ANTi-History, Critical Regionalism, and decolonialization.

1.0 PAST VS. PRESENT

1.1. ANTi-History
ANTi-History is grounded in ANT, but it focuses on interpretations of historical events and records by extending from ANT, postructuralism, and the sociology of science and knowledge, in order to make sense of the past and its impact on the present. This applies especially to power relationships within a specific sociopolitical network, for instance, one identified by gender, ethnic, cultural, or other backgrounds, which are actants that have often been
underrepresented in Euro-America centralized history writing. Gabrielle Durepos and Albert J. Mills, who are considered the initiators of this fairly new approach to history studies, state that ANTi-History “developed out of an interest in how knowledge, particularly historical knowledge, comes into being and influences human action” (Durepos and Mills 2010, 27). They further elaborate that it “is rooted in the concerns of Foucauldian poststructuralism to understand the ways in which the present is constructed through reference to past events, that is, that history can be seen as a study of the present rather than that of the past” (Ibid., my emphasis). In other words, the aim of ANTi-History is to trace the sociopolitical actants and actions, the networks in which those cohere, and how that forms our contemporary knowledge. In doing so, the intention is certainly not to just ‘objectively’ represent the past, or to replace existing histories either, but to reveal, deconstruct, and/or reassemble factors that have earlier been marginalized, hidden, overlooked, denigrated, or suppressed within a context in question:

In this process, histories are revealed as useful guides to human action at the same time that they are reassembled for current action rather than grounded in fact. Hence the term ANTi-History, which draws on the signifier of ANT to signal a link with actor-network theory and that suggest the tension between the simultaneous construction and destabilization of history projects (Ibid.).

Their point, then, leads to the concept of Applied History, according to which present-day problems can be solved by knowledge of the past. There are obvious similarities when comparing the principles of ANTi-History and Applied History, since the aim of the latter is to comprehend past events in order to ‘solve’ current problems. However, as those problems in most instances of a design process are the so-called wicked problems that have no definite or singular ‘solutions’, we do need additional analytical frameworks, such as ANT or ANTi-History, due to the ambiguity and multiplicity of the actants and actions in architectural research. In this respect, and relevant to Critical Regionalism and decolonization, it is significant, according to Durepos and Mills, that “in this way, people can become aware of the sociopolitical role of history and its significance in the creation and privileging of identities” (Mills and Durepos 2010, 27). Furthermore, as case studies are an integral part of design research (see, e.g., Sarvimäki 2017), as well as that of ANT – and ANTi-History by extension – it, even in “its infancy”, as described by Durepos and Mills, can offer additional means of interpretation in “pluralizing of historical accounts that recognizes and celebrates the problematic nature of history and its link to knowledge, power, and identity”, which “involves the careful development of story-telling that serves to tell a tale without telling the tale” (Ibid., 28). For that reason, it is essential to discuss context-specific features of architectural design and research, before proceeding to the narrative and a tale of the case study on the Marie-Tjibaou Cultural Centre in the second section of this paper.

1.2. Critical regionalism

Given that Critical Regionalism as a term was established in the early 1980s, too, as part of the poststructuralist paradigm shift, it has certain connections to ANT, in addition to the wider postmodern discourse of the time. Well, if ANT is controversial, so is Critical Regionalism. Without going to the many assessments and disagreements regarding this contemporary view on regionalism, introduction of Critical Regionalism did plausibly expand architectural discourse beyond the confines of the purist ideology of modernist architecture, which by the mid-twentieth century had evolved into the International Style that largely disregarded concerns about the context of a building (though this is a generalization for which space does not allow discussion here). Also, it brought into light criticism on the Euro-America centered world views, specifically in terms of decolonial, feminist and other emancipatory interpretations of architecture (see especially Eggener 2002, and Waisman 1994).

Although the term Critical Regionalism was introduced by Alexander Tzonis and Liane Lefaivre already in 1981 (Tzonis and Lefaivre 1981), was further popularized by Kenneth Frampton in several publications (e.g., Frampton 1983a, 1983b, 1987), and became considered somewhat obsolete during the following decades, recently it seems to have gained momentum, specifically in the context of the developing world and the former colonies (see, e.g., Tzonis and Lefaivre 2001, 2003, 2011). Thus, the concept of Critical Regionalism is still prevalent and perhaps even more prominent than before, due to the conflict between current globalization
and international interventions, including global practice of architecture, and the simultaneous search for local identity, which, in many cases, has led to the desire for ethnic insularity – the latter being particularly apparent in the design actions of the Jean-Marie Tjibaou Cultural Centre.

Keith L. Eggener was one of the first scholars who started to critique Critical Regionalism, especially Frampton’s definition of it as a form of resistance, as well as the Euro-America centralized analyses which “on more than one occasion led to an interpretative flattening of diverse cultural materials, and a misunderstanding or devaluation of their founding intentions and most immediate meanings” (Eggener 2002, 233). By quoting Jane M. Jacobs, he goes even as far as describing critical regionalist rhetoric as “a revisionary form of imperialist nostalgia that defines the colonized as always engaged in conscious work against the ‘core’” (Jacobs 1996, 14-15, quoted in Eggener 2002, 234). In this article ‘Placing Resistance: A Critique of Critical Regionalism’, he points out that:

If so-called critical regionalist designs exemplified an “architecture of resistance,” it is ironic that writers discussing the places where these designs appeared so often emphasized one architect's interpretation of the region over all others: Tadao Ando for Japan, Oscar Niemeyer for Brazil, Charles Correa for India, and Luis Barragán for Mexico. [Elsewhere in the article he also lists Jorn Utzon for Denmark, Mario Botta for Ticinese Switzerland, J. A. Coderch for Catalonia, Alvaro Siza for Portugal, Gino Valle for Italy, and Dimitris and Susana Antonakakis for Greece.] In other words, a single correct regional style was implied, or imposed, sometimes from inside, more often from outside “the region” (Eggener 2002, 229, 230).

From the perspective of decolonialization, this is a pertinent point, particularly in terms of the center-periphery thinking, which according to Eggener implies that “No matter how vital, the peripheral is other than, deviant from, and lesser than the center, the norm” (Ibid., 232). In making his point, Eggener refers to Latin America in order to elucidate the meaning of Critical Regionalism from the viewpoint of Argentine Marina Waisman, according to whom “the Latin American version is quite different from that proposed by Kenneth Frampton, or Alexander Tzonis and Liane Lefaivre” (Waisman 1994, 32-33). She goes on stating that the Latin American culture, as part of “the general movement of history”, is a “unification of the spirit of times and the spirit of place” and, hence, Latin American contemporary architecture should be “understood as a movement of divergence rather than resistance (the term which Frampton prefers)” (Ibid.). Thus, this paper looks at regionalism specifically from transcultural perspective.

In rather recent Transcultural Architecture: The Limits and Opportunities of Critical Regionalism, Thorsten Botz-Bornstein continues the discourse and compatibly regards critical regionalism as a subcategory of transculturalism by analyzing various designs in some non-Western contexts: the Sief Palace Complex by Raili and Reima Pietilä in Kuwait City, Kuwait, the National Assembly Complex by Louis Kahn in Dhaka, Bangladesh, a few projects by Wang Shu in China, and those of H-Sang Seung in South Korea, in addition to the impact of the Wahhabism policy on architecture in Saudi Arabia. He also discusses Alvar Aalto’s and Ludwig Wittgenstein’s approaches to design as those relate to Tadao Ando’s architecture in Japan. (There is a chapter on the Alabama Rural Studio in the United States as well, not directly relevant to this paper’s perspective on decolonialization, though relevant to Critical Regionalism in architectural education overall.) Regarding the contexts of Kuwait, China, Korea, and Saudi Arabia, Botz-Bornstein states that “Eggener’s (as well as Marina Waisman’s) idea that regionalism is not always a response to the West but more often a consequence of local conditions can well be integrated into my defense of Critical Regionalism as a form of transculturalism” (Botz-Bornstein 2015, 3). He goes on arguing that “Transculturalism is more than the arbitrary combination of several cultures but transcends all particular cultures in order to invent a new common culture that is not meant to be new universalism” (Ibid., 37). In addition:

Transculturalism is not necessarily critical while Critical Regionalism is. Vice versa, all Critical Regionalism is transcultural because it overcomes one culture by critically reflecting it against another culture. As a matter of fact, most of the time, Critical Regionalism has not been seen as a coming to terms with two cultures but rather as coming to terms with the past and the present […] and it is important to specify differences
in order to distinguish transculturalism from multiculturalism and other strategies destined to synthesize different cultural elements (Ibid., 37-38).

Thus, questions remain: What are the actants of regional and/or national identities and how, if at all, should they be represented? What are the roles of local constituencies and international politics in this network? And to which extent interpretations of the past articulates architecture today? At least as partial answers to these questions, the following single-case study on the Jean-Marie Tjibaou Cultural Centre designed by Renzo Piano Workshop close to Nouméa, the capital of New Caledonia, aims to clarify the intricacies at hand by shedding light on the possibilities of applying the theoretical frameworks of both ANTI-History and Critical Regionalism to one decolonializing nation in the Asia-Pacific context. In contrast to the aforementioned study on the design process of an unbuilt project at OMA, which employed the principles of ANT, the goal of the below case study is, instead, to apply the principles of ANTI-History to an 'as built' analysis.

2.0 LOCAL VS. GLOBAL

2.1. Context of New Caledonia

Amongst the plethora of former colonies in the Asia-Pacific region, New Caledonia has somewhat different standing. To make a long story short, the islands have been inhabited at least since the 1600s BCE, were 'discovered' by James Cook in 1774 CE, became a French colony in 1853, served as a penitentiary from the 1860s until 1897, housed an important base of the Allied Forces during WW II, were declared an overseas territory of France in 1946, were considered for partial independence in the 1984 ‘Status Lemoine’, and gained a special status (statut particulier) in 1999, which started the gradual transfer of power from the French state to New Caledonia as a ‘unique collectivity’ of France. Throughout these stages, there were numerous uprisings and movements against French colonialization, of which those in the 1970-80s were led by indigenous independence fighter, Jean-Marie Tjibaou, midst other separatists. The Matignon Accords in 1988, after the Ouvéa tragedy in April of the same year, stabilized the precarious political situation in New Caledonia for a decade, followed by the 1998 Nouméa Accord, consistent with which a referendum on independence was to be held in 15-20 years; the election took place in November 2018, with the result of 56 percent of voters rejecting independence (e.g., Shineberg and Foster 2018).

Like usually (if not always), financial interests were the primary drivers of colonialization of New Caledonia as well. In this occurrence, the discovery of nickel in 1864 started the prosperous mining business on the islands, after trade in sandalwood had declined. Hence, overseas migrant workers were actively recruited as labor for the mines, which partially contributed to the ethnic multiplicity. Still today the economy of New Caledonia relies heavily on nickel mining, in addition to subsidies from France, alongside service industry, agriculture and other less contributing fields (Ibid.). It is worth noting that “in the mid-1980s, New Caledonia ranked third in world nickel reserves and production, after Canada and the USSR” (Taylor 1997, 28). Since this also is when many New Caledonian independence movements were crashed, and considerable political compromises were made, it is not difficult to see the connections between financial and political goals.

The French politics in the 1980s were marked by societal, cultural and economic reforms, which were launched by President Francois Mitterrand during his exceptionally long presidential term from 1981 till 1995. Among these, the Grand Travaux, or ‘Major Projects’ program, was most significant architecturally speaking (also called grands projets présidentiels, ‘presidential grand projects’). The cultural and ethnic dimensions of these policies were reflected by such building projects as the Institute of Arab World by Jean Nouvel in Paris, France (1981-87), and the Jean-Marie Tjibaou Cultural Centre by Renzo Piano close to Nouméa, New Caledonia (1991-98); the latter is discussed below from the perspective of the cultural, social, political and financial actants and actions of its design network. In ‘Putting Architecture in its Social Place: A Cultural Political Economy of Architecture’, for instance, Paul Jones argues that in certain circumstances external forces, such as political interests, can
condition architecture and its design outcomes, as architecture always is political and connected with social order, particularly in imagining a new world order. He points out, referring to Frampton, that architecture is the least autonomous of the cultural agents and illustrates the role of easily recognizable iconic buildings designed by high-profile “starchitects” as a strategy of “place-marketing” in “political-economic contexts” (Jones 2009). Regarding architecture of the Jean-Marie Tjibaou Cultural Centre, Kylie Message correspondingly contends that the project was directly linked with the Matignon Accords, in the attempt of the French government to appease social and ethnic tension and to ensure its economically important presence in New Caledonia (Message 2006), in which acknowledgement of local identity was a significant asset. Hence, we must ask: What constitutes New Caledonian identity?

Due to historic migration waves from/to the other Pacific islands, and further primarily from Asia and Europe, New Caledonia has become highly diverse ethnically, culturally and socially. Its population is comprised of various groups of peoples, of whom the Kanaks are regarded as the indigenous New Caledonians. Then again, this is only a partial story of the ethnic fabric of postcolonial New Caledonia. Even among the Melanesians (including the Kanaks), who constitute approximately two-fifths of the population, there are several Polynesian minorities. Besides one-third of New Caledonians with European ancestry, who dominate the trades, businesses and high-ranking governmental posts, the rest includes descendants of mainly Indonesian and Vietnamese migrant workers. It is interesting to note that 13.6 percent of the respondents identified themselves as ‘other/undefined’ in this 2014 census. Along with French and Kanak that have special legal recognition, roughly 30 Melanesian languages are spoken in New Caledonia. As to religions, 54 percent of New Caledonians are adherents of the Roman Catholic Church, but there are also other Christian groups that constitute more than 30 percent of the population, in addition to 2.7 percent of Muslims and approximately 10 percent of ‘nonreligious’ or ‘other/undefined’ citizens. Also, the distribution of wealth and landownership is very unequal between the different ethnic groups: On average the income of Melanesian households is one-fourth of those with European ancestry, whereas two-thirds of the land is in the hands of the latter, even though few of them depend on agriculture and cattle raising like the Melanesians do, as described by Shineberg and Foster. The authors further point out that these “differing cultures have given rise to two distinct ways of life, known as kanak and caldoche; people of mixed descent tend to adhere to one or the other” (Shineberg and Foster 2018). While it is debatable whether people should be labeled according to their ethnicity and/or ancestry, the point here is that defining New Caledonian identity is challenging, to say the least, which also makes it difficult to analyze architecture meant to reflect its culture.

2.2. Jean-Marie Tjibaou Cultural Centre

As the last of Mitterrand’s Grand Travaux projects, an international architectural competition was organized in 1991 for a facility to endorse New Caledonian identity. Among the selected ten competitors, out of 170 who had expressed their interest, was Renzo Piano; possibly chosen to be one of the finalists because the French authorities were already familiar with him, owing to the competition-winning design for the Centre Georges Pompidou with Richard Rogers in 1977. Renzo Piano Building Workshop won the New Caledonian competition and the facility was named Jean-Marie Tjibaou Cultural Centre (below TCC for short), although originally it was to be Centre Culturel Kanak – one of the many compromises made under the political, social and racial pressures. It was named so to honor the Kanak leader of the independence movement who was assassinated on 4th of May in 1989 by another separatist accusing Tjibaou for not having been radical enough in the negotiations for independence. In the Matignon Accords, Tjibaou had, however, proposed the establishment of an agency, which became known as the Agence de Développement de la Culture Kanak (ADCK), to promote research and representation of Kanak heritage, identity, linguistic, handicrafts and arts. In a letter to the French Prime Minister, Michel Rocard, soon after the accords were signed, Tjibaou refers to the past 134 years of French control over the destiny of New Caledonia and states that France “cannot hide behind the role of arbiter. It is not judge but actor” (Waddell 2009, 176), which is elucidating wording from the perspective of ANT. Eric Waddell, referring to Alban Bensa who was the anthropologist involved in the TCC project, emphasizes its complex dual objective which, on the one hand, was to increase French influence in the Pacific and, on the
other, to restore “the flouted identity of a population that had been brutally colonized by the same France” (Bensa 2005, 34, quoted in Waddell 2009, 197).

For Piano, the politico-symbolic expectations of the project, developed in collaboration with ADCK after Tjibaou’s death, were inevitable, which is manifested in the many references to the design principles of TCC (among many, in Findley 2005, and most importantly by Piano himself already in 1997). In addition to those, Piano’s praised sustainable strategies, including natural ventilation achieved by orientation toward the direction of the prevailing trade winds and the use of louvers in the insulating double skin, are well documented in literature. Henceforth, TCC is here discussed solely from the perspective of ANTi-History. In this respect, it is worth noting that the guiding concept of the design is said to have been a Kanak hut with its tall, conical, thatched roof, which Piano, avoiding any literal and ‘kitsch’ interpretations, expressed in contemporary way by his signature ‘material lightness’ of the ten vertical, ribbed structures, called cases and made chiefly of laminated iroko wood and stainless steel. These display spaces, the tallest being over 200 meters high, added with the exterior gardens exhibiting native plants and a sunken amphitheater for communal gatherings, are positioned sideways along a covered allee on the leeward side, which relates to Kanak cosmology and creation mythology, according to Bensa. The layout with a winding trail leading to the entrance further reflects the local vernacular tradition and landscaping of indirect approach to a dwelling. Illuminating is Findley’s description of the Centre’s opening day when “non-Kanak visitors searched in confusion for the entrance, while Kanak visitors wandered calmly to it” (Findley 1998, 102).

Yet, there are divergent views on the architecture of TCC. From the ecological viewpoint, many critics have questioned the sustainability of choosing iroko wood as building material, since it was imported from Africa, even if there are local timbers available with rather similar qualities. In addition, the case structures are regarded as unsustainable because the members were prefabricated in France and transported to the other side of the world, leaving behind a considerable carbon footprint. Renzo Piano Building Workshop’s decision to open the cases above for ventilation also has been criticized because it did not allow placement of a central pole, which in the Pacific cultures has been the symbol of a leader and in this case its absence represents the lack of understanding the role of Tjibaou not only as an indigenous independence fighter, but also that of a son of a Kanak chief. Further, creating an iconic monumental building for an indigenous culture that didn’t traditionally adhere to the Western concept of ‘architecture’ is problematic (for more, see e.g., Thompson 2005 and its references), which corresponds to Jones’ point above of “place-marketing” – instead of place-making – by iconic buildings designed by “starchitects”, among whom Piano certainly belongs. Indeed, TCC has become the primary tourist attraction of New Caledonia, currently receiving more than 100,000 visitors annually according to the Centre’s official website. Moreover, the very notion of expressing Kanak identity by architecture designed by an Italian architect and financed by the former French colonial regime, certainly calls for more ANTi-historical re-readings regarding the power relations in the context of New Caledonia. This is even more significant due to the less discussed and sensitive issue of the ethnic diversity on the islands, in which discourse the architecture of TCC has even been seen to help preserving the colonial legacy and commodifying the indigenous, as argued by Mike Austin (2007).

Corresponding to what was mentioned earlier in relation to Critical Regionalism, the challenge of a multicultural setting becomes apparent in this case study, too. Accordingly, Message points out that TCC’s architecture has been a subject to debate in New Caledonia as well, where people think that it is “either too focused on Kanak culture” or “not Kanak enough” (Message 2006, 21). So, is TCC an example of transcultural and/or critical regionalist architecture? Based on the ethnic insularity described above, it clearly isn’t sufficiently critical to be regarded as the latter, while it undoubtedly transcends world cultures in coming to terms with the past and the present in the dialectic synthesis “between modernity and tradition, global and local, individual and community, tolerance and resistance” (Thompson 2005, 250), in line with the characteristics of transculturalism. By doing so, TCC has fulfilled Tjibaou’s vision of
not returning to a stagnant tradition, but to bring the Kanak culture to the contemporary discourse (Waddell 2008).

CONCLUSION
The aim of the above case study on the Jean-Marie Tjibaou Cultural Centre with ANTi-History as the theoretical framework is to show that, among the many possible actants of ANT, at least political, economic and socio-ethnic concerns were interconnected in this particular postcolonial context, which led to the design actions, later to various interpretations of its design, and so on, in this ever-expanding network of hybrid epistemological bases of architectural analyses. In terms of poststructural views of history as a study of the present, rather than that of the past, it also reveals the limitations of present-day oversimplifications of cultural and ethnic identity of a place, the much-discussed genius loci of the critical regionalist and phenomenological discourse. Among the many possible real-world applications, this methodical framework likewise appears as valuable means of ‘as built’ post-occupation evaluations (POE), which could be applied to practice-based research on the whole, within the wider umbrella of Applied History. Moreover, the lessons from a tale of TCC, without trying to tell the tale, therefore seem promising applications of ANTi-History to the education of architecture with precedent studies being an integral part of both design studios and history-theory subjects. This, in turn, would be pertinent in the future praxis when the upcoming architectural practitioners enter the profession with skills in critical thinking and design research.

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Because it was not possible to conduct actual fieldwork for this paper, including interviews or other qualitative data generation methods, which would have been ideal in a case study with focus on regionalism and interpretations from the perspective of ANTi-History, I am indebted to my former student, Sofia Zuccato. Born and raised in New Caledonia, she provided me with inspiration regarding the context and valuable insider views of the complex sociopolitical situation on the islands.

REFERENCES
Findley, L. 1998. ‘Piano Nobile – Pritzker Prize laureate Renzo Piano’s startling Tjibaou Cultural Centre merges local traditions with his signature technical innovations’, Architecture, 87 (10), 96-105.


ENDNOTES

1 Mary Louise Pratt introduced the phrase “Contact zone.” According to Pratt, this term refers to social spaces where cultures meet, clash and grapple with each other, often in contexts of highly asymmetrical relations of power, such as colonialism, slavery, or their aftermaths as they lived out in many parts of the world today. See Pratt (1991).

2 Louis Kahn was working on designing the Indian Institute of Management in Ahmedabad (started 1961) and Dhaka’s Assembly Complex (1962–63), hence he was already well traveled in South Asia. Through his travels he knew much about the Mughal landscape in South Asia.

3 “Kahn’s scheme for the Institute is spatially orchestrated in a similar way to a monastery: a secluded intellectual community” (Flederer 2019).
The term *genius loci* has a Roman root, which means protective spirit of the place. In Latin, the word *genius* comes from guardian deity or spirit that watches over each person's birth, incarnation, and talent.

The “chronotope” is how configurations of time and space are represented. It is primarily used in literature and philosophy. Russian literary scholar M. M. Bakhtin used it as a part of his literary work, which is derived from the Greek *time* and *space* and therefore, literally translated as “time-space.” See also Clifford (1997).

Clifford questions the concept of “culture” as a rooted body (grows, lives, dies and so on) and rather argues for routes (or travel) for cultural exchange mode.

Louis Khan has an essence of time in his work and often beyond any particular phase or paradigm and is “timeless”. For more see Kahn (2003).

Bengal: The people in Bengal speak a common language, Bangla/Bengali, which is formed from Sanskrit roots. The Bengali-speaking eastern region of India and Bangladesh together are called Bengal. Bengali is thus used both as noun and adjective. Prior to Bengal’s division-in 1905, it was one region of the Indian subcontinent sharing a common language and culture. After this division, East Bengal became Bangladesh, and part of the region was called West Bengal, which today falls in India.

Kahn’s design and construction work for this Assembly Complex spans two eras: one under Pakistan, and the second phase in post-1971 independent Bangladesh.

Note: The Assembly Complex project was given to Kahn in 1963, at a politically tumultuous time for Bangladesh. Dhaka was the capital of East Bengal, or then East Pakistan, under the Pakistani regime. Later in 1971, East Pakistan gained independence, renaming itself Bangladesh.
CULTURAL PRODUCTION
The right to the city in informal settlements: two case studies of post-disaster adaptation in Latin America

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ABSTRACT: Today small-towns in western Uruguay are facing challenges related to informal settlements development, intensification of industrial agriculture, and climate change. In the last decade, different strategic plans and policies carried out by governments at multiple levels have attempted to regularize and/or resettle informal settlements in different towns and cities. Despite governmental efforts, informal settlements continue to grow in areas that are at high environmental risk, and where social-spatial fragmentation has increased between the formal and informal fabric. Lefebvre’s concept “right to the city” is a response to social-spatial inequalities and it emphasizes the idea that disenfranchised communities have the right to occupy and transform urban space. Using Lefebvre’s “right to the city” and “the production of space”, this paper studies informal housing and informal settlements in two neighborhoods in a small-town in western Uruguay and how they adapt to climate change consequences. It reveals how local residents occupy and transform space in two informal neighborhoods to solve their housing needs and to access to resources and infrastructure after an extreme weather event. Based on two case studies, this article reveals spatial patterns of informal settlements, the relationship between formal and informal fabric, and the ways post-disaster informal settlements and environments are represented. Field-work was conducted in 2018 and methods included spatial mapping analysis, semi-structured interviews with key actors, participant observation, and analyses of secondary data. Findings suggest that top-down bureaucratic decision-making process during post-disaster reconstruction limited residents’ agency and their right to participate and transform the urbanization process and the places they inhabit. This decision-making process was guided by restricted representations of space determining whether or not residents would qualify for subsidized housing programs. This study aims to encourage communities to develop community-based initiatives that could allow them not only to anticipate and react to environmental stresses but to thrive in the long-term future.

KEYWORDS: informal settlements, post-disaster housing, spatial justice, decision-making process

INTRODUCTION

Informal settlement developments in Latin America started approximately in the 1950s as informal land occupations without any legal title and any service infrastructure. These settlements began to consolidate over the years by on-going self-help housing constructions and gradual development of basic services and infrastructure provided by local governments. Despite the settlement consolidation or regularization, the majority of the housing quality continues to be precarious due to low-quality and improvised use of building materials and construction deficiencies (P. M. Ward 2015, 4-7)

Informal settlements are areas that are more vulnerable and at higher risk of being impacted by climate change. Although some Latin American cities have developed plans for adaptation to climate change (Sánchez Rodríguez 2013), the majority of remote small towns and rural areas are vulnerable to extreme climate events due to lack of information, lack of official
emergency response protocols, and limited resources for mitigation and adaptation (Thompson 2016).

In Uruguay different strategic plans and policies carried out by governments at multiple levels have attempted to regularize and/or resettle the informal settlements in different towns and cities. However, these plans have not incorporated climate change adaptation strategies. Despite governmental efforts to improve housing conditions of vulnerable and disadvantaged communities, informal settlements continue to grow in areas that are at high environmental risk and where social-spatial fragmentation has increased between the formal and informal fabric. Since urban informality and climate change adaptations are major issues faced in urban and rural areas, it is critical to understand why and how planning efforts for informal settlements need to consider both housing needs and adaptations to climate change.

Dolores is a small-town located in Southwestern Uruguay with a population of 17,174 inhabitants (Instituto Nacional de Estadísticas 2011) and it primarily relies on agricultural production. In the last two decades, this region has shifted towards industrial agriculture production and agri-businesses. Currently, Dolores is facing challenges related to climate change, growth of industrial agriculture (Thompson 2014, 2016), and increasing social-spatial inequalities (DINOT and Intendencia de Soriano 2017).

A tornado categorized as F3 in the Fujita scale touched down in Dolores on April 15th of 2016 (Escala Dolores 2017). This extreme weather event severely impacted informal housing areas in the low-income neighborhoods Barrio Cadol and Barrio Los Altos. Post-disaster housing adaptations were developed by governmental institutions at local and national level, primarily to assist affected residents from these informal settlements.

This article uses a spatial justice approach to understand uneven development and post-disaster reconstruction process in areas that are at high environmental risk. In informal settlements, vulnerability and risk are intensified by non-climatic factors such as poverty and unequal access to resources and infrastructure.

Through the lens of Lefebvre’s “the right to the city” (1996), this article argues that asymmetric geographies can be challenged through community participation in the decision-making process and post-disaster housing adaptations. It studies how post-disaster environment is conceptualized, surveyed, and mapped. Thus, it exposes the power dynamics and post-disaster reconstruction actions guided by these “representations of space” (Lefebvre 1991). Finally, it discusses the challenges of subsidized post-disaster housing adaptions as a way for architecture and social scientists to reflect on environmental stresses.

1.0 SPATIAL (IN)JUSTICE IN INFORMAL SETTLEMENTS

1.1 The right to the city
In order to understand spatial justice implications in informal settlements post-disaster reconstruction process, it is important to analyze the relationship between social justice and urbanization processes and discuss the significance of spatial justice and the claim of right to the city as a way to challenge the current production of uneven development processes.

In the 1960s, Henry Lefebvre (1991) (1996) introduced the spatial dimension to social processes arguing that space embodies relationships of power and it is produced as an instrument of control and domination. Additionally, spatial injustice can be challenged by those who are negatively affected (Lefebvre 1996). Lefebvre’s right to the city highlights the right of local residents to access to urban resources, to occupy urban space and to transform it. The right to the city is not associated to the term “citizenship” that implies membership in specific nationality or ethnicity. In contrast, it empowers inhabitants of space, it is earned by experiencing everyday life in the urban space (Purcell 2002, 102). This highlights the inclusive characteristic of the right of the city, as a right that also belongs to marginalized and
disenfranchised communities. In this sense, the right to the city is beyond the idea of the urban condition, including small-towns, rural areas, and rural communities (Limonad and Monte-Mor 2015).

Harvey’s seminal work “Social Justice and the City” (1973) advocated for territorial distributive justice of economic resources to ensure the access to resources and urban infrastructure by the entire society (Harvey 1973, 14-15). Later, Smith (2008) highlighted the importance of addressing social inequalities by understanding uneven landscapes from multiple perspectives including natural, spatial, and social processes. Contemporary approaches to social justice and urbanization processes highlight holistic approaches including the spatial relationship of social and economic conditions (Connolly and Steil 2009, 34). Spatial justice theory argues that social and spatial inequalities created by unjust urbanizations and geographical uneven development, systematically oppress segments of the population reducing their well-being, their participation in social life, and their access to resources (Soja 2010, 71-79). Although participation in the decision-making process provides an opportunity to claim the right to the city, if they are not critically engaged and lack of inclusion, communities can experience barriers to participate in the decision-making process to claim their right to inhabit and transform space (McCann 2002, 78).

This paper uses Lefebvre’s “The Right to City” and “The Production of Space” as a theoretical framework to discuss the ways disenfranchised communities in informal settlements are included or excluded from decision-making process and subsidized housing recovery actions, limiting their right to participate and transform the urbanization process.

1.2 Informal settlements’ vulnerability, resilience, and adaptation to climate change

Informal settlements are produced by spatial injustices and are located in areas that are at high environmental risk, where the physical safety and health of its inhabitants is at risks on daily basis. As Mike Davis stated about informal settlers, “they are the pioneer settlers of swamps, floodplains, volcano slopes, unstable hillsides, rubbish mountains, chemical dumps, railroad sidings, and desert fringes” (Davis 2006, 121)

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the predisposition to be negatively impacted by climate change (Field 2014). Vulnerability involves risks and exposure to hazards, and lack of capacity to cope and adapt to climate change effects by moderating or avoiding harm. In addition, vulnerability and exposure are intensified by non-climatic factors produced by unequal development and multidimensional poverty (Field 2014, 39-40).

Resilience definitions can include both preparedness and reaction to severe weather events. In cases of extreme weather events or disturbances, reactive adaptation includes the capacity that communities have to rapidly restore basic services and infrastructure. Existing literature emphasizes the idea of transformative adaptation where communities are able to not just restore and repair their built environment but to transform it into better and more sustainable environment (Revi 2014, 548-549).

According to the IPCC, Latin America has been severely impacted by extreme weather events and one of its major challenges has been to reduce vulnerability and risks of exposure to climate hazards. Despite some countries’ efforts to mitigate risks from climate change, the region experiences several constrains due to lack of appropriate information, lack of capacity-building, and limited resources (Magrin 2014). There are few Latin American cities that have developed strategies, policies, and plans for adaptation to climate change (Sánchez Rodríguez 2013, 71). In countries with increasing inequalities, climate change and extreme weather events will increase poverty, and will exacerbate the existing inequalities deteriorating livelihoods and wellbeing of communities, preventing access to resources and food, intensifying social exclusion, and inhibiting efforts to alleviate poverty (Olsson 2014).
The Economic Commission for Latin America and the Caribbean, highlights the importance of access to information to enable capacity-building and strategies for climate change adaptation (Sánchez Rodríguez 2013, 17). In case of severe weather events, the lack of information and official protocols for preparedness and evacuation can extremely affect low-income communities and informal settlements.

The built environment and infrastructure, depending on their design, construction, and structural qualities, can enhance or prevent the capacity for anticipatory adaptation to reduce climate change impacts. Additionally, the lack of appropriate infrastructure such as good quality of roads can prevent access of emergency vehicles and timely evacuation, and residents can experience barriers to access to food, work, and health care, among others (Revilla 2014, 558-559)

2.0 METHODOLOGY
This study includes data collected during fieldwork in Uruguay during June and July of 2018. Purposive snowball sampling was used to identify major actors involved in local decisions. During fieldwork, 14 participants were interviewed, with diverse roles and views on community matters. Using a semi-structured questionnaire, participants were asked about post-disaster short-term and long-term effects. They were asked about post-disaster emergency actions, long-term reconstruction plans, and how different actors were involved in decision-making processes.

Using Geographic Information Systems (GIS) and cross-referencing information from Relevamiento Emergencia Dolores (MVOTMA 2016), spatial analysis was conducted to identify spatial transformations including the tornado path and its impacts on informal housing areas and the built environment. This spatial analysis was triangulated to verify data obtained from interviews and observations done during fieldwork in June-July 2018. Secondary data included research materials, reports and presentations by non-governmental organizations (NGOs) and new laws and regulations from governmental institutions.

2.0 CASE STUDIES: BARRIO CADOL AND BARRIO LOS ALTOS

3.1 Informal housing under an extreme weather event
After a natural disaster, spatial inequalities can be intensified by the different pace of recovery, different pace of assistance, displacement, and involuntary resettlement (Tafti and Tomlinson 2018, 4).

On April 15th, 2016 the small-town Dolores located in Southwestern Uruguay was affected by a tornado categorized as F3 in the Fujita scale with winds between 250 km/h and 330 km/h (Escala Dolores 2017). Approximately, a third of the entire town was affected by the tornado. In its pathway from West to East, the tornado passed through different neighborhoods including low-income and informal housing areas in Barrio Cadol and Barrio Altos de Dolores (see Figure 1).

Barrio Cadol is located in the West part of the town next to an industrial agriculture storage and processing facility. This is a middle-income and low-income neighborhood with both formal and informal housing. Barrio Los Altos de Dolores is a new development located in the periphery in the East part of town where the majority of housing and land tenure is informal. Both Barrio Cadol and Barrio Los Altos presented informal housing areas with severe overcrowded living conditions, with cases of multiple families living in a single house and cases of multiple housing units built per site. Capacity to resist and adapt to extreme weather events in these low-income neighborhoods was limited due to pre-existing overcrowded housing conditions, precarious housing constructions using light roofing materials, and lack of safe structural building systems (Notes from fieldwork).
3.2 The production of space: post-disaster spatial representation

In this section we use Lefebvre's (1991) theory about “The Production of Space” as an analytical framework to understand the complex urbanization process where the production of physical space (spatial practice), the production of knowledge about space (representation of space), and the production of meanings of space (representational space) are interconnected (Schmid 2016, 27-41). When space is conceptualized, abstracted, and represented through maps and policies, it establishes a particular order becoming a tool for empowerment or domination (Lefebvre 1991, 229-291). Maps represent a specific view of the world and they have the ability to include or exclude physical realities and communities from the discourse (C. Jacob 1996) (Jacob and Dahl 2006).

Furthermore, a critical analysis of representations of space, maps and policies, can reveal privileged dynamics of power, ideas, and actions guided by these representations. This can be illustrated in the post-tornado reconstruction process in the Barrio Cadol and Barrio Los Altos in Dolores where an initial survey and mapping development guided the decision-making process regarding resource allocations and post-recovery reconstruction actions.

Post-disaster survey and maps were conducted to identify a dynamic spatial boundary of the affected urban area and to quantify the tornado damage (see figure 2). They were directed by the Intendencia (Municipal government) with support from national government agencies (Agency of Social Development (MIDES); Agency of Housing, Planning, and Environment (MVOTMA)) as well as local chapters of professional organizations (Uruguayan Association of Social Workers (ADASU) and the Uruguayan Association of Architects (SAU)). These representations of space, survey and maps were key instruments used by the government at municipal and national level to assess the physical impact of the tornado and to assign resources for reconstruction. A staff from the municipal government stated:

“We identify a percentage of the affected housing units...the level of housing damage...this allowed the allocation of financial resources from the national government...this allowed the Agency of Housing to hire a Development and construction company to start the housing reconstruction...” (Dolores - staff from the municipal government, June, 2018)

During the survey, an audit housing form was used to assess the level of damage of each housing unit. Three different categories were used to classify the level of damage: category (A) included buildings with roof damage and load-bearing structural damage; category (B) included buildings with roof damage, load-bearing structure damage, and partial damage of the interior and exterior walls; and category (C) included buildings with 100% damage of the roof and walls (see survey results in Table 1).
These survey and maps impacted the decision-making process during reconstruction, regularization, and resettlement of informal housing. Throughout the survey and mapping process, surveyors encounter several challenges due to the oversimplified and restricting nature of the housing audit form and the rating scale system to assess building damage. Thus, the representation tools, survey and mapping methods, had not been designed to be used in the specific context of informal housing. For example, surveyor found there were several housing units and several families living in one land parcel and the audit form did not allow to include that information. A staff from the municipal government stated:

"Another challenge that we had when we were assessing housing damages was that there were four or five families living in one land parcel, so it wasn’t reasonable to re-build in the same overcrowding conditions." (Dolores - staff from the municipal government, June, 2018)

Additionally, the post-disaster representations of space in Barrio Cadol and Barrio Los Altos guided a top-down bureaucratic decision-making process that privileged on-site reconstruction and created displacement of some residents. Since the post-disaster survey and maps represented the affected land parcels but not the different housing units within each parcel, residents with land tenure benefitted from on-site reconstruction. On the other hand, residents who did not own the land were occupying, and were resettled into the subsidized new social housing development “Complejo el Prado”, located in other area of the town.

3.3 The right to the city: post-disaster housing adaptations

In this section we highlight the need for clamming the right to the city as a way to challenge the power dynamics that produce uneven geographies. Claiming the right to the city through participation in the decision-making process could empower disenfranchised communities embracing their right to transform the spaces they inhabit. This section illustrates the different ways informal settlers’ right to the city was ignored limiting their agency and participation in the decision-making process in the post-disaster housing recovery actions.

Right after the tornado in 2016, an emergency shelter was improvised as a first response to accommodate the residents who had experienced substantial housing damage, especially from Barrio Cadol and Barrio Los Altos. After a week, residents from these neighborhoods were resettled in shipping container emergency homes provided by the MVOTMA. The initial survey and maps determined the placement of these emergency homes as well as the final housing reconstruction in-situ or in a resettled area. Depending on residents’ land tenure,
shipping container emergency homes were placed on residents' owned land or in public owned sites. The majority of these containers were placed in three municipal and public sites: two sites were owned by the municipality (one across the School 97 and another one in Prado Park), the third site was in the land of the elementary School 102. Residents lived in the shipping container emergency homes until their housing reconstruction was completed (in some cases, took more than one year). Housing reconstruction was subsidized by the Agency of Housing, Planning, and Environment (MVOTMA) and MEVIR. An elected official described: “MEVIR built around 60/70 homes... and a total of 180 new housing units were built by MEVIR and a private construction company hired by MVOTMA in land donated by the Intendencia.” (Dolores – elected official, June, 2018)

Like the emergency housing relief, there were different approaches to housing reconstruction depending on the residents’ land tenure. In-situ reconstruction was as done through self-help housing with building materials and technical advice provided by governmental institutions. This type of in-situ subsidized housing benefited residents that had land tenure in Barrio Cadol and Barrio Los Altos (see Figure 3). The majority of the residents from Barrio Cadol and Barrio Los Altos, who did not own the land and were occupying, were not resettled in their original neighborhoods. They slowly transitioned from the shipping container emergency homes and resettled in the subsidized social housing complex “Complejo el Prado” located in the North-Eastern part of the town. This resettlement created new challenges for the affected residents who had to adapt to a new life style in a multi-family housing environment with shared services and building policies.

Residents who qualified for subsidized housing relief programs and residents who did not qualify for those programs, were identified using the initial survey and maps. This presented another significant challenge for residents who did not qualify for subsidized housing programs and were not able to afford reconstruction of their homes. Two years after the tornado some residents were still struggling to adapt and reconstruct their damaged homes (see Figure 4). A staff from the municipal government stated: “The Housing Agency (MVOTMA) was the institution that determined which families would
benefit from subsidized housing (…) all the decisions were made using the survey. Using the survey, the MVOTMA determined who would qualify for subsidized housing and who would not qualify.” (Dolores - staff from the municipal government, June, 2018)

Figure 4: Damaged house, 2 years after the tornado. Source: (Authors, 2018)

Moreover, the post-disaster housing reconstruction process represented a challenge and controversy within and outside the community. There were major concerns about the appropriateness of time-consuming housing solutions in case of emergencies. A community member stated:

“There was big pressure from the community, the Housing Agency (MVOTMA) was not providing timely emergency solution because they said that they were conducting the survey to understand how they were going to help.” (Dolores – community member, June, 2018)

Community members criticized the top-down bureaucratic decision-making process during reconstruction, and the lack of flexibility to access to financial resources for housing reconstruction. A community member stated:

“For the families that did not qualify for subsidized housing, the government offered financial assistance through loans for housing reconstruction but this was a long bureaucratic process (…) so families did not receive their loans on a timely manner and had to endure a rainy and cold winter with damaged roofs and walls.” (Dolores – community member, June, 2018)

During the reconstruction process, community members and actors were concerned about the quality and durability of the new constructions. A staff from the municipal government stated:

“During the reconstruction process, in self-help housing, the architects offering advise found several construction mistakes (…) it was common to see very poor quality of reinforced concrete (…) columns without foundation.” (Dolores - staff from the municipal government, June, 2018)

Some of the post-disaster housing solutions got building pathologies within one or two years after reconstruction because of the use of low-quality materials, lack of quality control during the construction process, and lack of appropriate design (Notes from fieldwork). Long-term
sustainability of post-disaster housing relief in Barrio Cadol and Barrio Los Altos could be undermined by their durability and building performance, limiting the capacity to adapt and resist to future hazard climate events. Because of the top-down nature of the bureaucratic decision-making process, informal settlements’ residents experienced barriers to access to post-disaster housing relief and resources and their participation in the post-disaster reconstruction decision-making progress was limited.

CONCLUSIONS
Like many remote small-towns and rural areas in Latin America, small-towns in Southwestern Uruguay are vulnerable to climate change and extreme climate events due to lack of information, lack of official protocols, and limited resources for mitigation and adaptation. Poverty and unequal access to resources and infrastructure increases vulnerability in informal settlements, affecting their capacity to adapt to climate change. In Barrio Cadol and Barrio Los Altos, pre-disaster overcrowded conditions, use of precarious housing materials, and lack of safe structural systems, undermined the capacity to resist to extreme weather events.

The case studies in Barrio Cadol and Barrio Los Altos illustrate how spatial inequalities can be intensified by unequal access to subsidized housing, unequal access to financial resources, and involuntary resettlement after an extreme weather event. This study highlights the significance of claiming the right to the city as a way of shifting power relations in the post-disaster reconstruction decision-making process, understanding the way post-disaster environment is represented and surveyed to address social-spatial inequalities in post-disaster recovery process. We aim to illustrate how these post-disaster spatial representations can guide reconstruction actions but can also create uneven power dynamics, benefiting some residents while neglecting others. In Barrio Cadol and Barrio Los Altos, post-disaster survey and maps were key instruments used by the government at municipal and national level to assess building damages, and to guide reconstruction actions regarding allocation of resources determining, whether or not, residents would qualify for subsidized housing programs. Additionally, the post-disaster survey and mapping process presented several challenges in Barrio Cadol and Barrio Los Altos due to the nature of these tools which were not suitable for informal housing.

Finally, this study reveals barriers for adaptation to climate change that limit resilience in informal settlements. During the post-disaster housing reconstruction process, residents in Barrio Cadol and Barrio Los Altos experienced barriers to access to housing and resources due to lack of timely housing solutions, top-down bureaucratic decision-making process, and the lack of flexible financial resources. These barriers limited residents’ agency and their right to participate and transform the urbanization process and the places they inhabit. As communities continue to experience the effects of climate change, it is important to develop community-based initiatives that could allow communities not only to anticipate and react to environmental stresses but to thrive in the long-term future.

REFERENCES


CULTURAL PRODUCTION


ENDNOTES

i Agency of Social Development stands for Ministerio de Desarrollo Social (MIDES)

ii Agency of Housing, Planning, and Environment stands for Ministerio de Vivienda Ordenamiento Territorial and Medioambiente (MVOTMA)

iii Uruguayan Association of Social Workers stands for Asociacion Uruguaya de Asistentes Sociales (ADASU)

iv Uruguayan Association of Architects stands for Sociedad Uruguaya de Arquitectos (SAU)

v MEVIR (Movimiento para la Erradicación de la Vivienda Rural Insalubre) is a governmental commission for the eradication of the unhealthy rural housing.
Shaping the periphery: Emergent architectures in Latin America

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ABSTRACT: In an age that has become interested in urban issues at the planetary scale, it is advantageous for architectural design research to bridge the micro, meso and macro scales of the built environment. This article addresses the macro by comparing metrics of global urbanization, and then outlines the disparities between ‘the urban condition(s)’ found in North and South America. A more nuanced description of the uneven conditions of geographical development found in formal and informal constructions in Latin America sheds light on the context of this study, which sets the stage for a presentation of research that investigates several socially disjointed environments that represent the spatiotemporal conditions present in much of the contemporary Latin American urban landscape. This work has involved the participation of undergraduate students, graduate architecture students and faculty at Universidad Piloto de Colombia. The design research addresses the conditions of the emergent conditions of Latin American cities through participatory action research. Aspects of this research have been introduced into a design research studio setting where students have mapped the urban conditions and levels of forced displacement. Over the past 4 years, a network of private and public institutions and a NGO have worked with a vulnerable community located at the southern periphery of Bogota, Colombia to articulate alternative visions for future development than what has been scripted by the local planning department. The physical transformation of several strategic points of their neighborhood has begun through processes of ‘autoconstruccion’. This paper outlines these processes and the observed impact that the transformation of the built environment has fostered in the community.

KEYWORDS: Participatory Action Research, Emergent Architecture, Insurgent Architects, Co-creation, Post-Conflict Architecture

INTRODUCTION

In an age that has become interested in urban issues at the planetary scale, it is advantageous for architectural design research to bridge the micro, meso and macro scales of the built environment. This article addresses the macro by comparing statistics, then by outlining the disparities between ‘the urban condition(s)’ found in North and South America. A more nuanced description of the uneven conditions of geographical development found in formal and informal constructions in Latin America sheds light on the context of this study, which will set the stage for a presentation of research that investigates the socially disjointed environments common in the spatiotemporal conditions of the contemporary Latin American city. This work has involved the participation of undergraduate students, graduate architecture students and faculty at X University. The design research addresses the conditions of the emergent conditions of Latin American cities through participatory action research. Aspects of this research have been introduced into a design research studio setting where students have mapped the urban conditions and levels of forced displacement. Design models and prototypes have served as important artifacts to develop consensus among several stakeholders. Over the past 4 years, a network of private and public institutions and a NGO have worked with a vulnerable community located at the southern periphery of Bogota, Colombia to articulate alternative visions for future development than what has been scripted by the local planning department. The physical transformation of several strategic points has begun through processes of ‘autoconstruccion’.
1.0 PROJECTING URBANIZATION

"Space and time, the material foundations of human experience, have been transformed, as the space of flows dominates the space of places." (Castells, p. 1)

The rate of urbanization across the globe reached an important milestone on May 23, 2007 when urban dwellers surpassed rural inhabitants. The United Nations Department of Economic and Social Affairs estimates that urbanites reached 55% of world population in the decade that followed and will be 68% of the global population by 2050. The sheer numbers are daunting when milestones of the past century are situated next to current numbers. For example, in 1950, 750 million people lived in cities and now there are over 4.2 billion urban inhabitants. In many regions of the world it has become nearly impossible to create accurate projections necessary for the infrastructural planning to accommodate such rapid growth.

The numbers are consistent across the Americas and demonstrate similar levels of urbanity at just above 80%. However, looking beyond the numbers it is clear that the similarities stop there. The qualities of urban life are quite different in the global north when compared with the global south. In 1934, Thompson and Whelpton of the Scripps Foundation for Research in Populations Problems presented their findings to the Natural Resources Board. This study indicated the projected linear growth that would maintain a level of constancy for US citizens due to the careful appropriation of resources. Though simplified and not predictive of the impact that other major world events had, the growth of the United States has followed the predicted pattern. The patterns of urban growth and the conditions of the built environment in Latin America are starkly different.

The availability of resources and technology has become comparable, yet differences in the accessibility and level of development of the infrastructure demonstrate the disparity. Manuel Castell’s conceptualization of information networks and their impact on urbanism established a useful framework to understand the impact of the “Spaces of Flows” on the urban conditions late in the twentieth century. Several decades into the 21 century, however, it has become necessary to reframe this argument. Castell’s account of ubiquitous computing and digital platforms for the transmission of information raised questions about how physical infrastructure would be transformed when information moves without the need for the physical manifestation of this exchange. However, the volatility of climatic conditions, violence and political turmoil have actually caused the forced displacement of over 68 million people.

The design research included herein addresses the question of architectural agency in contexts where the “flow” of people has not ceased. This paper introduces a shift in inquiry that addresses the instability of urban centers and seeks to understand the implications of the accelerated growth that has occurred due to the reception of people who have been the victims of forced displacement. The invitation of this conference asks for narratives that illustrate the role of academics and researchers to apply design research and how this has affected praxis. The research of this paper will outline how the author is mapping and confronting the precarious conditions associated with forced migration in Latin America.
2.0 IMPACT OF INTERNAL DISPLACEMENT ON LATIN AMERICAN URBANIZATION

Architectural histories have presented Latin America development through descriptions of the uneven socio-politico circumstances found in many territories. This is categorized as formal and informal constructions and the tensions between these dimensions. In Colombian cities, such as Bogota and Medellin, the informally settled periphery has become a point where citizens (many who have been displaced due to the armed conflict) have inhabited spaces where sovereign power and bio-power coincide. Moreover, the role of the designer and the agency of the object of the constitutive entanglement of the material and the social are charged conditions, as the built environment becomes a tacit artifact embedded with these tensions. (Knorr-Cetina 1997, Latour 2005, Orlikowski and Scott 2008).

Latin America has a violent history that has been punctuated with war and governmental turmoil. In the case of Colombia, the nation is entering a new phase after a fifty-year civil war against guerilla rebels. The Revolutionary Armed Forces of Colombia (FARC) and the Colombian National Government reached a peace agreement in 2016, which established a clear route for the demobilization of this left-wing guerilla group. The bilateral cease-fire has permitted a certain level of settling to occur, yet a great number of afflicted citizens have sought refuge in urban centers and have populated the informal developments found at the periphery of cities, such as Cali, Medellin and Bogota. Colombia is the country of the highest number of internally displaced people (IDP) in the world. According to the Internal Displacement Monitoring Centre more than 6.5 million Colombian citizens have been displaced. There was an estimated deficit of one million housing units in the urban environments in 2011. The Colombian government allotted 583 million dollars in 2013 for the construction of low-income housing to help alleviate the stress of this tremendous influx of urban residents. These funds have been injected into new housing projects, which are beneficial to some extent. However, the existing favelas have also absorbed the problematic without the proper tools or resources to navigate this situation in a satisfactory way. Most of our work has been under the pretext of “insurgent architecture” and with the methodology established by Orlando Fals Borda’s “Participatory Action Research.” We have built co-creation projects that have provided us with valuable insight. Our current focus, however, takes a step back to understand how the contemporary issue of exacerbated levels of human migration is affecting urban centers.

3.0 RESEARCH QUESTIONS

What agency does design have when enlisted for the service of these people? Can the co-creation of the built environment strengthen vulnerable communities? What tactics are worth replicating? The content herein focuses on architectural responses that I have been involved with as a way to study and engage Colombian communities that have been affected by violence and displacement both directly and indirectly.
4.0 FORMS OF PRACTICE - PARTICIPATORY ACTION RESEARCH

“The freedom to make and remake our cities and ourselves is, I want to argue, one of the most precious yet most neglected of our human rights.” - David Harvey, The Right to the City

There is a fundamental role of practice in this research. We have been working with a community in the neighborhood Altos de Cazuca of Comuna 4 of Soacha. This community is involved in this research because they have acknowledged sub-levels of development in their local infrastructure which they seek to address proactively. Their involvement with this investigation is conditional: they have agreed on the premise that the academic expertise
offered will be translated into tangible results. Recognizing the importance of understanding displacement from rural areas, we have also worked with a community of peasant farmers and indigenous groups.

The research methodology that has been chosen for this work is classified as Participatory Action Research (PAR). A Colombian sociologist, Orlando Fals Borda, provided a framework that we have opted to respect. According to Fals Borda, the use of PAR has “grown worldwide due to its pertinence to the initiation and promotion of radical changes at the grassroots level where unsolved economic, political and social problems have been accumulating a dangerous potential. PAR claims to further change processes in constructive non-violent ways due to its emphases on awareness building processes.” At the intersection of this research, civic engagement and teaching, we are working to further understand the role of design activism and how it can affect communities facing the complexities of displacement.

Two projects are used herein to demonstrate how we are working with displaced peoples and fragile communities in Colombia. The first is a park and the second is a gathering place. These projects have engaged students and community members with whom we have sought to analyze symptoms, identify cracks and take action at the scale of urban/rural acupuncture. The use of tactics, as described by Michel de Certeau, is used to exploit gaps in the playing field and to form projects of co-creation that have the potential to generate novel and inventive outcomes.

The first case study is being developed with a community in the periphery of Bogota. One particular example with them is the work of co-creation being done on a lot that had become a deposit for demolition waste. Before actually starting to think about landscape architecture, the challenge was to activate the community and to catalyze discussion and action. Several years of workshops with inhabitants of every age group helped change the paradigm of what it means to be an empowered citizen. Interaction with local authorities has led to mixed results which has meant that the inhabitants have assumed active roles in the planning and construction of public space. Thus the park shown here became a project that was designed and built with the San Rafael neighborhood in Cazuca.

Figure 5: Image on the left is a rendered plan of park and was developed with my students after several meetings with the community. Image on the right is a photograph of the park in development.

At the other end of the spectrum is a project that I have been involved with in Santa Rosa de Cabal in the coffee region of Colombia. The project is called MinkaLAB and the name is derived from the word minga which signifies collaborative work to the indigenous communities of the Andes Mountain Range. My main contribution has been the design and construction of a Maloca, a ceremonial dwelling common to many of the indigenous tribes of the Amazon and in the Andes mountain range. This has become the gathering place for cultural encounters, including the annual minga, a collaborative exchange, between a diverse population that
includes, but is not limited to; members of various indigenous tribes, designers, farmers, urbanites and collectives, architects, psychologists, medicine men, chefs, etc. This gathering has created a platform for exchange between a diverse group of participants who share the common goal of keeping ancestral knowledge alive and promoting healthy ways of living. In this case, the development of the event/platform is a tactic that is part of a larger strategy that involves heightening levels of consciousness through the sharing of knowledge. While this has traditionally served as a vehicle to perpetuate one’s own culture, our collaborative work together resituates the idea of ‘norm’ and asks what it could be. This is particularly timely in the context of Colombia as the government is currently navigating the paths with the most potential to meet the needs of displaced citizens. One particular observation is that though many have fled to urban centers, rural life is actually preferred and desired.

Figure 6. Image is a site plan of the Maloca that was constructed with MinkaLAB by author's design firm

5.0 INTERFACE WITH THE “NON-STANDARD” DESIGN STUDIO
The pedagogical aspect of this work has served is an exploratory space for architecture students to become aware of issues that lay outside standard scope of architecture. The series of studios has developed narratives that address the strange nature of our reality that is anything but standard: The prompt for the students stated, "We are situated on planet earth in an epoch unofficially known as the Anthropocene. We reap the benefits of an industrialized, technologically advanced and connected society; however, we also inherit the consequences, which include political instability, de-territorialization, accelerationism and environmental catastrophe. Confronting these truths means that we must question the “standards” which regulate service and industry and the “standard” modes of architectural practice.” Students who chose the Nonstandard Studio were challenged to think critically about the role of design amidst volatile global conditions. Participants were encouraged to think outside of the box and create hypotheses about what agency design and architecture have to address these conditions. Digital tools were used to probe these conjectures and take projects a step further. Modelling, simulation, visualization and fabrication served as iterative procedures that were vital for a rigorous and revealing design process. Mapping with GIS and analyzing the data available were two of the activities that allowed students to trace displacement, analyze the relationship to territorial occupation and visualize this phenomenon through geographical notation. This part of the design research shed light on the way that instability of forced displacement has influenced the cultural production of the built environment in Latin America.

CONCLUSIONS
This research is on-going and has yet to be conclusive. Up to this point, one lesson worth sharing and discussing is the degree of difficulty that developing these projects entail. Places in such a state of flux do not easily permit strategy to be planned, enacted and studied.
Maneuvering changes in politics, economic conditions, zoning and trade agreements are but a few of the variables that will affect the building industry in the post conflict era. As these issues are outside the control of a designer, it is futile to develop a strategy that is obsolete before it can be carried out. Therefore, the focus must be on tactics. In The Practice of Everyday Life, Michel de Certeau explains that a tactic is set up "on and with a terrain imposed on it and organized by the law of a foreign power." As architects, we understand that we “must vigilantly make use of the cracks that particular conjunctions open in the surveillance of the proprietary powers. It poaches in them. It creates surprises in them.”

The case studies included in this article shed light on several ways that acts of co-creation are being developed in Colombian communities. It is premature to offer conclusions and so in lieu of results; this paper articulates how we are probing dis-junctions in the post-conflict context of Colombia that has left a massive amount of people displaced and living in precarious habitats. The tactical acts being undertaken in both urban and rural areas are used to illustrate innovative forms of developing stronger communities through conversation, collaboration, co-creation, design and construction. The provocation is that the dissemination and debate of this work will lead to another level of articulation that would be of benefit for architects confronting design problems for populations that have been displaced.

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REFERENCES

Riffing on Kuma: culture-based sustainably via pattern and layering

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ABSTRACT: This study is based on an architecture studio that examines culture as an integral part of architectural production, on the theory that achieving a deeper level of sustainability requires a thorough-going engagement with culture. Believing that culture encompasses and is a society’s approach to all the pillars (ecological, social, economic) of sustainable development. Achieving this requires deeper insight into the myriad ways in which culture can shape architecture, which in turn shapes culture. While the link between culture and sustainability is increasingly accepted, what culture is relative to architecture needs more careful analysis. We will first review how studying artifacts beyond the confines of architectural production sparked deeper understandings of how culture is both persistent and dynamic across time and circumstance. Our focus, however, will be Kengo Kuma’s theory of how pattern and layering are potent vehicles for enacting culture as sustainability—“The rediscovery of the heritage of traditional Japanese patterns and boundaries can unveil new horizons and new challenges to sustainability in world’s architecture. Through layering we can protect ourselves from natural elements, without detaching us from nature” (Liotta & Belfiore, 94). We will show how our own “riff” on this through analyses and making exercises—helped students internalize qualitative and quantitative sustainability values. Students embarked on project design ready to test how culture, as embodied in things like food growing and preparation, climatic and seasonal awareness aligned with patterns of activity, and layered spatial practices, could inform sustainable approaches. This enhanced mode of design thinking will enable them to function more meaningfully, as well as pragmatically, out in the world. This is a case study based on qualitative methods of evaluation.

KEYWORDS: Culture, Kuma, Pattern, Layering, Sustainability

INTRODUCTION
For several years we have been teaching an architecture studio that examines culture as an integral part of architectural production through the lens of Japanese culture. Our underlying goal, in addition to broadening students’ exposure to other histories and ways of thinking, is to reinforce the notion that achieving a deeper level of sustainability in architecture requires a thorough-going engagement with culture. As seen in the third diagram of a 2015, European Cooperation in Science and Technology Action IS1007 paper entitled “Culture In, For and As Sustainable Development.” (Figure 1) culture encompasses and is a society’s approach to all the pillars (ecological, social, economic) of sustainable development. Achieving this requires deeper insight into the myriad ways in which culture can shape architecture, which in turn shapes culture. While the link between culture and sustainability is increasingly accepted, what culture is relative to architecture needs more careful analysis. The studio is for undergraduate seniors drawn from both pre-professional and liberal arts institutions in our region. For most of them, this studio is the first where culture is introduced as a driving component in the design process for both architecture and sustainability. While these ideas have been developed in an academic milieu, we conceived this pedagogy based on its direct relevance to professional practice.
1.0 BACKGROUND

1.1 Summary of previous study

In a paper given in 2018 at the NCBDS Conference, we argued that culture is a necessary underpinning of most if not all sustainably-based actions (Darling & Mann 2018), and we put forth architecture’s obligation to think more deeply about how culture is manifested and shaped by the built environment, while cautiously navigating through such issues as imitation and appropriation. We discussed Barbara Allen’s notion of a “performative regionalism” that in our thinking, moves beyond the Critical Regionalism of Tzonis, Lefaiver and Frampton, and invites architecture to play a more active role in embracing the cycles of human activity as pertaining to the seasons and climate. Turning our focus to how space can support performance or “lived culture”, Allen argues, leads to more culturally embedded results:

Performative regionalism provides an understanding of the interaction of people and place that allows architecture to be understood as, in part, an enabler of cultural practices. (Allen 2007, 426)

In our earlier paper, we focused on the study of baskets as artifacts—in part because a major collection was being exhibited at the time—but also because of the transparency of maker to material to user, and the inherent “structurality” and tectonic sense of detail. We described how we did several exercises during the first half of the semester, from research to analysis with drawing and making assignments that translated and required material engagement at a human scale. Through investigating non-architectural precedents as diverse as the baskets of Tanabe Chickuunsai IV or garments by Rei Kawakubo, factors such as time, materiality, layering, the body, and the relationship to nature, emerged as recurrent cultural themes as manifested in made artifacts (Figure 2).

Introducing a sense of spatial layering, interweaving and rhythmic delineation via baskets in a museum, where students could walk around them, see their scale and notice details of construction, this immediately enhanced their spatial sensibility, including a sense of structure.
as an essential element of space-making. Students then created constructions using only bamboo skewers, fuel line and tissue paper, translating formal or conceptual principles from their precedent artifacts into a made object (Figure 3).

Figure 3: Bamboo construction by students Erin Keating and Anna Arscott

1.2 Kengo Kuma and patterns and layering
In continuing to develop the theme of how the study of the broader history and culture deepens students’ understanding of the intertwining of culture and making, we will focus on ideas of pattern and layering that followed the preliminary basket exercises described in the previous paper. In the initial studio, we based the project on a site in Japan, which provided the rationale for dipping into the culture. A year has passed, furthering development and changes to the curriculum that enable us to compare results. This past fall (2018) we located the project on our U.S.-based campus. The site selection deliberately included an existing historic building that has a strong institutional (but not stylistic) connection to Japan, but nonetheless this change required a different kind of rationale for using Japanese culture as a springboard, one which hinged on the paradox of applying cultural translation in a seemingly unconnected culture and environment.

We found a possible basis for this in Kengo Kuma’s ideas as put forth in Patterns and Layering, Liotta and Belfiore’s book about research in Kuma’s academic studio at Tokyo University. Its basic premise is that the long Japanese tradition of abstracting nature through sophisticated pattern and layering techniques embody a strategy towards a more performative architecture that can transcend a particular place and climate for a more performative architecture. When Kuma playfully states that “Japanese architecture is a treasure-trove of boundary techniques,” (Kuma 2010, 10) he is offering up the possibility that concepts such as patterning and layering are simultaneously embedded in Japan’s culture but also available for borrowing by others:

Spatial layering is a tool that can radically redefine the role of architecture and its way of interacting with context, both physical, social and cultural. The rediscovery of the heritage of traditional Japanese patterns and boundaries can unveil new horizons and new challenges to sustainability in world’s architecture. Through layering we can protect ourselves from natural elements, without detaching us from nature. (Liotta & Belfiore 2012, 94)

We realized that these potent concepts might be used as techniques for transferring culturally embedded knowledge to a more universal platform in the studio. Before launching into how we applied this, however, a more in-depth discussion about layering and patterns needs to be articulated. Because of our personal connections to the culture, the instructors had an intuitive understanding of what Kuma was getting at, but we knew from experience that such concepts can be elusive to those unfamiliar with Japanese culture. The ideas needed further unpacking beyond a simple reading discussion. Most of our students have limited exposure to cultural studies much less critical theory about cultural exchange and transformation, so a lot of ground had to be covered quickly. Luckily, we could get off to a quick start via a fine example of a traditional Japanese tea room at one of our participating institutions, and Saana’s Grace Farm—as a premier example of a contemporary work of Japanese origin involving cultural translation—which is a field trip away (Figure 4).
Layering as a word immediately conjures spatial conditions, so in that sense it is intuitive. However, the built environment experienced by students, particularly from the U.S. suffers from a lack (or loss) of layering. Even if it is easy on some reflection for students to ponder their love of traditional porches and mudrooms, or other appealing and useful transitions between inside and outside environments, such spatially nuanced typologies are often underutilized when actually designing, thus meriting an intentional focus on layering.

Layering in Japanese architecture occurs along horizontal and vertical axes and performs both culturally and environmentally. Vitorino has developed a table categorizing nine Minka (vernacular Japanese house) typologies that are seen in different geographical and thus climatological regions of Japan. As a long island extending from 31 deg North in southern Kyushu to 45.5 deg North in northern Hokkaido, (for reference, relative to the eastern US, Savannah Georgia is at 32 deg North and Montreal Canada is at 45.5 deg North) there is a big range in mean annual temperature and corresponding differences in rainfall versus snowfall. Using the genetic climate model developed by Gersmehl, Kammrath and Gross, Japan, similar to the Eastern US, is in a frontal climate characterized by variability with hot humid summers and cold dry winters. Further to the north, Hokkaido is colder and very snowy, while south in Kyushu, there are palm trees and typhoons. This is not unlike the difference between Vermont and Charleston, South Carolina—so although it may seem paradoxical to look to Japanese layering techniques when designing for the east coast, in terms of climate, a quick comparison of the psychrometric charts for Sapporo, Japan and our local climate, approximated by weather data from Chicopee Falls, MA shows the two to have similarities. (Figure 5)
CULTURAL PRODUCTION

As Rapaport states in *House Form and Culture*:

One need not deny the importance of climate to question its determining role in the creation of built form. Examination of the extreme difference in urban patterns and house types... shows them to be much more related to culture than to climate. (Rapaport 1969, 18)

This is definitely the case in comparing the building typologies that have evolved in the Eastern US in comparison to Japan, and also within these two countries. It is for cultural reasons that the patterns of building in Savannah, GA are more similar to Amherst, MA and similarly the building patterns in Kyushu are more similar to Sapporo than Amherst is to Sapporo despite the more similar shared climate between these northern locations. Despite the large temperature variations, the cultural similarities and shared building traditions have led to layering strategies, horizontally and vertically, fixed and movable, that can be found throughout Japan.

Vitorino’s table categorizes vertical layers as part of the lateral envelope: Intermediate zones of habitation including verandas and porches, and fixed and movable layers including fixed walls and movable doors such as wooden Amado, and shoji-screens. Thinking along horizontal layers, there is the entry level across a threshold, and often a level for a wooden floor and a slightly raised tatami floor. In Japan, the horizontal and vertical layers have been formalized as boundaries between sites for the ritualized sequence of actions, patterns of living, and the physical surfaces themselves that have been exploited by the Japanese as surfaces for geometric pattern making.

![Figure 6: Vertical and horizontal layering in Japanese architecture (Author 2019)](image)

Figure 6 is an abstracted diagram showing a hypothetical layering sequence through a space. Under a protective overhang is the first layer, traditionally, sliding wooden doors or Amado and a wooden threshold into the *genkan* entry. Culturally, this is where one removes shoes and rises vertically into the interior, home or public space. Typically, one would then rise onto a wooden floor and then across another layer of a sliding fusama door (a sliding opaque wood framed panels traditionally finished with paper on both sides) into a tatami room. The opposite side of a tatami room might have shoji screens with the ability to filter light, an *engawa* or outer veranda and a final outer sliding wall to open the *engawa* completely to the garden. An additional protective layer of sliding wooden doors are often stored in a box attached to the exterior wall and closed in the evenings. Within the garden and beyond are additional landscape layers that are borrowed extensions of the internal space as have been written about extensively by F.L. Wright and others. This means that the innermost tatami rooms which are the primary living spaces are layered within multiple levels both horizontally and vertically. Vernacular buildings in the eastern US, also in a frontal climate, have traditionally had layers for climate control such as the covered porch and vestibule entry but differ in the cultural role that these intermediary places have, and lack the large expanses of sliding walls and screens. While the above texts demonstrate that these ideas have been around for a while, Kuma is able to repackage them in more contemporary and universal terms.

1.4 Pattern

Kuma and others such as Japan scholar Donald Richie, have articulated how pattern has a special place in Japanese culture:
among men, the Japanese are probably the foremost pattern makers. They are a patterned people who live in a patterned country, a land where habit is exalted to rite; where the exemplar still exists; where the shape of an idea or an action may be as important as its content...where the profile of the country depends upon the shape of living—Donald Richie (Liotta & Belfiore 2012, 9)

Most often, the discussion begins with the role of *katagami*, which are stencils for bloc-printing patterns on cloth or paper that date to the 19th century, in which each pattern takes on a symbolic role as much as ornamental, often embodying an abstracted reference to nature, or alternatively represent family crests etc. Their enduring ubiquity in Japan gives them status as cultural reference points (considered among the Important Intangible Cultural Properties of Japan. The patterns are seen as both harnessing geometric regularity and repetition, while at the same time invoking the dynamic, irregular, and de-centered syncopations that together embody the natural. (unlike European stencil work the tended towards the scenographic or floral, katagami features bold graphical shapes and contrasts, and a sense that the forms have been honed to express the essential quality of the object or idea represented) Such pattern systems are said to have had a powerful influence on early Modernists, in addition to having the potential to exert influences anew. (Liotta & Belfiore 2012)

Kuma’s invocation of the word “pattern” is in itself daring in the context of contemporary architecture’s legacy where pattern has tended to be eschewed along with “ornament” (at least in the Amero-European context). Ornament itself has been undergoing a long, slow process of recovery via publications such as Moussavi’s *Function of Ornament*—as a trajectory of digital design, where patterns emerge inherently from structural and other generative operations. Moussavi sees the potential for new cultural expression and meaning in these processes and products, declaring that “Architecture needs mechanisms that allow it to become connected to culture (Liotta & Belfiore 2012, 19) Kuma’s own built work naturally exemplifies such ideas. After shedding the Western-influenced, Post-modern and symbol-laden work of his early years, he has embraced deep searches into materiality and their inherent expressive potential, often through seemingly simple means such as slatting, stacking, crossing—to generate buildings that are virtually composed of “pattern” at a volumetric and tectonic scale. While the buildings’ authorship is readily identifiable, the conceit is that the patterning-as-construction erases the architect as the overweening form-determiner.

Pattern is form expressed through materiality, but as a concept it also transcends form: referencing back to Ritchie, pattern is also “the shape of ideas or actions” and consequently, that which gives expression to “the shape of living.” Even in *Patterns and Layering*, these multiplicities can be seen amongst the individual contributors from the Kuma studio, where some focus primarily on the formal and symbolic consequences of a pattern analysis while others on the potential environmental strategies of using “patterned” layers. Across the body of the text, we observed that pattern is discussed primarily in the following ways:

1) As an abstracted visual representation of nature, acting to capture its essential characteristics
2) As an integral part of generative/digital processes (applicable from small- to large-scale)
3) As the inherent tectonic of screening or filtering layers, which tend to be built up of parts and repetition—essentially for the purpose of modulating environmental forces.
4) As a pattern of behavior, of both humans and non-humans, shaped by daily or seasonal cycles of living.

In other words, each of these aspects are separately available for expressing a culture-based sustainability, whether it occurs as a graphical representation of the interconnectedness between humans and the environment, or as filtering layers that actively modulate climatic conditions or otherwise delineate zones of inhabitation. Multiple aspects can happen within the same object or objects, but they are nonetheless separate mechanisms at work—the first being primarily symbolic, the latter being both active and symbolic through purpose. One could further say that objects like screens, or thick layers of woven thatch, invite human interaction and awareness of the environment through the opportunity to be adjusted or be otherwise tended to—tying readily into the notion of sustainability as lived culture. This idea treads into
the fourth manifestation of pattern as a “pattern of behavior”, but this point was subject to some debate as to whether it was explicitly or implicitly addressed in the book’s text, if at all. Certainly, by quoting Ritchie, the idea of pattern cutting across all aspects of Japanese culture, from technique to habit to land use, is invoked—but the point is not fully taken up elsewhere. Even the subsequent discourse on layering as an essential characteristic of Japanese spatial culture focuses primarily on the visual/perceptual realm as opposed to how layered spaces support a host of lived behaviors that are still foundational to the culture. This may seem like a fine point, but as we found, particularly in the studio context, an important lacuna.

“Pattern of behavior” naturally evokes Christopher Alexander—a connection NOT made in Patterns and Layering—but which should nonetheless be considered relevant: “…we must begin by understanding that every place is given its character by certain patterns of events that keep happening there.” (Alexander 1979,4) or: “All acts of building are governed by a pattern language of some sort, and the patterns in the world are there, entirely because they are created by the pattern languages which people use.” (Alexander 1979, xi) Or referring back to Barbara Allen’s Performative Regionalism, when she states that in Louisiana, one designs for large extended families to gather and dance as opposed to a good view. (Canizaro 2007, 426) In a traditional setting, this might further manifest in activities such as plant tending, food drying and pickling, washing and drying, repair of household goods, retail activities out of the home, moon-viewing and other seasonal celebrations, and so on—activities that could require distinct temperature zones or degree of ventilation, wet or messy activities, protected outdoor areas, degrees of privacy or sheltering for example. The key point was that patterns are not only about a visual representation or an activated spatiality or a structuring of adaptable environmental zones—but that patterns of behavior that are more environmentally sustainable can be supported and shaped anew by aligning with the multiplicity of environmental zones that emerge from a layered architecture articulated by patterned/layered separations. In other words, that the tectonic exploration advocated by Kuma should be meshed with an Alexander/Allen sensibility about lived culture. In modern life, a new look at activities that give us more interaction with and stewardship of the environment, perhaps in different guises and new tectonics—are ripe for invention.

2.0 APPLICATION IN THE STUDIO

2.1 Patterns and layering applied to site ‘forces’ analysis

Pedagogically, our challenge was to develop a sequence of design prompts to enable a translation into material expression of these concepts of layering and patterning that students were exposed to more broadly through field trips, readings, broad cultural research and more specific material culture research including architectural precedents. Our approach was to assign two more conceptual making exercises focused specifically on layering and patterns before introducing a specific building program. Project 4 was a site analysis prompt (Figure 7) and Project 5 was a landform and structure prompt (Figure 8). Although students were thinking spatially about the eventual project site, we intentionally did not assign the building program during these initial exercises.

Thinking of pattern as a means to express spatial gradients on a site, the design assignment that most directly engaged students with the ideas of layering and pattern making discussed above was the site analysis project in which students were asked to choose 3 site “forces” and develop a graphic pattern to represent these forces across the site. Examples of forces given were: the range of vehicular and pedestrian behavior, warm to cold areas of the site, wind, site hydrology, views from the site, vegetation, etc. For all of the site forces, students were to consider the gradient of these forces across the site and use their pattern making to communicate the intensity and scale of the gradient of their force across the site, i.e most sunny to least sunny. Students were challenged to develop the pattern to further represent secondary or more nuanced aspects of the information, i.e. how to represent pedestrians walking versus a bicyclist or skateboarder? Further, students were prompted to think about how the “forces” they represent might or might not be influencing each other. Ultimately, we
wanted to conjoin the derivation of pattern and the activity of layering with the capturing and conveying of real information.

After developing their site force patterns, students were to cut the analysis patterns using the laser cutter to develop patterned screens considering positive and negative space, the need for the pattern to hold together structurally as well as for communicative and aesthetic effect of how best to sequence and present their three layers. Students were encouraged to experiment with interlayering, folding, using spacers, and to create some depth between the analysis layers to show them in an interesting and meaningful way. Among the several agendas, was the goal to make physically manifest things that are less tangible though no less present, such as mechanical fan noise of a neighboring building or infrequent but loud garbage trucks, wind gusting or runoff during storms—phenomena that are often ignored even in practice, but which must truly come to the fore in a performative architecture.

Although in preparation, students read excerpts from “Patterns and Layering,” one of the biggest challenges we found was that even with this reading, students struggled with the distinction between pattern making and diagramming and developing analytical layers that could communicate tangible site information within a graphic pattern. The most successful examples became both “diagrams of spatial organization” existing on the site as well as “generative element(s)” of the ultimate projects that were developed.

2.2 Site “forces” analysis segue into landform-based concept design

Perhaps the biggest break through this year was in the development of Project 5: Landform & Structure, an intermediary conceptual exercise that required student to translate directly their site analysis layers into landform topographies in direct response to the conditions that they observed and analyzed on the site. By keeping this assignment essentially program free, students had the freedom to spatially develop the site in response to and extending upon the layers and patterns within their “site forces” project. In developing their Landforms, students were again working with layered sheet material, cutting, folding, bending and lifting in response to sun, wind, light, circulation, etc. Using similar techniques and translating the layered and patterned analytical constructions of the site into shaped topographies and geometries positioned students to push, pull and adjust this second iteration into Project 6, when students were assigned the full building program. Thus the intuitions of the pattern making and layering that students explored in Project 4 were maintained as active ideas in their final projects.
2.3 Building programming for patterns and layering

By invoking William G. Clark who was foundational to the agricultural legacies of both our institution and that of Hokkaido, Japan—and the historic building bearing his name at the center of the site—we had a means to both indulge in a nod to Japanese cultural practices yet focus more universally on the importance of cultural and environmental responsiveness. We intentionally developed a multi-faceted program with spaces that would be best served with a gradient of light conditions, temperature control, privacy, accessibility—“liminal” spaces as spatial layers that service and equip the program spaces, while often mediating climatic zones between the inside and outside. These are the very spaces that are often not clearly articulated in typical “program brief” square footages, so we made sure to spell them out and describe how and when they might be used in conjunction with the more fully conditions spaces, while also encouraging further invention. This allowed students to fully consider how the daily rhythms and patterns of life and culture are enabled while making buildings that are more performative both ecologically and sociologically (Figures 9 and 10). The combination of the preparatory exercises that activated a patterning and layering sensibility in the students, and a highly descriptive program that enabled them to envision and justify functional scenarios was in our opinion highly successful for almost all students, yielding lively and convincing results that were quite unlike their previous studio work.

Figure 8: Project 5 - Landform and Structure. Student Hannah Clark

Figure 9: Project 6 - Student Center for Sustainability. Student: Caroline Dolan

Figure 10: Project 6 - Student Center for Sustainability. Student: Courtney Jurzynski
CONCLUSION

This was the fourth time that we co-taught a culture and sustainability-based studio and each time we have refined the semester’s sequence. This past fall, the combination of Project 4 – Site Forces with Project 5 – Landforms and Structure, enabled the most direct translation that we have seen of students being able to transfer thinking and physical making around concepts of spatial layering and patterns directly into their design proposals. The transition to a local site that students could see and visit, as well as a carefully developed program that consciously combined spaces needing gradients of light, air, temperature were also critical in this success. Moving forward, it may be helpful to have students analyze katagami precedents more directly for pattern-to-meaning techniques, and also to have them organize the given program into gradients more directly aligned to the three site forces each chose for their initial site investigations, enabling them to more quickly grasp and translate their layered form making exercises into the relatively large and complex building program and site.

In relationship to professional practice, we feel that utilizing “hands-on” pattern/layer-making to bridge the gap between diagrammatic analysis and building design would be effective, since professionals are often similarly challenged to visualize the multiple and often non-visual factors impacting a site and program. In addition, the technique of using a detailed program narrative where building activities are further aligned with variable thermal zones can define strategic positionings and help guide the design process to not only reduce energy bills, but to produce buildings where a more complex interaction between climate and building are envisioned and shared:

…it is possible to rethink both the meaning and the role patterns might play as diagrams of spatial organization and generative element of a project. Today there is renewed interest in elaborating an architecture that can again balance economic and social forces and connect space through different spatial devices and in the study of their application and meaning in architecture. (Liotta & Belfiore, 2012, 17)

REFERENCES

Manila’s resettlement communities: how the built environment structures kid’s social lives

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ABSTRACT: Manila, the densest city in the world, actively resettles families from informal-inner city communities to large social housing communities on the urban fringe. This paper describes these resettlements from the perspective of teenage residents (kids). I applied an inductive research methodology and qualitative methods to investigate the relationship between architecture and kid’s social lives. Collaborating with four resettlement communities, I collected and analyzed photographs, interview transcripts, observations, and drawings by kids, community advocates, and government officials. I suggest that kids in the resettlement communities are looking for ways to mentally adjust to their situation as they shift into the reality and responsibility of limited resources. They use cell phones and social media for entertainment and for testing out new identities that are uninhibited by their environmental constraints.

KEYWORDS: resettlements, social housing, kids, urban morphology, and equity

INTRODUCTION
At 4:30 am, the sky still dark and most of the community sleeping, half of the kids in Garden Village wake up and prepare for school. The first shift of secondary school is from 6 am to noon and the second shift runs from noon to 6 pm. Scheduling two shifts of classes per day is a common practice in Manila’s peripheral communities where resources are scarce and even buildings must work overtime to accommodate demand. However, the kids “don’t mind” getting up early; they told me that there isn’t anything to do or anywhere safe to go so they stay home anyway (Interview with Caril 2018).

Manila, the densest city in the world, actively resettles families from informal-inner city communities to large social housing communities on the urban fringe. These resettlement communities range from 500 to 15,000 families collocated on vast stretches of former agricultural land. Promoters of resettlement communities argue that they are potential stepping-stones to a better life while critics challenge that the cost is extreme isolation. International humanitarian organizations are aware that these remote communities face daunting challenges such as a lack of basic infrastructure, transportation, and jobs leading many scholars to argue that they are seeding grounds for future slums. Yet, the tangible impacts of this typology (remote social housing architecture) on the everyday lives of the residents are often overlooked.

Following the work of Janice Pearlman and Louise Chawla, this research scratches the surface of contemporary social housing schemes in a global city to understand kid’s unique perspective. Specifically, teenagers (kids aged 12-16) are physiologically developing their frontal lobes, which forms their identity and deep perceptions of the world around them. How does this type of spatial isolation affect kid’s perceptions their environment? How does the architecture support or inhibit social reproduction? And, how has social housing in the Philippines evolved to produce this typology?

I’ve applied an inductive research methodology and qualitative methods to answer these questions. Over a period of eight months, living on the fringe of Manila and collaborating with four resettlement communities, I collected and analyzed over 432 photographs taken and 16
maps made by teen residents, 105 hours of site observations, and 61 hours of audio recordings with kids, community advocates, and government officials. I found that the architecture and urban design of resettlements impact kid’s identity, accessibility, and encourage digital means of community through an administration that provides little stability.

1.0 SOCIAL HOUSING IN MANILA, PHILIPPINES

Here, on the urban fringe, the National Housing Authority (NHA) has approved sites for the resettlement of informal communities from Manila’s thriving city center. The government cites a neoliberal agenda for relocating the communities to the periphery: land is cheap on the fringe, informal settlers must learn how to integrate into the economy, and the city needs to leverage the high-value land currently occupied to generate income (Interview with HLURB 2018). While it is clear that the inner-city informal communities are prone to unsafe and hazardous conditions, I argue that relocation to the extreme periphery has dangerous social consequences not previously considered even though the Philippines presents a tradition of relocating marginalized residents.

Informality and the demand for subsidized or “social” housing is a deeply political and social issue embedded in the island nation starting with the imbalance of resources between the landowning elite and the tenant farmers. Colonized by Spain, Japan, and the United States of America (USA) the Philippines underwent centuries of agricultural exploitation by way of haciendas (plantations) that echoed feudal property-rights and ultimately displaced millions of tenant farmers. Following the Spanish-American War, the USA sought to use the Philippines’ rich agricultural resources to expand economic development. In 1901, the government under American administration held 93% of the islands’ land area (Dolan 1991). The Catholic Church was the second largest private landowner and through negotiations with the USA sold the majority to Filipino estate owners (Seekins 1993). In the later stages of the American Colonial Period, a Commonwealth system was established to subdue rising insurrection regarding pressures on the failing sharecropping system especially around the countries growing commercial port city, Manila.

American President Taft commissioned Architect Daniel Burnham to design plans for the physical redevelopment of Manila. While this garden-city plan was never fully carried out some of the ideals were evident in the structuring of corridors and public space. Burnham saw possibility in the exotic environment but believed that the city could benefit from the influence of a “progressive [sic] civilization” (e.g. the USA). While his plan possessed climatically specific designs it did not address social equity and gave no caveat for low-income housing (Burnham 1905).

Yet, social inequality worsened due to competition for tenant land and the increasing population of the landless working class despite efforts from social revolutionaries such as Benigno Ramos and President Manuel Quezon. The Philippines’ federally initiated relocation programs have their roots here. The People’s Homesite Corporation (PHC) was the first government-housing agency to be established in the Philippines. One of the most notorious projects by the PHC was the 1940 Kamuning Housing Project. These suburban Manila communities intended to relocate poor farmers were the first to include community services and facilities such as schools, open spaces, markets, and utilities. Around this time, squatters, looking for service work in the port, inhabited reclaimed land from Manila Bay; over the next three decades this settlement would come to be Tondo Foreshore – Manila’s largest slum and the one in most need of basic urban services (World Bank 1976).

Just a year after PHC was established, the government enacted the National Land Settlement Administration (NSLA) who’s mission was “to facilitate acquisition, settlement, and cultivation of public lands, to afford an opportunity to own farms for tenant farmers in congested areas, to encourage migration to sparsely populated regions, and to develop money-crops to take the place of the present export crops to America” (Commonwealth Act No. 441, 1939). When the Second World War broke out major relocation settlement areas were already established with
populations upwards of 50,000 hectares signifying to working class Filipinos that top-down resettlement was a viable option (Manapat 2010).

However, due to its strategic position in the Pacific, Manila was a major site of conflict in World War II (WWII) suffering destruction to the built environment only second to Warsaw, Poland. During the reconstruction period, the Philippine government tried various social programs to stabilize unrest as the majority of land was still held by a small group of elite landowners who exploited tenant farmers and many working-class poor were rendered homeless from the WWII fallout. The democratic system failed to produce equitable legislation likely because most political candidates came from large land-holding families. In 1945, President Jose Laurel created the National Housing Corporation (NHC) and two years later, under a newly independent Philippine government, President Manuel Roxas merged the NHC with the PHC to create the People’s Homesite and Housing Corporation (PHHC).

Each president appears to have used social housing as a cornerstone issue to define his or her term in office ultimately with little lasting material effect. President Magsaysay established the National Resettlement and Rehabilitation Administration (NARRA), which excised land to indigent families for farming. In 1963, President Macapagal enacted the Agricultural Land Reform Code which abolished tenancy based on harvest yields and replaced it with a leasehold system based on fixed rent. This was a significant advancement that helped to break-up the haciendas but was inhibited by congress’ failure to allocate funds for implementation. In the years that followed, six more agencies were established each for a separate and distinct facet of urban informality and housing insecurity.

The notorious dictator, Ferdinand Marcos, framed the next era (1965-1986) of social housing. He attempted to balance the agricultural economy with industry by procuring large foreign loans to finance massive infrastructure projects. During his first term, the increase in federal spending was well received and he was the first Philippine president to democratically win a second term. But, as funds ran out interest rates increased and inflation dramatically rose which triggered social instability. Marcos reacted by decreeing martial law that lasted 15 years. During this period he enacted some social housing legislation. Most notably he abolished the many existing housing agencies and created the National Housing Authority (NHA) to take over and integrate their functions. A few years later he created the Ministry of Human Settlements (MHS) to take a holistic approach to housing (NHA was placed as an attached agency to MHS). MHS developed a standard set of guidelines for social housing called Batasang Pambansa 220 (BP 220). Of specific importance, this legislation made transparent a new shift in the theory of social housing to rely on the private sector and officially defined new categories and requirements for housing:

- It is hereby declared a policy of the Government to promote and encourage the development of economic and socialized housing projects, primarily by the private sector… [emphasis by author]

Economic and socialized housing refers to housing units which are within the affordability level of the average and low-income earners which is thirty percent of the gross family income… and to government-initiated sites and services develop and construction… in depressed areas (BP 220 1982).

The law for architectural life safety codes for economic and social housing is still written as BP 220; it is revised by the Housing and Land Use Regulation Board (HLURB) and implemented by the National Architectural Council (NAC).

One of Marcos most notable programs under the new NHA was Bagong Lipunan Improvement of Sites and Services (BLISS). BLISS was intended to illustrate to surrounding rural communities the benefits of a ‘settlement’ approach to community buildings. It ultimately constructed over 230,000 housing units.

When the People’s Power Revolution overthrew President Marcos and he fled the country, President Corazon Aquino was elected in 1986. She shut down the MHS and reorganized social housing efforts through a National Shelter Program. This effort was coordinated through
a newly formed Housing and Urban Development Coordinating Council (HUDCC) chaired by a Presidential appointee (EO No. 90 1986). President Aquino maintained the success of the National Shelter Program through public-private partnerships in social housing and directed government agencies to, “encourage greater private sector participant in low-cost housing through liberalization of development standards, simplification of regulations and decentralization of approvals for permits and licenses” (EO No. 90 1986). She allocated a large amount of public land for social housing. Many informal settlers occupied public land in Manila at this time because they knew they would get resettlement options under her administration (Interview with TAO 2018). During the final months of her presidency, Aquino’s government passed what is still the foremost law on social housing, the Urban Development and Housing Act of 1992 (UDHA).

According to Dr. Grace Ramos, professor of Architecture at the University of the Philippines, the UDHA 1992 intended to ensure social housing was a priority by setting guidelines and metrics for success. However, she critiques the policy as vague, lacking participatory methods, instilling inadequate architectural guidelines, and measuring success through quantitative brackets that mask the story:

- Design standards prescribed by the various building and planning laws are problematic. The application of the concepts of ergonomics and anthropometrics to low-cost housing have been very much oriented to the physical realm. Minimum dimensions of house components are largely taken from measurements of the users while laying out of functional zones are based on very rational analyses of sequential movements, oftentimes based on western models” (Ramos 1999).

Despite the push back, the HDUA supported the construction of nearly one million housing units on the urban fringe. In the late 1990s, along with many western capitalist nations, the government shifted its perspective on social housing from a highly centralized and subsidized perspective to a market-oriented approach. President Fidel Ramos had the idea of ‘toilet-communities.’ During his time in office, the NHA acquired large plots of land and put down slabs with only a toilet (no partitions or roof) (Interview with TAO 2018). The minimalist idea assumed residents would eventually invest in their home. However, these communities became seeding grounds for blight because the residents didn’t have the knowledge or materials to construction homes to a safe standard. People used what they could find-old wood, galvanized iron sheets, and tarpaulin. President Ramos also focused on military housing and under his term NHA experimented with 3-story housing along the railway easement (higher density, in-city housing). However, most residents sold their units to those more enterprising. Critiques argue that the high-density units were too small especially since residents didn’t have access to outdoor space (18 sqm for an average family of 6).

President “Erap” Estrada is likened to American President Ronald Regan because he always played the hero during his acting career was beloved by Filipinos. His presidential cornerstone was a mass housing development (55,600 units) called Erap City (Kasiglahan Village) administered through his newly formed Presidential Commission for Mass Housing (EO No. 159). Erap invited private investment through the Asian Development Bank and the project received over 3.2 billion pesos (roughly $61M) from SSS, Landbank of the Philippines, and NSJBI. This was one of the first all-horizontal housing communities constructed on agricultural land outside of suburban Manila – displacing over 200 farmers. Ironically constructed to relocate settlers from the flood-prone banks of the Pasig River, this community also experienced significant flooding over the past decade likely due to poor grading and insufficient stormwater design. Over 80% of residents did not have access to livelihoods due to the remote fringe location. But, the community fed into the culturally imbued concept of ‘home’ being a function of land-ownership – something that wasn’t offered with the high-density in-city housing promoted by both President Corazon Aquino and President Fidel Ramos.

President Gloria Macapagal Arroyo supported many large resettlement sites. The Philippine National Railways Clearing Act moved informal settlers from dangerous railway easements to the distant fringe of Bulacan, Laguna, and Cavite (at least 60,000 families). But, once these easements were cleared new informal communities formed again due to the lack of policing.
Following Ketzana, a destructive typhoon, President Arroyo reallocated funds from the relocation program to focus on building high-density in-city housing. But, informal settlers didn’t want to live in multi-story housing because of the cramped space and the cultural stigma that “home” is in the land. This perception only worsened due to the poor architectural designs of the high-density social housing units that limited access to natural light, offered no cross-ventilation, and had little opportunity for parents to see their children playing from their unit, etc. Another major issue was that settler’s experiences in low-density blight communities inadequately prepared them for the responsibility and maintenance required of living in high-density units; without oversight or organization the buildings were often abandoned or sold.

President Benigno Aquino III was known for his support of a participatory planning method through the NHA that resulted in communities such as the Sampaloc Project. These communities are small in scale, incorporate behavior requirements (such as keeping the community clean), and are located in the metropolitan areas of Manila. Aquino targeted informal residents in danger zones due to environmental natural disasters such as fire, flooding, earthquakes, and typhoons (Yolanda victims explicitly). Unlike many countries grappling with social housing and informality, the Philippines is an exceptionally dangerous state for housing insecurity because of the environmental conditions. Typhoons, earthquakes, landslides, flooding, and volcanic eruptions have plagued the state’s most marginalized residents making stable housing an even more critical concern.

Finally, the current President, Rodrigo Duterte, has taken a neoliberal perspective and shifted the responsibility of social housing to the market economy. In this light he reduced the national social housing budget to less than half of 1% in his term (from 1.1% to 0.46%) (Interview TAO 2018). The remaining social housing projects are tied to the threat of the Islamic State in Marawi (Mindanao) or military housing to support his war on drugs.

Social housing in the Philippines is closely tied to each Presidential campaign. Constant turnover of housing agencies and juggling for control have rendered little material changes but rather a pendulum swinging between strategies always with a focus on ‘numbers of housing units’ over qualitative assessments. Over the past three decades, social housing has transitioned from a public responsibility to an opportunity for the private industry. Relocation is not a new concept but rather a century-old plan for dealing with the pressures of a rural-urban migration. Administrations have alternated through in-city or off-city models; horizontal or vertical typologies; self-help housing or holistic housing models. As urban designers and architects work toward tailoring solutions to the next relocation project, little empirical work has been done to understand, qualitatively, how relocation affects the residents.

2.0 METHODOLOGY

Over the period of eight months, I worked with kids living in resettlement communities on Manila’s periphery to understand how the built environment their perspective. This was a mixed-methods study using a participatory approach to increase accessibility to kids. The post-positivist perspective relied on inductive methods to reflexively collect and analyze data. Through these iterative cycles of data collection and analysis, I was able to adjust the methods to fit participant’s needs, refine questions, and validate data.

I chose a case study model to compare youth experiences across resettlement communities varying in population, age, and housing typology. I defined a case as a discrete resettlement community. Within each case, I repeated the sequential methods working with kids and their peers. To select cases, I conducted a site visit of 9 peripheral resettlement communities. After receiving permission from each community, I selected four that were diverse and politically stable. These four communities are located on the north side of Manila and have approximately the same duration of commute into the city.
Table 1: Site selection criteria with chosen sites highlighted.

<table>
<thead>
<tr>
<th>Community</th>
<th>Barangay (Neighborhood)</th>
<th>Province</th>
<th>Distance to Manila</th>
<th>Population (Families)</th>
<th>Age</th>
<th>Housing Typology (Flr Area/Lot Size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Jose Del Monte</td>
<td>Muzon</td>
<td>Bulacan</td>
<td>39 km</td>
<td>4,283</td>
<td>6</td>
<td>22sqm/40sqm, some lofts, rowhouses (RH)</td>
</tr>
<tr>
<td>Heights</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pabahay 2000</td>
<td>Muzon</td>
<td>Bulacan</td>
<td>32 km</td>
<td>7,045</td>
<td>20</td>
<td>22sqm/36sqm,RH, 1 flr</td>
</tr>
<tr>
<td>Garden Village</td>
<td>Graceville</td>
<td>Bulacan</td>
<td>30 km</td>
<td>494</td>
<td>1</td>
<td>45sqm/40sqm, duplex, 2flr</td>
</tr>
<tr>
<td>Towerville VI</td>
<td>Graceville</td>
<td>Bulacan</td>
<td>27 km</td>
<td>8,514</td>
<td>12</td>
<td>22.5sqm/36sqm,RH, 1 flr</td>
</tr>
<tr>
<td>Golden Horizons</td>
<td>Hugo Perez</td>
<td>Cavite</td>
<td>50 km</td>
<td>1,500</td>
<td>7</td>
<td>N/A, RH, 1flr</td>
</tr>
<tr>
<td>Dorothea 1</td>
<td>Halang</td>
<td>Cavite</td>
<td>49 km</td>
<td>5</td>
<td>N/A, RH, 1flr</td>
<td></td>
</tr>
<tr>
<td>Belmont Homes</td>
<td>Halang</td>
<td>Cavite</td>
<td>48 km</td>
<td>54</td>
<td>1</td>
<td>N/A, RH, some lofts</td>
</tr>
<tr>
<td>Bronzeville 2</td>
<td>Halang</td>
<td>Cavite</td>
<td>51 km</td>
<td>270</td>
<td>4</td>
<td>N/A, RH, some lofts</td>
</tr>
<tr>
<td>Resettlement Site</td>
<td>San Isidro</td>
<td>Rizal</td>
<td>36 km</td>
<td>0</td>
<td>1</td>
<td>N/A, RH, some lofts</td>
</tr>
</tbody>
</table>

The research captures kid’s perspectives through multiple mediums as they often have trouble communicating through words. First, I gathered general perceptions by holding one focus group of at least 8 kids in each case. After the focus groups, I conducted semi-structured interviews with new kids. By analyzing focus group responses, I was able to develop specific participant recruitment criteria and tailor interview questions to each case. During the first interview, kids were given a disposable camera to take pictures of spaces they hang out in their community. Analyzing the first-round interview responses led to emerging themes and a refined set of follow-up interview questions. I returned the photographs to each teen asking him/her to write a caption for each photo and to plot the photo location on a community map. The kids were then asked to draw their daily route, identify places they regularly hang out and the homes of people they connect with on social media. After analyzing the third round of data and developing a working theory, I identified 6 “social spaces of significance” in each case. I conducted 4 2-hour site observations using behavior mapping in 15-minute increments to document patterns of use in each space. To validate the findings, I also conducted 12 contextual interviews with school guidance counselors, homeowner’s association members, parents, and barangay (neighborhood) officials.

The data collection and analysis process was iterative following principles of grounded theory. I used Dedoose Software to systematically code and analyze the interview transcripts, photographs, and maps immediately following each phase. The top codes were “hangouts,” “basketball court,” “barkadas” (clique), “walking,” “nature,” “Facebook.” To adhere to principles of child safeguarding during the research process, I initially recruited and trained 6 local residents per case to identify and approach potential kid-participants and their parents for interest in the study. This step ensured the privacy of the kids (and the community). Following, I met with potential kid-participants and their legal guardian to explain the project risks/benefits through a translator in the local language (Tagalog). I selected kids on the basis of diversity of age, gender, and school attendance with the goal of understanding a wide range of perspectives. This process was followed for recruiting kids for focus groups, interviews, and mapping exercises.

3.0 RESETTLEMENT ARCHITECTURE

Distance, in the greater Manila metropolitan region, is best measured in time because of the deeply congested traffic. The four communities that I worked with were all located about a 4 hour commute to Metro Manila on an uneventful day. They were all in the province of San Jose del Monte City where many of its 700,000 residents were relocated from Manila in the 1970s/80s. Frequent heavy rainfall exacerbated traffic and typically left rural communities stranded without access to basic resources. Public transportation to these areas was limited to commercial nodes where residents could use jeepneys and then rickshaws to eventually
arrive home but these vehicles were unequipped to deal with flooding and landslides. Accessibility, due to limited services, geographic distance, and quality of infrastructure was a major concern of all residents in each case. The two communities in Barangay Graceville, Garden Village and Towerville 6, were the closest (about a 20 minute drive or 1 hour walk) to the transportation hub at Tungko built on the first floor of the SM City SJDM shopping mall with the other two communities farther out.

3.1 Garden Village
Garden Village was a new community of 700 plots but just over 500 families had relocated in the past year with more pending. The community was clean and new - living up to its name as a "garden village" because of a strongly enforced homeowner’s association that emphasized planting around the houses. Each family was allotted a duplex unit with a side and front yard and alley-access in the back. The streets were wide but with out sidewalks to accommodate on-street parking (as none of the houses had driveways or carports). Most residents didn’t have a car but some were taxi drivers or would entertain relatives and so there were always a few cars on each street.

The community was difficult to find and more difficult to enter. The residents of Garden Village had deep solidarity and cohesion as they had fought to first remain and then to be relocated as a community from a long-held informal settlement on public land that was now leased to Ayala Land Inc. (to build a commercial live-work-play center, Vertis North). As part of the government lease, Ayala was responsible for procuring a relocation site. The company was pressured by investors to expedite the relocation process and negotiated with the settlement’s People’s Organization (PO) for some atypical participation in the site selection and design process. NHA hired Dowal Realty & Management Systems Company as the designer of record.

The PO had some input into selecting their site (from a list of 3 others) and chose the only site that allowed their community to stay together even though it was farther outside the city than many found comfortable. The site was also desirable because a river on three sides wrapped it; the site was a dead-end and for many this was a safety feature because it allowed them to control access. After driving through the rural area the road stops at a closed metal gate. Two resident-volunteer guards are posted 24-hours and above them a sign proudly reads, "SRCC Garden Village…"

Inside, the road leads to a traffic circle surrounded by duplex houses. The residents also had some small influence on the layout of their units. Cost was tightly controlled so they opted for larger lots and a two-story shell by compensating with an unfinished, interior second floor. The units came as a single room with a built-in counter and an attached bathroom. As residents saved money they improved their houses. Some common improvements were awnings over the entrance, metal security bars on the windows, a second level floor and staircase, interior partitions.

3.2 Towerville 6
Towerville 6 was located just a few kilometers from Garden Village but it was vastly distant in form and character. It was one of many expansions to an older relocation site with a combined population of over 30,000 families spread over Barangay Graceville and Barangay Muzon. The community was rundown and tired with an air of tension on the streets. The residents did not relocate from the same informal community or the same ancestral village at the same time; neighbors spoke different languages and had different conditions governing relocation. Some were victims of Typhoon Ondoy while others were resettled from railway easements and still others were relocated from public property. Without similar cultures or circumstances the community didn’t form a strong PO and was not able to advocate for their interests in the way Garden Village was successful. The residents of Towerville 6 did not have a say in their relocation site or in the design of the community or the layout of their homes. This detachment from their surroundings resulted in a lack of household maintenance and an increased presence of violence.
The community had been living together since 2006 and over the last decade the hardships of remote relocation had visibly taken a toll. The narrow lanes were dotted with abandoned carts and vehicles. The houses were constructed in rows each sharing a common wall (zero-lot line). Initially, the houses were setback 6 m back from the street curb to accommodate a sidewalk but long-ago homeowners unanimously encroached on this frontage with a small porch, a sari-sari store, or an expansion.\(^v\) The single-room houses were one-level with a small, attached bathroom along the rear alley. As with the front of the house, the alley, too, had been encroached and now was impassable by foot traffic. Many families used the alley encroachment space as the kitchen and for storage of bedding. Few residents made architectural improvements suggesting that they did not consider the community as a long-term solution.

### 3.3 San Jose Del Monte Heights (Sjdmh)

*Barangay Muzon* is approximately a 45-minute drive farther into the agrarian countryside from *Barangay Graceville*. There is some commercial development along the major road intersection that features one franchise fast food store, Jolli Bee. The sprawling community of SJDMH was located just three kilometers from this intersection. Although over six years old, the community was still expanding; it was an active site for relocation. It was home to just under 5,000 families who had been relocated in two distinct phases with construction of community amenities and several annex zones on-going.

Like Towerville 6, many of the residents did not know each other before relocating to SJDMH. The community was initiated as a resilience/risk reduction strategy as many were living in informal communities inside flood planes and active danger zones. However, the relocation was wrought with typical challenges: residents were evicted and their homes razed before utilities were set up in SJDMH. Many participants recalled a period of 12-18 month in which they carried water from the creek for bathing, washing, and cooking, they paid a daily fee for access to an electric generator (organized by the neighborhood), and had to purchase water by the drum from the city. But, they had hope because they saw a pathway to home ownership.

The streets in SJDMH are wide and often stripped for a make-shift basketball court. Houses range in typology from single-level row houses to loftable duplexes similar to those in Garden Village. Some are maintained and painted while others are in disrepair. The community is spatially open – too open. Sprawled across a hill-top there is no visual connection from one end of the community to the other. Vacant fields awkwardly interject into the street grid and break up the cohesion. The community has no main gate or guard system and feels as though the clusters of houses between the fields operate as individual units.

### 3.4 Pabahay 2000

Pabahay 2000 lies three kilometers on the other side of the Jolli Bee. This is the oldest community I worked with originating in 1998. The community has undergone many transformations and many presidential campaigns. The community is only accessible through a two-way loop that dead-ends into a gated community. Other than from the cramped and inhumane density, it would be hard to tell from the architecture that this community was once and perhaps still is a social housing site. Today, every unit has undergone at least one renovation. Lots have been combined, divided, and raised. Property has been sold to enterprising neighbors and the NHA estimates that perhaps 40% of the residents would not qualify for social housing.

Originally planned with one street size and one house layout copied throughout the entire site, the community has morphed into a complete town with a main street lined by commercial use: bakeries, computer cafes, restaurants, poultry supply, liquor stores, ice cream stores, resale shops, sportswear, private schools, water filling stations, etc. The standard single-room single-level layout as constructed in Towerville VI has completely vanished underneath medium density mid-rise construction.
The residents came from a few different locations. Some echoed Garden Village as they were relocated from an informal community on public land in North Triangle when the government leased the land to SM Land Inc. to develop the SM North commercial shopping center. Others were relocated from flood prone areas around Tondo. The community, as a now hybrid social housing project has little cohesion but residents also feel less stigmatized.

4.0 KID'S PERSPECTIVE
The kids in these four communities had similar enough experiences to warrant generalizable themes. Most significantly, they told me about where and how they socialize, they talked about their fears and hopes the environment presented, and they shared their reflections on their identity and future.

When asked about their ideal space almost all kids mentioned “trees” and “grass.” Those who had bikes imagined trails for riding while others, picnics. The kids talked a lot about nature – about wanting to be in it – as if being surrounded by agricultural fields wasn’t ‘in nature.’ They differentiated between the ‘controlled’ nature of public space in urban areas like parks and the dangerous wilds that surrounded them. They told terrifying stories of rapes, kidnapping, and animals that lurked in the wilds. They didn’t dare explore or play in the wilds. The exception was a few younger boys in Garden Village who liked to climb down the floodwall and swim in the river that divided their community from an informal settlement. However, they also said it was dangerous to be there because the informal settlers would throw rocks at them and sometimes adults would even cross the river and steal from their houses.

Their parents were afraid for them too. It was always better to stay close to the house. The parents in Garden Village allowed their kids almost free rein because gate guards controlled community access and everyone knew everyone. There was an element of this type of freedom in the cluster formations of SJDMH but most kids described tight spatial boundaries – usually a block or two from their home and strict curfews. Girls were allowed less freedom under the guise of protection while boys were allowed more space and time. In communities of mixed relocates, kids (both girls and boys) talked of gang violence and the pressure to join a group for protection. Drugs seemed to be limited to alcohol and cigarettes (about half of the kids participated) but none mentioned or knew anyone on harder substances.

None of the communities have open space with nature. Half of them have basketball courts (the ideal Filipino child is male and plays basketball, girls have a limited childhood and stay home to help with chores and take care of siblings). Barangay Graceville developed a nature park for residents, which has beautiful trees and is well maintained. However, the park is too far from Garden Village or Towerville VI for kids to go unaccompanied. The park has rules, restricted hours, and is often overcome with adults.

The kids use the street corners as their open space by default. They sit on the curb, lean against the houses, and sometimes escape to the alleys. Some more daring youngsters convert unoccupied houses into fort-like headquarters for their barkada. Sometimes they have standing meetings to play but many coordinate through Facebook Messenger (FBm). All of the kids have a personal cell phone and most had a smart phone. Very few actually had a data plan but FBm operates without data. The kids spent much of their free time at the peso arcadia (computer café) playing multi-user video games or FBm. Their social media connections were both local friends as well as friends back in Manila and abroad. They used this outlet as a means of identity expressed unattached to their physical surroundings.

Older kids made the long walk to the commercial center to use the free Wi-Fi. It took an hour each way and many skipped out of school to make the journey and return before dark. The route wasn’t safe at night. They had to decide to walk the busy highway and risk getting hit by a car or through some rural neighborhoods where gangs controlled the streets or drunkards loitered. But, they relished the time they spent at the mall. There was air conditioning, free Wi-Fi, and a Starbucks. The bright over-lighting made it feel safe and all of the white surfaces made the mall feel clean and even modern. It was so unlike their community – dark, stained...
concrete, trash. At the mall, they felt that released from the problems in their community and their family. Their Facebook pages said as much. They took selfies in front of popular stores and hung out on the mall’s expansive second-level patio that overlooked a greenfield site. There were so many people there and security guards. This was safe nature.

CONCLUSION
The kids in Manila’s relocation communities are challenged with inadequate spaces for socialization and compensate by investing in the virtual world of Facebook. Their spatial decisions are dictated by real threats to their safety but also by a desire to fit into a global commercial community. Although these relocation communities are located in remote and spacious areas, kid’s daily environment is consolidated to a few blocks. This affects how they see themselves and their communities.

The Philippines has a long history of managing housing insecurity through relocating marginalized residents to the urban fringe. Government corruption, inadequate funding, and gerrymandering organizational responsibilities have only inhibited progress to social housing. Some more innovative programs have attempted in-city relocation but efforts at high-density housing have failed due to anomic with the social conventions of apartment living. This study contributes to a developing body of research on kid’s social spaces. Throughout its execution I have attempted to include the voices of teenagers. Resettlement communities produce challenging landscapes. Kids may value many different kinds of spaces for a variety of reasons. I suggest that inductive participatory methods of this kind seem to provide a very useful direction for further research on the relationship between kids and the built environment. In particular, this calls for careful and detailed studies of how kids socialize in their communities. This approach places considerable emphasis on the role of public space in the development of agency.

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REFERENCES
Ley* (Interview 1), interviewed by Lyndsey Deaton and Mia Perez, San Jose Del Monte, Philippines, 9 AUG 2018. Interview in Tagalog. Translated by Sheena Cases.
Analyn* and Mahalia.* (Interview with Housing and Land Use Regulatory Board Senior National Staff), interviewed by Lyndsey Deaton, Quezon City, Philippines 12 SEP 2018.
Varona, Faith (Interview 1 with Technical Assistance Movement for People and Environment President; TAO-Pilipinas), interviewed by Lyndsey Deaton, Quezon City, Philippines, 21 AUG 2018.
Commonwealth Act No. 441. An Act Creating the National Land Settlement Administration. 03 JUN 1939.
CULTURAL PRODUCTION

Executive Order No. 90. Signed on 17 DEC 1986.

ENDNOTES

i Children selected their pseudonyms as denoted with an asterisk.
ii Manila was an established centuries-old city with a population over 220,000. The Americanization of territories and possessions was largely to the comfort of American businesses and for easy of social control.
iii This study was endorsed by the University of Oregon Institutional Review Board (IRB) and collected informed consent. The IRB assessed and minimized risks to participants and the university. The project was reviewed, amended, and endorsed by Save the Children Philippines, for compliance with the principles of Child Safeguarding.
iv During my site selection period, general elections created a state of emergency in Cavite. My project partner closed field operations in Cavite for a standard period of 90 days, which precluded any work in this area.
vi A sari-sari store is a home-based convenience store. About 20% of the homes dedicated frontage space for a sari-sari store. It was a main form of income for women as they were able to manage the store while rearing children at home. Programmatically, this space takes away from livable family space.
Designing Eden: The future of rule based city-making

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ABSTRACT: The omnipresence of the algorithmic gaze is not just easing the capacity to crawl, index, and rank everything according to rule-based praxises but also shifting the dimensions of where, when, and how citizens move or circulate through the urban commons (O'Brien, 2018). In the absence of urban thinkers or participatory planning, these new alterations take place within the invisible peripheries of algorithms. This paper examines the change, and the spatial currencies reconditioned by the interplay of city-making and city-indexing as infrastructure, urban spaces, and built settings become indistinctively itemized. It recognizes that this is an ongoing process that continues to flatten, catalog, and index the physical characteristics of space which produces a virtual inventory of urban proportions subjecting city officials to accelerate the re-privatization, deregulation, and re-colonization of vast territories. It is within these transactions that we see a re-territorializing of the city's context and the uneven usage of spatial distribution underway. In the case of the American city, the range of impact caused by these emerging transactions is seemingly local, but we claim that the dynamics of city-indexing reverberate across different scales extending from local to regional, and national proportions.

To depict our work, we choose a comparative method that aims to associate the impact of rule-base praxis with changes at the urban and regional scale. To start, we correlate the re-scaling of territories at a suburban sector in Silicon Valley with the re-development plans for downtown Las Vegas. We then linked those actions to the 2017-2018 bids enacted by Amazon and the likely effect it may yield from the northeastern region of the USA (a zone first identified by Jean Gottmann as a co-dependent megalopolis in 1961 and later coined as BOSWASH by Herman Khan in 1967) to the Midwest.

KEYWORDS: City-Making, City-Indexing, Eden and Spatial Commodities.

INTRODUCTION

The codification of the city fabric, once only attributed to planners and cartographers, is transitioning to machine learning processes that affect the spatial organizations of urban commons. Known as a quantifiable system based on the tracking of users, and the itemization of built context it is grounded on abstract logic that makes no distinctions between urban thinkers, participatory planners, and programmers yet it knows how to privilege pre-determine interest that can test the perseverance of pre-designed environments. In furthering this idea, we asked, what are the matrixes that anticipate the contextual interpolations defining the urban settings in the 21st century where pre-determined inputs trigger unexpected outcomes? The question first prompted from noting that cities struggle to exalt their uniqueness or to rank among “The top ten cities for healthy living,” “The best cities to work in,” and “The twenty superstar cities in North America;” lead us to note that the problem originates around human’s desire to quantify, codify and classify facts, objects, and symbols indistinctively. And this kind of recording has failed to develop significant parameters for how to validate a city's existence impartially and according to environmental constraints. This inability to focus on the quality of life gives rise for machine programmers to increasingly use quantification methods to recondition our built context. Thus, in less than a decade the strengths of algorithmic inputs and the fragility of urban planners begin to exhibit “new-old” kinds of deviations that continue to impact city legislation and citizenship (Shu, 2019).
Throughout this paper, we look at how this shift obliterates city-making, an act that in turn prioritizes city-indexing. And while both of these praxises are designed to support selected interest, each one has distinctly different economical, political, and technological goals. Yes, both methods deal with urban context, but city-making is a palpable undertaking related to the modes of production that over the centuries focused on building urban settings. Conversely, city-indexing is an emerging system, a quantifiable process that immediately itemizes the built environment allowing stakeholders to pick and choose from the availability of its physical inventory. The difference between these two approaches is clear and paramount to heighten the economic inequalities that are currently at play and threatening to eliminate the potentials for realizing environments capable of sustaining urban diversity. Thus, we sought to examine the cause and effect of this switch, per enactments that are now impacting the urban fabric of the USA. Within this analysis, we are also claiming that city-indexing is forwarding a new range of territorialization that aims to re-arrange public access under conflicting ideologies from data-driven logics. It leads us to critically grasp the velocity of these changes from the lens of three performances that effectively display how city-indexing hones the potential to reshape an entire urban fabric from a local area, a county, or over a large geographical zone.

Our findings capture the current economical, political and technological instruments applied to commodify physical spaces and concludes that these practices are ineffective to address and sustain the future arrangements of the urban commons. Yet, turning to the practical aspects of data awareness and social equity, a rule base praxis is a valuable tool that can become instrumental in supporting participatory planning. Where city-making and city-indexing jointly aid in understanding how to improve life as a catalyst for manifold co-existence.

1.0 CITY-MAKING:
To define city-making, one has to remember that ten thousand years ago cities did not exist. The invention of the city as told by historians started when homo sapiens learned to trust and form alliances, avoid intrusions, and evade extinctions. For millennia, this process empowered collective actions that generated improvements in habits and socio-cultural interactions (Tattersall, 2012). In time, prosperity and longevity yield the Age of Enlightenment as advanced systems of communication and scientific discoveries spearhead new types of civic engagement (Darnton 2018), and this, in turn, ignited fresh ideas for shared governance and new kinds of prosperities with which to re-invent the city. Thus city-making is a praxis that spurs urban evolution over centuries. It is the mass production of building and planning that eventually generates novel approaches to continue the urbanization of the world (Dejean 2014). Over time, these actions have generated global cities, innovation bubbles, and disenfranchised zones (Sassen 2014). But, fast forward to the 21st century, city-making is under siege, an unimagined crystallization of technocratic ideologies seeks to obliter ate the long-held pursue to define the perfect place, the city of god, the Eden-like paradise (Stephenson, 1997). Thus, the buildup of human's spatial ingenuity struggles to forward city-making as a planning device. In most cases, the 20th-century city that seemed to transform through the successes, failures, and struggles of citizens, stakeholders, and legislators; the one that often redefined urbanity through collective dependencies or in mirroring a type of Manhattanism is lost, rendering city-making less effective to innovate and to remain:

"a theater of progress __ its future can be extrapolated forever; since the exterminating principles never cease to act, it follows that what is refinement one moment will be barbarism the next. Therefore, the performance can never end or even progress in the conventional sense of dramatic plotting; it can only be the cyclic restatement of a single theme; creation and destruction irrevocably interlock, endlessly reenacted."

(Koolhaas 1978,12)

But this is an ambiguous definition in the formation and manner by which the city grows; it is also a reflection of the utilitarian properties bestowed to city-making rather than a prologue to the potentials this approach offers to support the continuous development of cities.
2.0 CITY-INDEXING

While the vast majority of American cities are comparatively young, most conceived within the last 250 years, they grew and prospered as centers of mining and manufacturing, producing and distributing material goods. These types of cities lacked the historical trajectory and "ancient role in providing the services of government, higher education and the administration of justice." (Gottmann 1975). This preamble herald in the third quarter of the twentieth century denoted that the threat to cities was not its shrinkage in size but its shrinkage in “relative importance” due to lack of productivity. Declines in rank are of crucial significance to understand the future of everything, and for most cities, it can be its downfall. And ranking is precisely the kind of sentencing that Gottmann unveiled through his book Megalopolis: The Urbanized Northeastern Seaboard of the United States. As a geographer, it is Gottmann who first indexed and ranked cities as he cataloged the footprint of Boston, New York, Philadelphia, Baltimore, and Washington DC among smaller socio-political and economic interdependent places like Richmond or Norfolk. His territorial understanding was the first visualization to grasp the re-scaling power of urban growth and to demonstrate that the success of cities lies in its geographical, cultural, political, infrastructural and economical networks (Castells 1991).

Now in the first quarter of the twenty-first century, ubiquitous algorithms provide a way to mine all sorts of things and subjects. Under blurred regulations, the ultimate resource to rank urban commons in the 21st-century is not geography; it is data mining. It can find, recognize, and correlate data to study, analyze and optimize the pulse of change. Knowing how to govern and manage data-control to achieve data-governance promises more reliable predictions in a broad range of areas. As the accuracy, completeness, and strategic timeliness of data starts to affect our living environments, it becomes essential to ask the following questions: How do Technocrats possess the ability to accrue data and simulate desire scenarios? How do they index the information and catalog content? How do they rank public resources, commodities, and services at will? According to Microsoft researcher Yu Zheng, these questions are answered through one's understanding of urban computing.

"connects urban sensing, data management, data analytics, and service providing into a recurrent process for an unobtrusive and continuous improvement of people's lives, city operation systems, and the environment. Urban computing is an interdisciplinary field where computer sciences meet conventional city-related fields, like transportation, civil engineering, environment, economy, ecology, and sociology in the context of urban spaces." (Zheng 2011)

Here, the means to index, rank and identify places offer opportunities to itemize urban content. And while these identifiers prioritize the nurturing capabilities of readymade places, they are also instantaneously obliterating the potential praxises to detail the future revival of shrinking settlements. The conundrum matters, because it is now permissible to empower companies into bypassing the growing pains entangled in city-making and to invade data absorbed places instantly. City-indexing is, therefore, the ability to look at an entire city as a "readymade" parcel to be mined for relevance or amended according to the needs of stakeholders. Technocrats know city-indexing best and are now using conventional instruments like deregulation, privatization, and the re-colonization of private properties to re-appropriate existing urban space.

The magnitude of city-indexing is both a virtual and physical re-scaling of the city. Thus, the impact of these indexing processes tends to reshuffle civic buildings, reformat access to sidewalks, eliminate urban commons, and delete cultural grounds. The act reverberates beyond the gentrification of a neighborhood or a social class (Florida 2002) and moves towards the colonization of an entire city, region, and nation.

3.0 BRIEFINGS

The moment when the future of city-making becomes obsolete starts with the desire to automate and commodify the city according to the algorithmic gaze (Stewart 2018). From Gottmann's maps and writings, we can anticipate how technocrats will not only impact a city but all other codependent geographies and in effect delete the construct of city-making in place for city-indexing. This approach is not a re-script of Manhattanism where nothing lessens at
the local scale, not even the production of spatial innovation; it is a process in the absence of input from citizens, planners, legislators, and entrepreneurs. Here, the city is no longer a public performance with multiple actors collectively negotiating and progressing towards new radicalizations; instead, it is a city-indexing system that will only take into account the itemized parts of the existing city that empowers rule-base goals. In a matter of a click, Technocrats will likely own the rights to alter and access the content of multiple urban functions by setting forth a search. In other words, Technocrats can declare themselves the urban landlords of a chosen city as the following sequence of events will tell.

Through the lens of city-indexing, the ensuing narrations are enactments that seek to explain the spatial distribution and usage of spatial context driving centuries of city-making into oblivion. Absent of participatory planning, this transactional shift is unlike that of medieval times or the industrial revolution when manifestations where physically traceable. Yet, they are in similar ways, not align with the interests of local citizens but able to accelerate the re-colonization of civic commons.

3.1 Privatizing paradise: Downtown Las Vegas; from 2009 to now

"Frankly, it was a miracle!" ___That is what an official from The City of Las Vegas exclaimed when he described the negotiations conjured between Clark County Las Vegas and Zappos CEO. It entailed the purchase of a community-based domain, named First Friday (Peterson, 2011); the battering of Amazon.com stocks (Buchanan2017); the reshuffling of Zappos management (Lashinsky 2016); the privatization of Las Vegas City Hall (Spillman, 2012); and sixty acres of Downtown Las Vegas (Groth 2017), to launch "the city itself as a startup initiative" with a limited cap of three hundred and fifty million-dollars fund.

Initiated in 2012, the Downtown Project was the first effort of its kind aimed at revamping a city decade. The goal was to turn Downtown Las Vegas into an urban campus for smart and interesting people that would ignite a series of commercial startups as a simulated live SimCity game. All of the existing buildings within a sixty-acre-sandbox (a virtual space in which new or untested software can be run securely), the streets, and sidewalks around it became Tony Hsieh’s (Zappo’s CEO) conduit for venture capitalism (Cremades 2016). From 2012-2014 Hsieh’s team rapidly learned how to improve and tweak its errors, like an AI [artificial intelligence] bot using if-then conditions to calibrate data and rank businesses according to the frequencies and activities of its users. Instead of housing, public parks, schools, and public services, the Downtown Project first alter the streetscape. The team saw value from a user’s collisionable hour as quoted by from Tony Hsieh’s explanation:

"is an hour you spend in a downtown social space: having a cappuccino at its perpetually vinyl record-sound tracked coffee shop, for instance, or eating at one of its “restaurant concepts”, tinkering with a project in its “co-working spaces”, drinking in one of its ever-more-numerous bars, taking your pet to its members-only dog park, or playing oversized chess out behind Gold Spike. Do this for an hour a day, and you’ll have put in 365 collisionable hours after a year, all of which would count towards the Downtown Project’s stated goal of producing 100,000 such hours per acre, per year.” (Marshall 2014)

Taken from a city's management perspective, Tony Hsieh’s is the most valuable player of a sixty-acre sandbox on Fremont Street. His data-driven gaming approach for governing Downtown Las Vegas is unmatched, and to understand his game, one needs to know the crawling mechanics of database arbitrage where the simultaneous indexing and ranking of public property alters the concept of traditional urban context. To start, delete and re-start, The Downtown Project in Las Vegas ranks the area per event. Through real estate commodification and collisionable numbers, Tony is activating city content from the basis of “very serendipitous sequence of encounters.” Take for instance; “Life is Beautiful,” one of the multiple annual activities his Downtown Project team executes; it is a “music-art-cultural” festival that starts every September as a time-lapse motion event where hour by hour public domains like sidewalks and streets are closed off to the general public in order to service a private function. It culminates with a seventy-two-hour sequence of adventures in the middle of October that deafens a large footprint of the downtown core. Consider by officials as a genuinely unique sequence of successful gaming motions and from the perspective of a single gamer’s strategy, this year’s Life is Beautiful sold out in less than two hours and brought about one hundred and
eighty thousand visitors for 13 hours per day. Do the math! [13hrs] X [3 days] X [180,000 visitors] and then note that the total of all guest colsessionable hours yielded +/- seven million hours of serendipitous encounters in three days.

“What a brilliant startup!” (officials say).)

3.2. Regulate deregulate rollercoaster 2010
At Cupertino, a suburban area of Silicon Valley, the land has been colonized, subdivided, regulated and deregulated often and this went on from the middle of the seventeenth century until two thousand and five when Apple Inc. started to re-bundle the parcels for the creation of their second headquarters Apple C2. In less than a decade, one hundred of these acres purchased from Hewlett-Packard, an additional fifty acres acquired from undisclosed sellers, and ten acres purchased from various residents of the Summer Hill complex, plus the streets and sidewalks encompassed the new sandbox. And no one seems truly surprised with the purchasing process; everyone is aware of Apple Inc.’s disinterest in green goals. Too many documents already evidence their deafness to the surrounding communities and their own employees' needs (Galloway 2017). However, these purchases point to how a company indexed existing territory, deregulates land usage and disregards the spatial outcomes impacting the area from the perspective of zoning, scale, public access, and lack of human interaction (Sorkin 2011).

Acclaimed Architect Norman Foster and Apple’s CEO, Steve Jobs, once declared that Apple C2 would be the greenest place in the world, in part, because they allocated land to house nine thousand trees from three hundred and nine different species on their proposed park. A simple compare and contrast of site and scale deliver an analysis of the site; it also visualizes the environmental and social impact of C2’s park which only services thirteen thousand Apple Inc. employees. After completion, it will be seven times bigger than Chicago’s Millennium Park, which welcomes four million visitors per year and one-tenth the size of New York City’s Central Park, whose legendary capacity host forty + million visitors annually. Considering that C2's sandbox is almost equal in size to Tony Hsieh’s Downtown Las Vegas startup the city-indexing format is actively enabling corporations to open and close public commons of local citizens at whim. And the significance or differences in the territorialization of space from the lens of city-making processes to city-indexing praxis is evident by the rate with which public domain shrinks. (Fig.1).

Here, it is worth remembering Gottmann’s vision and the potential of shrinkage in “relative importance” as humans, not land or built context enter oblivion.

Figure 1: Type of Sandboxes and their relative scale to central park. Source: (Yeshayahu 2016)
The city of the east coast, whether it is Boston, Philadelphia, New York or Washington DC has endured three hundred years of re-colonization expanding into the socio-cultural and socio-political examples which many historians believed are the best-ingrained examples of the American City. They are the vivid foundations that forwarded city-making processes throughout America's history; this has changed, and while today's crawling processes always rank these cities atop, it is their grouping, as Gottmann points out, that becomes significant. It is, therefore not surprising that on November 2018 Jeff Bezos un-intently demonstrated just that. His open call for all cities to make independent bids and bundled their urban characteristics, political endeavors, and commons into one package to lure Amazon into implanting their second headquarters (HQ2) into their urban midst, resulted in two hundred and thirty-seven responses from the USA and one from Canada. Sixty-three American cities, out of the three hundred most populous cities abstained; this was a remarkable outcome for the first auction of urban-context in the world and for Bezos to own a massive amount of the nation's extensive data (Peterson 2018). Twenty cities made the final cut and two will now be recolonized.

Social media has relentlessly reported on the twenty finalists, the two final choices, and the risks or potential outcomes as signaled through Google's search engine that yields 2.21 M sites in 0.41 seconds when one types related issues for HQ2. Yet, little attention has been given to the long-standing history of the entire region hosting New York City and Washington DC. In this regard, it is critical to understand the geographies of these two cities and the impact of their interdependent infrastructural system for the nation. One clear implication underway, from the perspective of selling and buying urban context, is that the effect is not simply affecting the physicality of New York's infrastructure, its five boroughs and the tristate area of the east coast but also the historical co-dependencies of the BOS-WAS region that by default ricochet throughout the Midwest zone. The change, if effected, is likely to highlight the weakening of interdependencies with the rest of the nation (Saunders 2017). The political and managerial impact of urban context will now take on new meaning for the USA as New York City and Washington D.C., who seemingly rejoice with their independent success, will be required to connect the dots of their urban zone or look to ignore their managerial legacy. In this visualization, we are left with a series of questions: Can the other eighteen finalists also have reason to hope that venture capitalist will soon recolonize them? What will the other two hundred and eight disconnected cities do? Or better yet, what will all other cities in the USA do as their network dissolves and shrinks in “relative importance”? A possible answer will be that Landlord-Bezos like Hsieh, or Gates will care to account for how their corporate actions impact the future of our nation or assume a responsible role in developing healthier, equitable living outcomes rather than rapid undertakings spit out by ill conceive rule-base inputs.

CONCLUSION: CITIES OF OBLIVION MS-OH RIVER

Cities are living proofs that aid us in discovering comprehensive outlooks about the history of human's innovations. Choosing to interrupt the habitual ways we navigate through city-making and the behavior of our collective undertaking requires meditative design praxis, specific knowledge about the urban narratives through time, and the know-how-to identify weaknesses before they are experienced in real time. Tony Hsieh, has already place-planners and urban-thinkers in his Downtown Project team and has begun to express many regrets for his initial outlook (Guzman 2016). So in understanding that not all cities are facsimiles of the other and that the developed east and west coast are not islands within a nation, will likely deter technocrats from acting alone or exempted from learning about the socio-economic interdependencies and geographies impacting the shrinking zones of the Midwest.

Many believe that a nation left to ruins would not serve Technocrats to strengthen their re-colonization goals and like Gottman in the past, our new tools and outlooks ought to aid us in reflecting beyond the city's presence and to help in understanding how to engage with the impacting Anthropocene behavior as herald by Vladimir Vernadsky in 1936 (Yeshayahu 2008). Within this reasoning, rule-based logic can account for different types of densities in
fundamental ways and differ from imagining how to mimic superstar cities. To sustain life, cities can look to engage technocrats in capitalizing on city-indexing away from "business as usual" standards and to engage in rebooting, restarting or error-correcting past failures. Thus, as technocratic scenarios continue to advance their pursuit of city-indexing practices, the nation needs to develop a stance on city-making praxises for its population and future environmental interests (Zaera-Polo 2017). Within this reasoning, rule-based logic can account for different types of densities in fundamental ways and differ from imagining how to mimic superstar cities; it can help adapt the urban form and to re-embrace city-indexing; it can identify its undeterministic variables and seek to thrive from rule-based systems that engage in scientific-based experiments.

The resilience of city-making still holds a presence in the USA. In fact, while most Technocrats look for settlements in the megalopolis region between Washington DC and New York City the entire area ought to be on the alert as we believe the intent is to engulf instantaneous access to multiple major international airports, interstate highways, waterfront ports, public transports, tier-one educational systems, outstanding cultural outlets, and more. Imagine Bezos knowingly applying city-indexing to the content of what Jean Gottmann uncovered in 1961 and then consider his recolonizing advantage in placing HQ2 between Washington DC and New York City as government leaders offer incentives that devalue the sweat equity of hundreds of years of innovation developed by the production of city-making. Can an entire megalopolis turn into a rule-base sandbox? Undoubtedly, yes. And the Midwest must pay attention to the phenomena and seek to diversify its character and services per Justin Fox's analysis about the GDP and population index across the heartland of America (Fox 2018). So in a heuristic model, the feasible alternative for rule-based praxises will be to tool the reinvention of urbanity creatively, slowing down, mixing ideas, algorithmic intelligence; and learning to undo, reboot, error-correct while re-instituting city-making praxises. From such initiatives, one possible outcome is to in fact index the city's content; not to be atop a search engine's rankings or to ignore local citizens but to identify a road map that progressively and objectively assesses and benchmarks a way toward the development of improving Eden-like paradises.

REFERENCES


Expanding urban cultural production: operational landscape of 60 million chickens

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ABSTRACT: This research paper tackles the principle question of how operational landscapes operating at a territorial scale are impacting rural communities. The spatial design disciplines, as stewards of the built environment, need to take concerted steps to broaden their scope of design related to the franchise-driven space of corporate America. No longer can the permanence of architecture fall victim to the dynamic and flexible systems that created it. As such, this paper will present a case study focusing on Costco’s forthcoming chicken plant in Fremont, Nebraska as a form of “urban” cultural production constructed to service the 60 million rotisserie chickens sold by Costco wholesale stores each year.

KEYWORDS: Urbanism, Rural, Architecture, Operational Landscape

INTRODUCTION: OPERATIONALIZED [LANDSCAPE]
We exist in an Urban Age where more than half of the world’s population lives in cities. This trend is predicted to continue, with this figure increasing to two-thirds by the year 2050 (United Nations, 2018). Due to the ever-increasing size of the large population centers, the majority of urban research has primarily focused on cities or megaregions, though the urban is a form of cultural production that also involves the logistical and operational landscapes of the rural countryside. For several years the exploitation of rural space has been discussed by leading scholars in the fields of architecture, landscape architecture, and planning. Waldheim and Berger discuss the role of the logistics landscape, offering that “little attention has been given to the new landscapes necessitated by the growth of logistical networks and their attendant infrastructure” (2008). While Waldheim and Berger’s essay was written in 2008, their insight remains relevant today as these landscapes of logistical networks continue to generate new scales and patterns of urbanism that are still rarely discussed or attended to by the design disciplines. As a result, hyper-efficient protocols based on corporate and logistical operations continue to transform the built environment outside of large city centers in ways that often take precedence over traditional models of growth.

Radical transformations of land-use, infrastructure, and ecology that take place far beyond urban city limits have been described by Neil Brenner as operational landscapes of planetary urbanization, all of which have made urban density possible (2018). Examples of these transformations include the resource extraction, waste management, food production, water use, energy harvesting, improved transportation networks, and creation of infrastructure that sustain urban society. In 2014 Brenner posited that “even for those of us who may be focused [research] on the cities as zones of intervention [design], we can’t understand what is going on within them unless we look outside them, far outside them,” thus situating a vast space beyond urban areas in need of recognition and further exploration. This vast space has played a significant role in supporting urban growth throughout history, one such example being the clear-cut logging operations in the midwestern United States and central Canada between 1890-1920 that provided the lumber to build the modern commercial centers of Boston, New York, and Philadelphia (Belanger, 2010, 9). Even today, this and other transformations continue to create significant social, spatial, economic, and environmental change in rural spaces.
1.0 OPERATIONAL SPACES

1.1 Operationalized [Great Plains]
Most city inhabitants remain disconnected from the exploited operational landscapes that sustain their daily lives. Cities operate in a global-urban context, meaning that the globe acts as a continual process of urbanism where urban and rural spaces impact and influence one another. As a global issue, this interaction holds particular importance in the Great Plains given that the region’s rich resources and vast infrastructure continue to support major cities throughout the world. Regional examples of Great Plains operational landscapes include Tyson’s meatpacking and Costco’s chicken farming, along with the region’s agricultural production, commercial distribution centers, ethanol production, and wind farms, with many of these systems generating corporate monotowns such as Tyson Fresh Meat, Madison, NE (community population: 2,398, 50% employed) and AG Valley HQ, Edison, NE (community population: 131, 62% employed) (see Figure 1). With each monowntown comes a series of supporting architectural and planning considerations that typically last longer than the industry itself, and in more than one instance, after the corporate operation has run its course, cheaply constructed buildings and poorly planned spaces remain unused with little hope for repurposing. One recent example is a series of ethanol plants in Iowa and Minnesota that were closed in late 2018 due to low profit margins and currently sit unused amidst the rural landscape. With the countryside continually being altered based on the needs of cultural production for urban centers, understanding and documenting the systems altering both rural and urban communities is vital. Further investigation is necessary to understand the impacts of urban systems and operational landscapes impacting the Great Plains.

COMMUNITY CASE STUDY | MONOTOWNS

Figure 1: Preliminary taxonomy of Nebraska’s operational landscapes located in monotowns such as Tyson Fresh Meat, Madison (community population: 2,398, 50% employed) and AG Valley HQ, Edison (community population: 131, 62% employed). (Illustration by Caitlin (Tangeman) Snyder.)

Agriculture plays a significant role in the organization of space and logistics throughout the Great Plains, and the region is best known (to a fault) for maximizing the yields of primary agricultural crops such as corn and soybeans. Equally significant are the second-tier logistical operations benefitting from primary agriculture yields, which include livestock (cattle, hogs, poultry, sheep) and energy (biodiesel and ethanol). Most of these first- and second-tier operations have been labeled as high-importance and are well documented. The state of Nebraska specifically is the third-largest producer of corn in the country, ranks second in ethanol production and distillers grains (the feed ingredient produced by ethanol plants), ranks...
second in cow-calf production, and is the number-one producer of cattle on feed (Nebraska Corn Board, 2018). Nebraska and Iowa are primary sources for agricultural products and their geographic location is touted by corporations for their many cost-saving benefits.

2.2 Operationalized [Costco]
In 2016 plans were announced to expand poultry farms in the Great Plains. The potential expansion of these operations has been led by Costco Wholesale, which is set to redefine their current operating procedures of production and distribution for rotisserie chicken. The operationalized Great Plains was sought as a potential benefit to Costco Wholesale in considering the future of their rotisserie poultry operation.

To set the stage and appropriately situate the Nebraska poultry farm we must start with Costco’s $1.50 hotdog and soda combo, the price of which has remained unchanged since 1985 and is often referred to as the best deal in the entire store. In 2009 when Costco lost its main hotdog supplier (Licata, 2018) the company was forced to take over the manufacturing supply chain of hotdogs and now sells its own Kirkland brand hotdog. In 2016 Costco sold 128 million hotdogs in its 759 worldwide food court locations (purportedly four times the number sold by all major league ballparks combined, Maxfield, 2016), illustrating the financial impacts that large commercial businesses have when they take over supply chain logistics. Now Costco is planning to enter the poultry production business with the hope of streamlining operations and cutting costs.

2.3 Operationalized [poultry farms]
Tyson and Perdue are currently the two leading producers of poultry in the United States, with the Southeast U.S. serving as their primary region for production due to its year-round climate suitable for chickens (see Figure 2). Male and female chickens grown for commercially sold chicken meat are referred to as broilers, and are sold as either whole chickens or more frequently as specially cuts (breasts, legs, wings, etc.). A poultry operation typically consists of a series of buildings, including the hatchery (pullet barn), chicken barn, and slaughter plant. To the architectural discipline, these pre-engineered buildings are often categorized as logistically sophisticated but architecturally unimportant; they are typically built in haste and planned specifically for chickens rather than considering the building’s total lifespan and environmental impact.

Costco Wholesale is one major supplier that benefits enormously from poultry farming and meat packing, with the company’s sales of rotisserie chicken having grown by more than 8
CULTURAL PRODUCTION

percent annually since 2010—a rate more than three times that of poultry consumption nationwide (Sawyer, 2018, 2). Acknowledging this growth, in 2016 Costco entered the poultry business for “surety of supply, visibility up the chain, and cost control” (Sawyer, 2018, 2) and to ensure a steady supply of rotisserie chickens that could be sold at $4.99, a move reminiscent of how the company handled their hot dog operations.

To achieve the $4.99 price point Costco is building a new $300-400 million poultry production operation in Fremont, Nebraska. Nebraska and Iowa’s projected chicken farm production will handle 40 percent of Costco’s poultry needs, corresponding to roughly the western half of the United States along with Alaska and Hawaii (Gerlock, 2018). Nebraska and Iowa are important both for their geographic location and their production of corn and soybean, which already contribute to a significant operational landscape related to cattle grazing and meat packing (USDA, 2015). Will Sawyer, a lead animal protein economist, speaks to the significance of the change, stating that “never before has the U.S. seen a retailer integrate its meat supply to the farm level and take on direct exposure to the risk of animal husbandry, including feeding, animal welfare, harvesting, trade, disease and distribution” (Sawyer, 2018, 1). While Costco’s operational advancements are themselves significant for reasons both agricultural and economic, the design disciplines too must acknowledge the drastic spatial impacts and design opportunities brought about by these changes.

Dairy production is another animal protein business model that has adopted similar strategies of retailer integration. In 2016 Walmart announced that it was entering the milk processing business by building a $165 million processing facility in Fort Wayne, Indiana. Similar to Costco’s plan in Fremont, Walmart promised a new building and high-paying jobs; consequently, between 2016 and 2017 Fort Wayne’s population increased by approximately 2,000 people. The plant will produce milk for roughly 500 Walmart stores in five states and process milk sourced from nearly 30 dairy farms in Indiana and Michigan. While both operations expanded integrated corporate supply chains to operate at the scale of both the processing plant and the distributed source material, one striking difference is that Walmart’s processing plant operations do not extend all the way to the farmer, with Sawyer calling Costco’s more complex operational plan a “new level of risk exposure Costco is taking on to protect an important product line” (Sawyer, 2018, 3). The Costco operation adds a further level of integrated risk in that individual farmers are required to invest $2 million for each barn needed to participate.

Additionally, new Costco operations are changing farming practices. During the last several years family farms have reconsidered the future of their row crop farming practices and have turned to chicken barns as the next step. Throughout history the row crops and cattle of the Great Plains have supported urban growth by providing necessary food, and now the Costco operation’s chicken barns will serve the same end. As a result, the built environment of Fremont and the surrounding areas will be drastically altered as approximately 520 chicken barns are built over 130 sites (Farrell, 2018).

2.4 Operationalized [Fremont, NE]

Fremont has a population of roughly 26,000 people and is located 40 miles northwest of Omaha. The town currently participates in logistical operations via their single largest employer Wholestone (formerly Hormel Foods), a hog-processing plant that has been described as the country’s largest producer of Spam and that processes 10,000 hogs a day (Grabar, 2017). As a result, Fremont is connected to both highway and train infrastructure to serve Wholestone’s logistical and operational needs. To support and expand this connectivity, US-275, the primary highway between Omaha and Fremont, was updated to a four-lane expressway leading to downtown Omaha throughout 2002-2009. In December 2017 the then-Hormel workforce consisted of 4,000 Fremont residents (Grabar, 2017), a network and skilled workforce that was considered a benefit to Costco Wholesale when considering potential locations for future poultry production.
The new plant is scheduled to open by March 2019 and Costco agrees to keep it under production for at least 15 years (see Figure 3). With an estimated 17 million new chickens expected, the operation is anticipated to be among the region’s larger economic engines. The operation is also expected to bring an estimated $1.2 billion annual economic impact to the state, which led Governor Pete Ricketts to pronounce, “Folks, that’s how we grow Nebraska,” during a rally held on the Fremont outskirts. While Ricketts is clearly acknowledging the financial impact to the state, he makes no mention of the community’s willingness to participate in a new, global economic market on a grander scale. Costco’s operating procedures are exemplary in that they expand the company’s logistical operations to envelope poultry farming practices in ways that cause the space of distribution, delivery, and consumption to form one of the “more significant transformations of the built environment seen in the region over the past decade” (Waldheim, Berger, 2008, 219).

Changes to Fremont will include the addition of a processing plant located less than one mile south of downtown, though less apparent will be the 520 chicken barns distributed throughout the region. Costco will bring approximately 1,000 jobs to Fremont, including 820 production jobs and 100-supervisory or professional positions. Employees are expected to come from the surrounding counties of Douglas and Lancaster and to have a major impact on housing demands in Dodge county, where Fremont is located (Greater Fremont, 2017, 3.5). The Economic Development (ED) boost would affect the city of Fremont to the point of requiring the development of 1,194 total housing units by 2022, including 562 owner and 632 rental units, at an estimated target budget of $234 million (City of Fremont, 2018). A workforce housing initiative has been planned to provide housing for low-to-moderate income workers along with mixed-use buildings (Greater Fremont, 2017). With Costco creating both a direct and indirect impact on the city and surrounding areas, the question arises as to how the design disciplines can best participate in the change.

2.5 Operationalized [architecture]
From Albert Kahn in the 1920s to William McDonough in the early 2000s, the architecture profession has long been designing industrial and manufacturing facilities. In the 1920s rapid rates of industrial growth required Kahn to experiment with construction techniques and structural concepts, resulting in a new building type specifically for assembly line manufacturing (Bucci, 1993, 31). Similarly, McDonough’s design for the Ford Truck Plant in Dearborn, Michigan implemented a 10-acre vegetation roof, the largest installation of its kind.
in the United States. With the massive Costco rotisserie chicken expansion and similar projects occurring throughout the agricultural and livestock industries, a comparable need exists to research new solutions and experiment with new building types suited to both the industry and surrounding communities. With this in mind, the design profession should play an active role in the evolution of architecture related to these specific needs. How can these rapid changes foster innovative architectural solutions similar to those of the past? Or, in the absence of such solutions, will small towns outside of urban centers continue to be exploited for their geographic location and proximity to desirable resources?

The optimization of Great Plains monotowns is often littered with utilitarian forms of required industry buildings and supporting developments of housing and retail, an environment that is, “for better or worse, the contemporary North American urban realm” (Waldheim, Berger, 2008, 238). Building these monotowns so quickly requires us to consider what happens when these companies leave the town, since the corporate logic of creating quick and fast architecture often responds first and foremost to the needs of the company and the drive to maximize profit (see Figure 4). While most architects generally agree that these pre-engineered corporate models of architecture (e.g., strip malls and big box stores, as well as chicken barns) are highly efficient in their use of materials, space, and construction assembly, can these buildings continue to facilitate highly calibrated logistics while also considering spatial, material, and environmental impacts before, after, and during use? Considering the limited 15-year lifespan of Costco’s commitment to Fremont, it is vital that we examine possible future functions of these buildings, or even plan for the deconstruction of these utilitarian forms once they’ve outlived the usefulness of the operational model. If future function of these poultry buildings is difficult due to contamination and other environmental concerns, then their deconstruction and the reuse of their materials might be a better option. Such concerns are of particular importance to farmers who have spent $2 million on these barns, and to create a building that can more easily be deconstructed, the initial design must reconsider material selections, connections, and assemblies.

Figure 4: Fremont’s new poultry processing facility. (Photo courtesy of Twilight Greenaway Animal Welfare, Rural Environment and Agriculture Project.)
If such alternate applications cannot be found, then new strategies for supporting developments of housing and retail should surely be considered as well. Potential strategies could include a responsive housing typology capable of adjusting to varying family size and co-sharing needs as well as to unstable short-term corporate commitment to the community; for example, by using flexible modular housing units that could grow and shrink based on both community and corporate needs. In addition, the environmental impact of these systems and structures cannot be ignored, raising the bigger question of whether responsive architecture can effectively consider its environmental impact while also enabling rural communities to balance short-term corporate and long-term community needs. But the design and architecture professions cannot achieve this alone; to succeed, the professions must partner with material suppliers, fabricators, and construction firms—similar to the partnerships formed in the 1920s—to challenge industry standards with the desired outcome of designing a more responsive architecture. Instead of the design and construction process being linear and reactionary, this is a call to action for a more cyclical and responsive design and construction process. This revised process will generate a reactionary architecture that responds to fluctuating corporate and global economies while minimizing the negative effects on the local community.

The social, spatial, economic, and environmental future of Fremont and the surrounding area is unknown, though as the area braces for the impacts of Costco Wholesale poultry operations the design disciplines must pay closer attention to the continued pressures faced by rural communities, especially those choices that are urban-centric. The pressures faced by rural regions like Fremont are in some ways equal to—if not more spatially impactful than—those occurring within the urban areas themselves. The environmental impacts on these rural communities too should not raise any less concern than the impacts on urban areas.

CONCLUSION

The facts presented here indicate the pressure faced by small rural communities in the shadow of urban expansion. These pressures culminate in the changing social, spatial, economic, and environmental qualities of rural America. When asked whether understanding the role of buildings in the construction of multiple scales of cultural identity can help us understand who we are, we must first expand our definition of both “buildings” and “cultural identity.” The design discipline must start to engage buildings not typically produced by architects or urban designers, including those constructed for solely utilitarian purposes. In addition, advanced construction assemblies should consider a building’s lifespan in response to fluctuating corporate economies, including the elimination of the operational role for which they were originally designed. This repurposing of utilitarian buildings has occurred more recently and publicly with the reprogramming of suburbia’s big box stores, a consideration that can and should be made at the frontend of design rather than serving as a necessary reaction to social and economic forces. These notions, once accepted, will open up new spatial configurations and design opportunities for the disciplines.

The phrase “cultural identity,” commonly held in the Urban Age, can also no longer turn a blind eye to the impact on rural space that focuses primarily on urban growth. No longer should we consider the formal and spatial production of cultural identity to be solely regulated to the urban. Designers of the built environment must acknowledge that cultural identity occurs within and far outside the city center. As discussed by Brenner, by expanding these definitions, we begin to participate in the real cultural identity being produced, which is not only urban or rural, but global.

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REFERENCES


United States Department of Agriculture. USDA Poultry Production Data.
Middle Eastern maidans: the role of interactive and integrated public squares in urban social sustainability

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ABSTRACT: This paper focuses on two public squares (Maidans) in rapidly growing cities in the Middle East: Maidan Naghsh-e-Jahan in Isfahan, Iran and Maidan Rolla in Sharjah, UAE. These cities are selected for their social diversity and the intentional use of public squares in formalizing and directing city growth. As epicenters of urban performances, both Maidans have historically attracted diverse people across social strata and age. While Iran and UAE may not be considered model democratic states and each has a distinct demographic composition, the enhanced social interaction that takes place in the two case Maidans have lessons for making “safe, inclusive and accessible, green and public spaces” (Transforming Our World: the 2030 Agenda for Sustainable Development). In comparatively analyzing the two case Maidans, we aim to: 1) Identify their socio-spatial features; 2) present indicators of socially interactive and integrated public places. Using mixed-methods research, we first layer historical maps of the two cities to identify the case Maidans that have persisted over time. Second, we use “Space Syntax” to assess their integrative character. Finally, engaging Projects for Public Space criteria, we comparatively assess their interactive aspects to illustrate their shared urbanity.

KEYWORDS: Urban Social Sustainability; Social-Spatial Framework; Public Squares; Middle East; Maidans.

INTRODUCTION

Sustainability embraces three equally significant aspects: environmental, economic and social. Until the 1990s, environment and economy dominated the discourse on sustainability. Though social issues have surfaced since then (Dempsey et al. 2012) and social progress is seen as instrumental for this urban millennium, the role of interactive and integrated urban spaces in sustainable development of cities remains under explored. This paper comparatively analyzes two Middle Eastern Maidans (Maidan Naghsh-e-Jahan in Isfahan, Iran and Maidan Rolla in Sharjah) to identify historic socio-spatial parameters that facilitate and enhance chance encounters in spaces for unplanned uses, and develop place attachment for people of diverse backgrounds. Identifying urban continuity, spatial integration and social interaction as key factors, this research transcends most comparative discourse on global cities that use the framework of urban political economy in general and neoliberalism theory in particular (Peck, 2015).

1.0 PUBLIC SQUARE, SOCIAL INTERACTION, AND URBAN SOCIAL SUSTAINABILITY

1.1 Literature review

Public Square defined as an urban open space between buildings may or may not be equally accessible to city residents, regardless of gender, ethnicity, age, or socio-economic level. While public squares may be multi-functional or exclusive centers for political, economic, cultural activities, they operate as conduits of social interaction (Kirchner and Soflaei 2017). If public spaces are designed in a way that connects them to the larger city, they become socially interactive and attract people from all walks of life. Vibrant public squares are great venues to observe how people interact (Whyte 2001) but very few urbanists have revealed how people shape their experiences of difference in these spaces. This research builds upon the seminal work of Jan Gehl on the socially “self-reinforcing process” of public space and, Ali Madanipour
on urban design as multidisciplinary practice, respectively. Gehl (2010) focused on how to observe performance of public spaces in urban environments. Examining issues of sustainability, shared spaces, mixed-uses, the psychology of security, usability and levels of pedestrian comfort, he proposes empirical observations to demonstrate what makes public spaces ‘alive’. He identifies methods and tools to reconfigure public spaces into places for social cohesion and interaction. In contrast, Madanipour (1996) focuses on the intersection between urban design, the development process and everyday life, and, most recently (2017), has explored why the phenomenon of holding short term events in city spaces has gained traction today. While Gehl examined the varied uses of the same space in his studies, Madanipour explores the temporary construction and use of urban spaces that reflect the deep recurring crises of our age in which information technologies drives economies to remote consumption that are no longer place-specific. While city culture is diversified through ease of mobility, distinct classes of people driven by particular roles of monetary (private), regulatory (public) and experiential (social) uses of a city creates distinct types of urban spaces. Gehl’s tools of observing spatial uses of public spaces may be used to test Madanipour’s classification of social interactions across time to address the gap in merging theories on sustainable urbanism that usually prioritize economic and environmental concerns, or separately address spatial versus social performance of public places. Our conceptualization of the intersections between spatial and social aspects of urban sustainability helps identify indicators of effective public places and our comparative methodology generates a framework for urban analyses and design.

1.2 Research methodology
The recent “anti-Maidan” movement in eastern Europe acknowledges that, after Tahrir Square revolt (the “Arab Spring” of 2011), “the Kiev Maidan of 2013-14 gave a sense of what a successful urban revolt might look like” (Zelinska 2017) that could trigger a “Russian Spring”. This prompted our curiosity for understanding: What makes absolute states like Iran and the United Arab Emirates invest in creating Maidans that persistently accommodate upheavals through time? Why are diverse people across a growing city still attracted to the same historical Maidans? How have these two Maidans become successful as eventless public spaces lost in time where city residents congregate to observe and encounter strangers? These are questions that urban designers have long been occupied with, leading to an evolving focus on place-making. The concept of “Place-making” is a multi-layered and people-focused approach to planning and urban design that draws together the unique qualities of a place, including the social, environmental, physical, historical and aspirational attributes. The tradition of place-making is well established globally with organisations like the US-based Project for Public Spaces (PPS) set up to help people create public spaces that build strong communities, since ‘it takes a place to create a community and a community to create a place’. Engaging the four parameters used by PPS, our comparative analyses examines the two case Maidans through the lenses of:

1) Access and linkage: Access concerns how well a place is connected to its surroundings both visually and physically. Accessible public places have a high turnover in parking and, ideally, convenient public transit.
2) Comfort and image: Comfort and image are key to whether a place will be used. Perceptions about safety and cleanliness, the context of adjacent buildings, and a place’s character or charm are often foremost in people’s minds—as are more tangible issues such as having a comfortable place to sit.
3) Uses and activities: Activities that occur in a place—friendly social interactions, free public concerts, community art shows, and more—are its basic building blocks: they are the reasons why people come in the first place and why they return.
4) Sociability: Places that avoid strict monoprogramming and instead foster diverse types of social activities for different people, what we call “eventless” places where people go to observe or interact with strangers (Project for Public Spaces (PPS 2017).

Both the cities of Isfahan in Iran and Sharjah in UAE offer large open Maidans for social performances. These cities are selected for their social diversity and intentional public places.
that guided the city growth. The Maidan Naqsh-e-Jahan in Isfahan and the Maidan Rolla in Sharjah were both intentionally designed to direct city growth and now act as epicenters of urban performances, attracting diverse people across social strata and age. While the countries where these Maidans are located may not be considered model democratic states, the enhanced social interaction that takes place in these squares across time has lessons for making “safe, inclusive and accessible, green and public spaces (United Nations 2015)”. Our research aims to: 1) Identify socio-spatial features of two integrated Maidans; 2) Decode the role of design in encouraging diverse social interactions. We propose a mixed-method approach to analyze the case Maidans: first, we layer historical maps of the two cities to identify persistent open spaces over time. Then, using “Space Syntax” we assess and measure urban connectivity to identify case squares (Kirchner-Rab & Kubat et al. 2012). Space Syntax is used here as a diagnostic tool to understand how the history and evolution of the city’s structure had led to patterns of density, land use and socio-economic settlement. We hope to identify spatial causes of what are seen as barriers to social cohesion and scientifically evaluate the current problems, determine which land uses are appropriate for the continuance of economic and social gains, and develop priorities for increasing livability for visitors and inhabitants. As part of the Space Syntax study, we surveyed the pedestrian and vehicular activities in each case city in order to understand current movement patterns. Data obtained from the analyses generated a multilevel, electronic database of urban form and function, containing: levels of spatial integration in the current street networks; levels of pedestrian and vehicular movement. The survey of pedestrian and vehicular activity to designate the relations between movement patterns and the function areas has been done using the gate method. To define daily densities in both working days and holidays the counts has been conducted at different times of the day and distinct days of the week. Finally, we have conducted non-participative observations and periodic fieldwork spanning over a decade individually in the two cities and the results achieved from individual case analyses have been comparatively evaluated using the PPS criteria of assessing public spaces.

1.3 A Comparative case investigation: socio-spatial analysis of maidans in the middle east
Maidān in Urdu or Meydān in Persian, is defined as an open space either inside or near a town. The external Maidans are usually configured for events such as public meetings, polo matches, informal trade and largescale prayers for celebrations that could not be accommodated within the city mosques. The internal city Maidans, according to Dehkhoda dictionary (1931), are open spaces flanked by houses and/or shops. As landmarks, the internal Maidāns in Middle Eastern cities are the most effective urban spaces imprinted in minds of citizens and distinguish different parts and districts within a city. External Maidans are often internalized as cities grow, as revealed in the two case studies from Iran and the UAE, as follow:

a. Maidan Naghsh-e-Jahan in Isfahan, Iran: Isfahan is as one of the old cities in Iran that its historical identity dates back to 2,000 years ago. It was twice capital of Iran: once in 11th-12th centuries, and again in 16th -17th centuries. Maidan Naghsh-e-Jahan in Isfahan was constructed between 1598 and 1629 in Safavid era as the most significant period in the history of Iranian urbanism. It is one of UNESCO's world heritage sites that was conceptualized with careful attention to the socio-cultural values. It was designed in Isfahani style, by two famous local architects namely, Mohammad Reza Isfahani and Ali Akbar Isfahani, who were the best architects in that time. The concept design of Maidan Naghsh-e-Jahan illustrates a dynamic confluence in Iranian Safavid architecture of power (royal palace), public realm (square), and society (people). It was both a ceremonial place for the government and a multi-purpose urban space served for commerce, civic, religious, and political activities by the residents (Soflaei and Zhu 2013). Figure 1 shows the historic urban development of Isfahan metropolitan area, in 1976, 1990, 2001 and 2010. As it can be seen Isfahan was developed toward Maidan Naghsh-e-Jahan as the main public open spaces in this city (Bihamta et.al 2014).
b. Maidan Rolla in Sharjah, United Arab Emirates: Sharjah is the third largest city in the United Arab Emirates with coastlines along the Arabian Sea and the Persian Gulf. Sharjah’s historic urban configuration and the architectural features supported “seascape urbanism” (Kirchner 2012) where the souk (market) comprised of shops open on two ends lined the water as “floodable space” while a defensive wall with Al Hisn Fort lined the outer edge of the city, guarding the merchant houses in between from rising water and the desert nomads. While Sharjah has transformed significantly since the discovery of oil and associated rentier economies, mapping urban continuities reveals the persistence of Maidan Rolla first as an external open space outside the Al Hisn Fort, known in historical records as Saht Al Hisn, where the settled community traded with the nomadic tribesmen travelling to Sharjah form the desert hinterland. Figure 2 illustrates the urban growth of Sharjah from 1820 to 2012, illustrating urban continuity of the Saht Al Hisn at the cross axis within the historic district. Sharjah’s seascape urbanism was first transformed by the city’s encounter with the air in 1931 with the construction of the first landing strip and an “air fort” for the British Imperial Air (Stanley-Price 2012). In the 1960s, Sharjah planned its second transformation by hiring the British firm Halcrow to plan its modern extension into the desert, facilitating vehicular mobility and allowing its rapid urban expansion into the desert. Beginning in the 1970s, planned modern interventions in Sharjah imagined a new city with its back to the gulf facing the desert, rather than defending against it. The introduction of Bank street perpendicular to the water required the demolition of the old Al Hisn Fort, which was “reconstituted” soon after through a ruler’s Decree. Though the city’s relationship with water drastically changed after the introduction of Bank Street, the Saht Al Hisn remained an open and inclusive public space renamed as Maidan Rolla, commemorating the banyan tree (tr. al rawla in Arabic) planted by Sultan Al Saqr al Qasimi in the late 19th century.

Comparing the Maidan Naghsh-e-Jahan in Isfahan and Maidan Rolla in Sharjah, this paper focuses on issues social interaction and urban integration through factors identified in the PPS Methodology. Comparative analyses of the two Maidan’s access and linkage, comfort and image, uses and activities, and sociability are presented as follows:
1.3.1 Access and Linkage

1.3.1.1 Maidan Naghsh-e-Jahan in Isfahan, Iran:
As a large-scale monumental urban space, it is located in the center of city to provide easy and direct accessibility for residents. It with the dimension of 160 meters wide and 560 meters long, was designed as social places to stop, integrate and watch in this period of time. It is surrounded by the Shah Mosque in the south, Ali Qapu Palace in the west, Sheikh Loff Allah Mosque in the east, and Keisaria gate opens to the Isfahan’s grand bazaar in the North side. Maidan is contributed to the urban transition by the concept of connectivity that emphasizes on a system of streets with multiple routes and connections serving the same origins and destinations. It is not only relates to the number of intersections along a segment of street, but how an entire area is connected by the transportation system (Soflaei 2014). The car accessibility has been restricted in only two main streets and the other 15 streets has been designed just for pedestrians. This idea provides a strong connected network of roads and pedestrians to help traffic move smoother, reduce travel distances and times, and enhance walkability, safety, and urban vitality around the Maidan. It also provides better routing opportunities for emergency and delivery vehicles (solid waste, recycling, mail). Figure 3 shows integration map of historical fabric of Isfahan (using space syntax method), which the spectrum blue to red presents the increasing of global integration. Blue (higher) to Yellow (lowest) spectrum shows the value of global integration in urban spaces. Thus, in this way one can identify the organizer structure by integration of urban functions. The results of analysis have shown that Chahar-Bagh as the main north-south urban axis, and also Amadgah-Sharif Vaghi as the main east-west urban axis have higher global integration value (Azari and Khakzand 2014).

1.3.1.2 Maidan Rolla in Sharjah, United Arab Emirates
The transformation of Saht Al Hisn to Maidan Rolla from an amorphous open space to a defined and rectangular public place was framed within the grid-iron plan to extend Sharjah into the desert. Al Hisn Fort was demolished in 1971 to make room for the 18 concrete buildings introduced along the first vehicular Bank Street (also known as the Burj Road) that ran perpendicular to the water. The Fort was later re-compiled following a decree and converted to a museum from 1995-97. The Fort Museum now exists as a precarious island within the Bank Street that divides the historic core into two distinct zones, Al Mureijah heritage area and...
Al Shuweyhein arts area. While the Bank Street divides the historic district, it connects the Rolla Square to the water and the rest of the city. The waterfront and souqs (market) that once acted as a primary entry point to Sharjah ultimately became an industrial backdrop. Investigating accessibility issues in the historic area of Sharjah through the application of the Space Syntax methodology revealed that vehicular roads running parallel to the waterfront (connecting Sharjah to Ajman and Dubai cities) and the roads that run perpendicular to these, like the Bank Street, are the most integrated streets forming a grid-pattern integrated streets system (Figure 4). Inside of each integrated grid road system, the center, where the residential neighborhoods are located, is rather segregated. This finding might be reflecting the characteristics of residential neighborhoods where privacy is emphasized (Rab et al, 2012b).

**Figure 3**: Integration map of historical fabric of Isfahan, as it is clear the "Ghahar Bagh" axis has the highest global integration value (Azari and Khakzand 2014).

**Figure 4**: Segment Space Syntax map of Sharjah shows the streets surrounding Maidan Rolla as integrated (Kirchner-Rab & Kubat et al, 2012).

### 1.3.2 Comfort and Image

#### 1.3.2.1 Maidan Naghsh-e-Jahan in Isfahan

Maidan Naghsh-e-Jahan in Isfahan is designed based on the relation between human-god through flanking mosques and religious schools, between human-human through commercial, governmental and recreational spaces, and between human-nature through natural elements like water and plants. The location and design meet various needs (physically, emotionally, socially and spiritually) of residents and provide a space for participation and social interaction for all people regardless of gender, race, ethnicity, age or socio-economic level. This spatial continuity has also caused three dynamic relationship between nature (square), human (main bazaar) and God (mosque) as a philosophical ideology. Studying the evolutionary process of Iranian Maidan in Safavid era has shown that they have experienced many changes in the passage of time. However, the continuity of their use through the time in respect to the socio-cultural values and user satisfaction has led to enhance the identity and sense of belongings
for residents. Some aesthetic factors like symmetry, rhythm, geometric proportions, low-rise and human-scale enhance visual richness of this place (Figure 5).

1.3.2.2 Maidan Rolla in Sharjah, United Arab Emirates

The Bank Street is a prime example of struggle between the progressive spirit of borrowed modernity and nostalgic reverence for an authentic heritage. Once past the Fort, the Bank Street intersects with a major artery running parallel to the water linking Sharjah to the city-states of Ajman and Dubai along the sides. The Saht Al Hisn modernized and formalized to first Maidan Rolla and later Rolla Square when the city extended into the desert. Private investors and city officials have planned and are implementing a large-scale urban transformation in the Heart of Sharjah project. This urban regeneration aims to demolish 68 tall buildings along the Bank Street and the water front to make room for reconstructed traditional houses that were erased in the 1970s modernization. The banks are moving out and demolition already under way to make room for a leisure and culture district across the Al Mureijah Heritage Area and Al Shuweyhein Arts Area. Almost 30% of Sharjah resides in this historic district but growing success of the annual Heritage Days and the Sharjah Art Biennales have presented the need for appropriating public places as event spaces. The urban regeneration project intends to replace 300,000 square meters of prime real estate with 14,000 square meters of low-rise buildings supporting the emerging need to host events related to heritage, culture and art industries. By 2025, the Heart of Sharjah project will demolish mixed-use buildings along the Bank Street, where approximately 50,000 diverse inhabitants live, mostly walking or taking the boats to work. Maidan Rolla was redeveloped in 2014 as a family-friendly space, fenced to keep the “bachelors” (low-income migrant workers) out and attract more affluent visitors (Figure 6).

1.3.3 Uses and Activities

1.3.3.1 Maidan Naqsh-e-Jahan in Isfahan, Iran

It and other monumental buildings around it including Imam Mosque in the south, Aliqapoo palace in the west, Sheikh Lotfolah mosque in the east, and entrance gate of Qeysareyeh bazaar in the north side, all are masterpieces that were designed by creative Iranian Muslim architects such as Sheikh Bahaee, Ali Akbar and Mohammad Reza Ifahani. This multi-functional Maidan is a formal landscaped and eventless open space surrounded by distinct religious, recreational, educational and commercial facilities. It is integral to the city because of its unprogrammed attribute that provides equal opportunity for all residents of distinct neighborhoods who visit the different religious and non-religious buildings around the Maidan (Soflaei 2013). Bounded by distinct functional buildings, Maidan Naghsh-e-Jahan has been used for different religious ceremonies, national celebrations, sport matches, resting place for commercial caravans, and polo as one of the main social activities. Field investigation reveals that the intersection of political power and religious belief anchor the Maidan as a key social place.
1.3.3.2 Maidan Rolla in Sharjah, United Arab Emirates
The open and formal shape of the Rolla Square made it a viable and accessible public place in Sharjah, attracting people from all walks of life, including low-income “bachelor” workers. It represented the demographic structure of the UAE, where citizens constitute less than 18% of the total population. The non-citizen working class is divided into low-income “workers” and middle-income professional “expatriates”. The Sharjah Art Spaces adjacent to the Rolla Square are experimental urban infill buildings designed by architects. It has received international acclaim as “Sharjah biennial’s biggest architectural surprise turning pedestrian alleys into continuous shaded passages at both street level and roofscape” (Universe in Universe, 2016). During the Biennale, for a few weeks every other year, Sharjah’s urban condition becomes a spectacle. The Biennale artists love the attention they attract from the diverse residents in the Heart of Sharjah and have repeatedly in interviews conducted from 2010-2016 said that Sharjah’s cosmopolitan residents from all walks of life are their biggest attraction. Some even employ them as part of their performance. Once the Biennale artists are gone, these exhibition and “event” spaces revert back to the Central Business District character of the historic district. The open and formal shape of the Rolla Square presented these residents with a clear and accessible public place, but it is now off-limits to migrant workers who reside in Sharjah without their families.

1.3.4 Sociability
1.3.4.1 Maidan Naqsh-e-Jahan in Isfahan, Iran
It were designed as multi-functional urban spaces to invite people for different events (religious and non-religious) and activities (actively and passively), and have never lost its social function in the passage of time (Aghajani and Soflaei 2013). Table 1 shows the social function of Maidan Naghsh-e-Jahan in the passage of time, from the beginning of Safavid era till present time.

1.3.4.2 Maidan Rolla in Sharjah, United Arab Emirates
The trading harbour along Sharjah’s historic centre was relocated across the water in 2010, disrupting the historic relation of souq shops with the sea port and the traditional exchange between buyers and sellers. As the public places transform to accommodate visitors, these shops are now selling commodities attractive to tourists rather than residents. By demarcating the fenced boundaries of the Maidan Rolla, Sharjah is denying its working class the historically continued use of an inclusive public place for social encounters across class, gender and ethnic distribution (Table 2).
Table 1: Urban development and social transition in Naghsh-e Jahan square through the time

<table>
<thead>
<tr>
<th>Dynasty</th>
<th>Social Activities</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1788</td>
<td>Political activities, religious ceremonies, commercial activities, traditional gatherings, military marches, polo matches, horse riding competitions, Festivals, religious festivals, fireworks, puppetry, acting, storytelling.</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>1925</td>
<td>Permanent commercial space, temporary Friday’s Market, demolishing the green space in the middle of Maidan for military training (barrack).</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>1970</td>
<td>Revitalization of Maidan and design accessibilities for car and pedestrians, consideration of fountain and green spaces (landscape) in the middle of Maidan for recreational and civic activities.</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>2014</td>
<td>Restricting the entrance of cars to the Maidan to provide safety and security, paving open spaces and design a landscape in the middle of Maidan to minimize the air and visual pollutions such as traffic lights, bus station, bars and etc.</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Table 2: Urban development and social transition in Rolla square in Sharjah, United Arab Emirates

<table>
<thead>
<tr>
<th>Dynasty</th>
<th>Social Activities</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1931</td>
<td>Saht Al Hisn, as the external Maidan outside the Al Hisn Fort, where the settled community of Sharjah traded with the nomadic tribes of the desert hinterland.</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>1978</td>
<td>Rolla Tree in a Maidan in Sharjah, served residents for almost 150 years and withered away in August 1978 by unknown disease.</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>1990</td>
<td>Rolla Tree memorialized as central sculpture of Maidan Rolla in Sharjah, 1990s, provided a shaded respite to the working expatriates.</td>
<td><img src="image7.png" alt="Image" /></td>
</tr>
<tr>
<td>2001</td>
<td>Maidan Rolla revitalized as Rolla Park with fenced enclosure that limits the use of the public space by families and excluding the “workers”.</td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td>2013</td>
<td>SUPERFLEX’s The Bank project introduced benches, bins, playground toys for the residents of the tall buildings and imagined a new non-monetary banking model for the street. The Bank is an urban currency converter of personal memories and stories, bringing social profit to Bank Street.</td>
<td><img src="image9.png" alt="Image" /></td>
</tr>
</tbody>
</table>

CONCLUSION

The history and transformation of both case studies of Middle Eastern Maidans reveal that land uses are important determinants of the pedestrian movement in an area, and any interference with the land use might have a significant effect on the movement potential of the area along with the demographic configuration. The problem faced by both Maidans since the introduction of vehicular traffic is very similar to the cases of other Islamic cities as Jeddah (Hillier, 2008) and Isfahan (Karimi, 1997; Kanimi, 2003), where the modern development of the
city has caused the old heritage districts to become disconnected from the city at large. In these cases, as in Isfahan and Sharjah, the city developed based on modern urban planning principles focusing on the primacy of vehicular traffic the scale of the context increased. The historic fabric of these cities has changed as a result of major program of road building and physical reshaping which in turn has shifted the structure of the integration core and thus weakened the connection of the heritage district. In all these cases we can observe that the historic core has a structure itself but as the city gets developed this structure gets disconnected and the challenge for urban designers is not to “redesign” but to reconnect. While both Isfahan and Sharjah as growing cities envision demographic shifts, each is distinct from the other in the demographic composition of residents, citizens and visitors. While Isfahan is a city of Iranian residents receiving a fraction of tourists, Sharjah’s transitory population contains a fraction of UAE nationals, who are a minority in their own country. Oil economy has played a significant role in generating a transitory work force in most Gulf Corporation Countries. Despite distinct demographic composition, both cities transform their historically inclusive public places by connecting them to the suburbs for easy access. The integration map of historical fabric of Isfahan have also shown that Chahar-Bagh (as the main north-south urban axis) and Amadgah-Sharif Vaghfi (as the main east-west urban axis) make the connection between Maidan Naqsh-e-Jahan and grid street pattern of the city. The urban transformation in Sharjah’s historic district is creatively demolishing existing buildings and redefining the role of public spaces from historically inclusive Maidan Rolla of chance encounters to a restricted fenced park. Sharjah’s initiative to redevelop Maidan Rolla will limit enhanced chance encounters and unplanned uses that develop place attachment for people of diverse backgrounds. Social sustainability of cities will require redefining and broadening key concepts such as inclusiveness and quality of life to include accessible participation of people from all city residents. Urban integration and social interaction are key factors in public places that perform as anchors of socially sustainable cities. Both Maidans examined illustrate urban continuity and enhance chance encounters between residents and visitors.

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REFERENCES
Hillier, B. 2008. Using Space Syntax to Regenerate the Historic Centre of Jeddah or Why We Need Architectural Models of Whole Cities, presented at UIA World Congress, Torino, Italy.
CULTURAL PRODUCTION


Kirchner, Samia. 2012. Sharjah: Seascape Urbanism in a Khaliji 2 Port City. In Where do you stand? ACSA.


Soflaei, F. 2014. A Study on Revitalization of Baharestan Square in Tehran, Iran; Redesigning with the Goal of Changing from an Insufficient Traffic Node to a Sufficient Social Place. Saarbrücken, Germany: Scholars' Press.


256 Middle Eastern maidans: the role of interactive and integrated public squares in urban social sustainability
ABSTRACT: Climate change forced displacement and resettlement is becoming a pressing topic as the impacts of sea level rise, drought, and severe tropical storms increasingly impact communities' livelihoods. As communities and entire nations are forced to resettle, how will basic social and cultural structures be maintained? The transportation of resilient socio-cultural patterns becomes essential for maintaining the health and well-being of a community. Thus, the investigation of the dialectic relationship between culture and the built-environment is essential in the Anthropocene.

Through a multi-sited case study of the Republic of the Marshall Islands, this paper demonstrates the use of Indigenous Knowledge within the production of the built environment to negotiate the relationships between the social world, the natural world, and the colonial world. Three communities were studied spanning rural, peri-urban, and urban environments in order to demonstrate the application of Indigenous Knowledge across space and time in the production of the built-environment. Participant observation, unstructured interviews, mental mapping exercises, site documentation, and aerial mapping were among the methods used for data collection in order to triangulate evidence.

A framework of six systems of Indigenous Design Knowledge were uncovered; each have aided the Marshallese in the production of culturally-supportive environments in the face of colonization, urbanization, and the imposition of U.S. imperialism. While further investigation in the cultural production of space in the Marshallese Diaspora is required, it is argued that this framework of Marshallese Design Knowledge should be employed in the planning, design, and management of any future resettlement proposal to assist communities in the maintenance of healthy socio-cultural patterns through the cultural production of the built-environment. Furthermore, the methods and approach taken in this study demonstrate a useful framework for investigating the dialectic relationship between culture and the built-environment for other climate diasporas.

KEYWORDS: Indigenous knowledge, climate change, climate diaspora, design framework, deep-culture, urban planning, architecture

INTRODUCTION

The projected impact of global climate change on community resilience places a significant proportion of the world’s population in a precarious position; from sea level rise to receding glaciers and drought, the continued habitation on ancestral homes is at risk for communities across the world. The continuity of the Marshallese way of life is threatened by sea level rise, and many argue the nation is entering a climate migration (Burkett 2011; Heslin 2019). In the long-evolution of Marshallese culture, migration has been a resilience mechanism in face of climatic events; this has been a practice for many small island populations in need of refuge (Spennemann 2005). In a way, migration becomes a natural adaptive response.

Migration from the RMI to the United States has increased steadily since the Compact of Free Association between the two countries was signed following the departure of the United Nations Trust Territory of the Pacific (Hezel 1995). One might argue that current migration of Marshallese into the United States demonstrates an extension of these traditional forms of resilience to climatic events. The following literature helps to frame the application of the main findings from the research study as a way forward for assisting urban planners, urban
designers, and architects develop inclusive policies that allow for Marshallese communities to create their own sense of place and mitigate culture loss through resettlement.

1.0 Socially and Culturally Supportive Environments

Settlement without economic or social support is extremely difficult. Social capital becomes vital for the new immigrant. Indigenous knowledge could prove useful in ensuring the wellbeing of Indigenous communities facing environmental forced displacement. My previous research in post-disaster settlements of Haiti demonstrated the use of local knowledge, embedded in Haitian culture, in the development of social capital within self-settled post-disaster settlements (Miller 2014). Alexander et al. (1977) demonstrate the intricate connection between socio-cultural patterns and the design and construction of space that is both culturally supportive and supportive of social behavior. Alexander (2004) argues that the pattern language created through these socio-spatial behaviors assists in the development of wholeness. In addition, Lawrence and Low (1990), Low (2016), and Gehl (2011) demonstrate design patterns in the support of social and cultural behaviors and the benefits of these socio-spatial design patterns in enhancing social support systems for a community's wellbeing.

Within resettlement models, three primary models are discussed at length in the literature: Impoverishment risks and reconstruction (IRR); Involuntary Resettlement and Sustainable Livelihoods (IRSL); and Inherent Complexity (IC). In IRR, Cernea (1998) outlines eight risks faced by people subjected to displacement: landlessness, joblessness, homelessness, marginalization, social disarticulation, food insecurity, increased morbidity, and loss of access to common property resources. In the IRSL model, McDowell (2002) emphasizes the importance of socio-cultural components inherent in community disarticulation – the socio-cultural spatial patterns of self-organization, social interaction, and reciprocity – and the significance of social capital. Lastly, the IC model calls for open-ended participatory processes within resettlement programs that account for the inherent complexity of a resettlement program and the livelihoods of re-settlers. While it is unlikely that the everyday cultural patterns of a pre-displacement populations will be recovered, enabling participatory processes in planning and development efforts can mitigate shock and culture loss (Downing and Garcia-Downing 2009). This paper emphasizes the role of Indigenous Knowledge in the creation of placemaking and place attachment for resettled communities. Through these processes spatial production, social and cultural capital are developed within re-settled communities

1.1 Placemaking

Place is the centering of individual and shared meaning among a community (Relph 1976). It is where individuals and groups find meaning in their environment and the act of placemaking assists cultural and social capital (Lewicka 2013). The production of the city generates economic, cultural, social, and symbolic capital within a complex social and political dynamics (Bourdieu 1990). Placemaking is mediated within the social field, constructed through cultural, social, and political factors. The meaning imbued to space by a group of people are reflected by the negotiation between culture and the place-specific social practice (Low and Smith 2006; Massey 2005). The social relations among and between community groups and the everyday practices are shaped by institutions and socio-poetical structures (Sandoval and Maldonado 2012). The shift in the demographic landscape of a community begins to alter these structures and power relations, issues arise across groups, especially in relation to racialized space.

The structural power dynamics of the city play a significant role in the placemaking processes of immigrant communities. As everyday practice counters institutionally structured fields of power, the act of deterritorializing and reterritorializing space within immigrant creations of place, character, and identity shift the discourse of institutionalized planning codes (Dovey, Woodcock, and Wood 2009). Rios and Watkins (2015) demonstrate that placemaking is a translocal process of territorializing the ‘circuits’ of place as an assemblage; they demonstrate the temporality of place-identity and placemaking within receiving communities and the need to challenge the normative and binary assumptions about land use and spatial practice. Regarding ‘character’, Davison (2013) speaks to its role in the place-making of the Latino community in Fruitvale, California. ‘Character’ is produced only as a surface construction of
identity within the aesthetic of redevelopment rather than an embedded design pattern in the
construction of socio-culturally supportive space. As Dovey et al. (2009) state, ‘character’ is
not deep rooted. In negotiating the transnational field of social practice, Indigenous
placemaking raises an important question: What is the translocal placemaking of indigenous
urban communities within the politics of space and settler colonialism?

1.2 Indigenous Placemaking
For Indigenous communities, the boundaries of place vary from those of Ameri-European
concepts of land and property; the sense of place tied to the land is complex, shaped through
an intricate relationship between people and place (Nejad and Walker 2018; McGaw, Pieris,
and Potter 2011; Potter 2012). Placemaking in the context of Indigenous communities is
complex, and even more so for those displaced. When western planning and architecture is
implemented on Indigenous lands, the fluid nature of land tenure is erased by the legibility of
boundaries that demarcate power (Scott 1998). The plan or map is a territorial force that
colonizes space (Lozanovska 2002). These dynamics follow displaced Indigenous
communities as they are re-settled. In the Republic of the Marshall Islands, the United States
imposed their dominance on the landscape of the Marshall Islands by constructing Majuro and
Kwajalein as model American towns (Hirshberg 2015). The United States created a sense of
place based on the U.S. military industrial complex at the expense of Marshallese place-
identities. Through the Compact of Free Association this settler dominance of Marshallese is
carried onward through the current Marshallese migration into the United States. The relations
of power and privilege are reinforced through these everyday acts and the western
construction of the built-environment (Nejad and Walker 2018).

IK develops design processes that negotiate between settler and the aboriginal community.
The IK is used to position itself in relation to natural systems and the social world as well as
between the colonizer and the social world (Sheehan 2011). This means that within the context
of settler colonialism, IK does not necessarily prioritize the natural environment but rather the
survival of indigenous ways of life. In the Marshall Islands, the shift of land use from
subsistence livelihoods to its real estate values demonstrates an active decision re negotiation
of the value of land and the value of the natural environment. Of course, this position would
not exist without the impacts of urban development through settler colonialism of US
imperialism. Thus, demonstrating the evolution of IK from negotiating the relationship between
social livelihood and natural environments to social livelihood and colonialism.

The formation of the Indigenous habitus is an important component in the application of
Indigenous Knowledge to the creation of place-identity and place-attachment within the built-
environment. IK acts as the cultural guideline for the adaptation of physical form and negotiates
the power structure imposed upon by western planning regulations to benefit the continuity of
cultural patterns (Potter 2012). Furthermore, IK negotiates between the social world, the
natural world, and the built world (Sheehan 2011). From individual to individual and group to
group the outcome may be different, but the deep-cultural pattern is representative of IKs
power to assist in cultural maintenance.

1.3 Place Attachment
An important component of placemaking, place-attachment supports the wellbeing of a
community (Mazumdar et al. 2000). The cultural and social capital derived through place-
attachment provide a community a sense of place and support their wellbeing (Lewicka 2005).
Indigenous knowledge plays a vital role in an Indigenous community’s ability to create their
own sense of place. The maintenance of cultural practices such as strong social ties and family
co-residence improve community wellbeing through migration, and social capital plays a
significant component to community wellbeing (Rogers 1996).

Cultural and physical elements of place support identity and develop place-attachment. Mazumdar et al. (2000) identify the character of architecture to be an important component in
establishing place-attachment within enclaves. The character of a space as well as that of a
building also support place attachment. For example, an immigrant community may identify the landscape, both natural and cultural, of a receiving community with the homeland. Additionally, the ability of a community to participate in the control of space further supports their ability to make a place their own. Where immigrants can make social and cultural connections that confirm cultural identity place-attachment occurs (Main and Sandoval 2014). Thus, communities remake places through everyday practice, altering the dynamic nature of a place assemblage (Rios and Watkins 2015). This identity is grounded in both social and environmental experience, grounded in the dialectic relationship of people and environment. Architecture and spatial patterns within urban design or adaptation expresses collective identity. The question remains, how many generations will place-attachment and place-identity mitigate culture loss through processes of assimilation?

Gupta and Ferguson argue that the third generation is often defined as the generation in which assimilation has completed its course. However, Lozanovska (2008) argues that architecture and architectural design withhold the capacity to assist communities resist assimilation. Using the concept of ‘taste’ Lozanovska demonstrates the importance of analyzing architecture through complex systems or assemblages rather than binaries. The migrant house is an embodiment of everyday practice, a manifestation of aesthetic judgement and taste; the house provides a sense of agency and projects identity into the social and cultural field of practice (Lozanovska 2008). Again, the notions of distinction, character, and symbolic capital arise as important components within immigrant spatial identities.

2.0 METHODS

The research asked how a culturally supportive environment is produced within the context of settler colonialism, United State imperialism, and global pressures; this inquiry tested the existence of deep-cultural patterns within the dialectic relationship between culture and the environment. Employing a multi-sited case study, the research was conducted on three different villages in the RMI, consisting of Djarrit-Uliga-Delap, Majuro, an urban center; Laura, Majuro, a peri-urban village; and Namdrik Atoll, a remote atoll. The selection was based on the different contexts, demonstrating theoretical replication (Yin 2009). The research design consists of data collection through ethnographic field study of selected villages, buildings and site surveys, and archival research on each village selected, consisting of historical development, family lineage, and unstructured interviews. A deep-time perspective of the Marshallese culture-environment relationship was developed through a review of historic ethnographies, the archaeological record and archival data concerning historic change to the built-environment and human settlement. The goal was to uncover the changes within the Indigenous construction of the built-environment and its spatial arrangements, material use, building design, and the integration of resource use within the habitation zone known as the weto. The weto introduces one to the system of habitation that represents the cultural habitus.

Sampling consisted of two phases, the first phase was the primary field research collected on wetos and the second phase was a validation survey that tested emergent patterns across a larger population on Namdrik and Majuro. Following cultural protocols, Government officials, traditional chiefs, land owners, and community leaders assisted in gaining access to each site, introduced me to potential participants, and governed the scope of research. Self-selected sampling was employed for the selection of wetos at each site. A family needed to both understand the purpose of the research and agree to participate as well as agree with the extent of the data collection, which consisted of me participating in daily life on the weto for an extended time. The primary modes of data collection were participant observation, interviews, habitation surveys, and participatory mapping. The goal of the observations was to develop an understanding of the minutiae of daily life in regards to habitation. Interviews and participatory mapping exercises explored the changes through time in the production of the built-environment based on participants life experiences. Building and site surveys consisting of measured drawings of buildings and aerial imagery were analysed for spatial relationships using spatial analysis tools in ArcGIS and through Space Syntax using convex analysis. Qualitative research software was used to code and analyse the qualitative data, and ArcGIS, DepthmapX, ‘R’, and JASS were used for spatial analysis. Through the process of reviewing
historical ethnographies, archaeological records, field notes, continued communication with the communities, and reflexive practice, the generative patterns that governed the production of the built-environment in relation to the *weto* emerged.

### 3.0 FINDINGS

Through the analysis of everyday socio-cultural practices in the production of space, the research uncovered six interconnected deep-cultural patterns that are based on the intersection of family, identity, and land. These patterns are 1.) Land as wealth and 2.) Land as Identity, both of which are embedded within the *weto*, which represents the land tenure system through matrilineal inheritance of the Marshallese; 3.) *Ippan Doon* or togetherness, which manifests in the clustering of housing; 4.) *Juon Kijeek* or One Fire One Family, which represents the interconnection of family through the sharing of resources and knowledge; 5.) *Emlapwoj*, which represents the multi-generational family living arrangement; 6.) Process built housing, which represents the iterative process in developing effective design solutions that support everyday life. The patterns represent persistent socio-cultural spaces established through everyday behaviour, the continuity of spatial integration and ‘genotype’ (Hanson 1998) across rural and urban settlement, and the recreation of Indigenous processes amidst modern urbanization; all of which demonstrate cultural agency. While this paper focuses more on the application and implication of these findings for immigrant communities rather than on the demonstration of each pattern, Table 1 provides a brief overview of the manifestations of each knowledge system in relation to the three sites.

**Table 1**: Everyday manifestation of the six deep cultural patterns (IK systems) in each site.

<table>
<thead>
<tr>
<th>D.C.P.</th>
<th>Manifestation Namdrik</th>
<th>Manifestation Laura</th>
<th>Manifestation Majuro (DUUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land as Wealth</td>
<td>Cultivation for sustenance; cultivation of cash crops</td>
<td>Cultivation of taro; land leasing; cultivation of cash crops</td>
<td>Cultivation of bananas; land leasing; access to the city</td>
</tr>
<tr>
<td>Land as Identity</td>
<td>Traditional land tenure and presence of cemetery.</td>
<td>Traditional land tenure and presence of cemetery.</td>
<td>Traditional land tenure and presence of cemetery.</td>
</tr>
<tr>
<td><em>Ippan Doon</em></td>
<td>Clustering of houses along the lagoon at the widest part of the island.</td>
<td>Clustering of houses along the lagoon.</td>
<td>Clustering of houses to maintain family cohesion.</td>
</tr>
<tr>
<td><em>Juon Kijeek</em></td>
<td>Extended family shares meals from the central cookhouse.</td>
<td>Family shares meals from a family cookhouse. Western kitchen is introduced.</td>
<td>Family shares meals from a family cookhouse. Kitchen has largely replaced the cookhouse.</td>
</tr>
<tr>
<td><em>Emlapwoj</em></td>
<td>Alap’s house is the central structure of the <em>wēto</em> housing the grandparents and grandchildren.</td>
<td>The extended family lives under one roof. Parents occupy individual bedrooms while children share main room.</td>
<td>Alap’s house is the central to the <em>wēto</em>, housing the extended family. Similar arrangement to manifestation in Laura.</td>
</tr>
<tr>
<td>Process built housing</td>
<td>Community building process (<em>kumit</em>) is used in construction.</td>
<td>Community building process (<em>kumit</em>) is used in the construction of a USDA house.</td>
<td>Community building process (<em>kumit</em>) is used in the roof replacement of a house.</td>
</tr>
</tbody>
</table>

These patterns demonstrate the production of supportive environments through the practice of Indigenous Knowledge. While colonization and globalization have had major impacts on the built-form of the Marshall Islands and the Marshallese cultural evolution, I argue that these
everyday cultural spaces demonstrate deep cultural patterns that aid in the reproduction of the Marshallese place-identity, and that the active creation of these spaces and spatial organization represents Indigenous Knowledge. Marshallese create new spaces and adapt to existing western developments through Indigenous design knowledge in the production of culturally supportive built-environments. The presence of deep-cultural patterns and the application of IK in the creation of Marshallese space within the settler-colonial context is particularly relevant for migrant communities. Arguably, the Marshallese diaspora is a continuation of the settler colonial experience of Marshallese communities, directed by the imperial control of the United States.

4.0. APPLICATION

Indigenous knowledge aids in the construction of the Indigenous habitus, that is the deeply buried schemes that constitute a culture, transforming collective heritage into an individual and collective subconscious. As Bourdieu (1977) argues, the house symbolizes the epitome of the habitus, which demonstrates the significance of the built-environment in the construction of the habitus and the maintenance of culture. In the case of the Marshallese, the cultural construction of the indigenous habitus is often in opposition to outside influence. The six deep-cultural patterns present generative schemes within the dynamic system of the Marshallese habitus. As external and internal relationships evolve, these deep schemes provide constants. The reproduction of these cultural spaces demonstrates agency of the deep-cultural patterns and the adaptability of indigenous knowledge to pressures. “Land as Identity” speaks directly to the Marshallese Habitus. A councilman from Djarrit reflects on how his identity is formed through his relationship with the *weto* and the knowledge he gained through his ancestral lands. He stated:

> In fact there are other [places] way better than where I live, I know. But, I always came back home. Came back to my roots. When I go to school [in the USA] it made me, I didn’t find myself. What’s important. I have everything on this soil.

These six deep-cultural patterns contribute to an Indigenous Design Framework for Marshallese placemaking. While not a complete representation of all Marshallese placemaking patterns, it is conjectured that the application of this framework within immigrant communities will assist the formation of cultural capital, mitigate culture-loss and help to establish place-identity and place-attachment. Policies that support these processes will need to: 1) leverage the cultural capital apparent in adaptive strategies within the built environment and 2) ensure the ability of a culture to participate in the production of the built environment. For example, the *Emlapwoj* deterritorializes the structure of the western tract house and reterritorializes the segmentation of space as a microcosm of the village model - a settlement pattern of the extended family in which partnered couples live in sleeping huts while their children live with the grandparents in the larger main house. Figure 1 uses diagrams to express the evolution of this process. The Marshallese reconstruction of space supports everyday culture and has been observed within Marshallese communities in the United States.

Within the design of policy and planning for resettlement programs, the following areas need to be addressed in light of the findings. In resettlement planning, land tenure will need to follow existing land holdings with equal diversity and complexity of resources. Whether these are real-estate values or natural resources. Policies have to allow for the *Emlapwoj* to thrive, for example limitations need to be removed from the number of individuals in a household and restrictions lifted on requirements for permanent addresses of inhabitants who frequently move among family housing (a frequent issue cited in the Springdale, Arkansas school district discussed in interviews with the Marshallese community in northwest Arkansas). In a resettlement housing program, families could be provided the option to pool their housing allowances in order to afford a large house rather than smaller individual homes. The opportunity for self-built housing needs to be provided along with the opportunity to participate in a communal building process. A clear understanding of the implications of construction material choice on cultural processes needs to be established together with the community. Housing should provide the option for indoor kitchens and outdoor cookhouses as to not assimilate Marshallese household behavior to Ameri-European constructs. In combination,
housing arrangements should be based on both land holdings and family groups to replicate resource sharing among groups. Guidelines such as these are a start to the collaborative planning for resettlement. It is in the creation of architecture from the bottom-up, that is to say – the local that we can being to both respect Indigenous or endogenous design knowledge and decolonize the production of space. I argue that the Indigenous knowledge is far more important to the lives of the communities than the global/ western knowledge.

While it is idyllic to consider the application of these knowledge systems in the maintenance of culture through colonization, transnationalism, and climate migration, practices that counter the good of the community must be kept in mind. Wilson (2003) argue that Indigenous peoples use their relationship with the land as a method to resist colonial development. However, these negotiations often recreate the hegemonic social order. In the Marshalls, I would argue that some Marshallese land owners negotiate their relationship between the land and understanding of capitalism to leverage their position of power; they negotiate Indigenous ways of knowing and responsibility to the land with the desires of western development to utilize the land. Resource extraction or the pure exchange value of the land overshadow communal benefits of resource use and lead toward new forms of neo-colonialism. Thus, rather than seeing the land as a static traditional connotation of for example subsistence production – the land is used as a tool within the capitalist modes of production to benefit the position of the Marshallese land owner within the hegemonic order.

![Diagram](image.png)

Figure 1: Diagram to demonstrate the evolution of the *Emlapwoj* from the traditional formation to the urban formation.

**CONCLUSION**

The displacement of the Marshallese to the United States through economic push-pull factors and climate forced displacement demonstrates the extension of the neo-colonial hand through a transnational and borderless state of existence. Marshallese placemaking remains at odds with settler-colonialism, and the Marshallese diaspora is defined by a loss of place and a loss of the symbiotic relationship between place and self. Lozanovska (2002, 141) expresses that to exist in a diaspora is to exist in, “a kind of eternal homelessness or placelessness, paradoxically singed by ongoing home building and construction of settlements.” Tying these sentiments to the larger discourse of climate refugees, the climate diaspora suggests a desperate existence for communities across the globe who will have lost their identity associated with place and their ancestral homes. This makes the reality of indigenous placemaking ever more complex as displacement, borderlessness, and homelessness become realities to the continuity of the Marshallese cultural identity and that of Indigenous peoples globally.

Through shared experiences, histories, stories, symbols, place-names, landmarks, etc. in the built-environment enhances a collective sense of meaning; this sense of place identity reinforces a collective attachment of place through these interconnected memories, identities,
and sensory stimuli (Untaru 2002). Through these modes Marshallese communities re-create everyday cultural patterns within western forms of architecture and urban development while also constructing new meanings around heritage, such as the case of Americatown in Uliga, Majuro, RMI. In Springdale, Arkansas, a hidden aesthetic allows Marshallese to hide in plain sight and keep rule breaking hidden behinds the facade of a suburban duplex; the only distinguishable cue is the pile of shoes on the front porch stoop (Miller 2017). This notion of hidden aesthetic allows the Marshallese community to avoid risk associated with the surveillance of the municipal government; this process ties to Lozanvska’s (2008) resisting assimilation.

Social capital becomes embodied in place for better or worse, and the implications of place – especially in a settler colonial context – implicate one social group’s dominance over another. The symbolic capital of Indigenous placemaking as statements of identity and presence may provide opportunities to dismantle dominance. The ‘character’ or ‘distinction’ of these placemaking practices should be considered carefully. Davison (2013) argues that ‘Character’ is produced only as a surface construction of identity within the aesthetic of redevelopment rather than an embedded design pattern in the construction of socio-culturally supportive spaces; it is maintaining the power structures rather than being inclusive of Latino place-identity. Additionally, Dovey (2010, 7) argues that symbolic capital is seen more as a form of distinction rather than a form of capital, yet within the symbolic resistance of much Indigenous placemaking, such as the construction of hale on Mona Kea (see (Callis 2018)), it is clear that the symbolic capital is strengthened through both cultural and social practice, becoming a powerful gesture of identity in place – even if only temporarily. One must avoid undermining the symbolic capital represented by the character of place-making acts of Indigenous Peoples. The risk here is the oversimplification of placemaking practices.

Indigenous peoples are commonly left out of decision-making processes, I wonder if this will continue as many of the communities most impacted by climate-change forced displacement and resettlement are indigenous. This is especially true within discussions of urban development as opposed to rural (Behrendt 2009). Indigenous identities are often construed to being connected to nature rather than the physical form of the human made city; thus, Indigenous people are left outside of contemporary power in the city (McGaw, Pieris, and Potter 2011). To reiterate McGaw, “How do we decolonize the settler-colonial city?” (McGaw, Pieris, and Potter 2011, 307). As McGaw argues and my studies in the Marshalls demonstrate, the binary of settler-colonial and Indigenous place in the city is not binary, it is a complex interplay of negotiations. As I argue, these negotiations take place through the use of Indigenous Design Knowledge in the adaptation to and creation of culturally supportive spatial patterns.

To conclude, I argue that more grounded studies of communities facing climate forced displacement and resettlement are needed to better inform inclusive urban policies. Understanding how Marshallese placemaking happens within the diaspora, or any other group facing climate forced displacement will assets urban planners and policies makers to create more inclusive environments. Placemaking is everyone’s job.

REFERENCES


CULTURAL PRODUCTION


ENDNOTES

1 A deep-cultural pattern is a habit or ritual that has persisted through the long-evolution of the culture-environment relationship that manifests in built-form and in support of everyday culture. Deep cultural patterns are generative in nature, and various physical manifestations may share the same deep cultural pattern” (Miller 2018: 92).

2 The weto is based on matrilineal inheritance, the traditional land tenure system in the Marshall Islands. It is a transect of the islet of an atoll that provides land from the ocean to the lagoon. The weto provides for the division of land based on resource allocation to each family, allowing each family access to the lagoon resources, land resources, freshwater, and the ocean resources.
Inventing new modes of dissemination: applied preservation and cultural heritage pedagogy in interdisciplinary studios

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ABSTRACT: When we shift the word practice from noun to verb, practice turns into testing, experimenting with what is at hand. If we then apply this performative approach to the practice of teaching preservation and cultural heritage in a design studio setting, what would be the consequences? What would happen if we consider teaching as a practice of research and, consequently, of research as experimentation in a field that inherently resists innovation of practice?

Two professors, one from architecture, the other from interior design, offer preliminary answers to these questions while also laying out a model for a new critical pedagogy built on an interdisciplinary practice of teaching in which students from architecture, interior design, and landscape architecture have to address their own position within the context of a new studio while confronting a new language, i.e. that of the other discipline.

In this study we analyze two interdisciplinary studios we co-taught in 2017 and 2018 as case studies for applied history and the production of culture through our collaboration with the US Department of State’s Overseas Building Operations office in Cultural Heritage. In these research-based, interdisciplinary design studios we were tasked by the State Department to develop new methodologies of documenting and disseminating via websites information about two historic properties abroad, the Winfield House (London) and the Villa Petschek (Prague), both historically significant American Ambassadors’ Residences.

Our work resulted in a body of research that emerged out of applied onsite field work combined with analytic methods, archival investigations, and interdisciplinary communication to create a holistic understanding of the role historic properties abroad can play in the production of culture within an academic environment that is linked through current technology to society at large.

KEYWORDS: Diplomacy, US Department of State, Interdisciplinary Studio Pedagogy, Architecture, Interior Design

INTRODUCTION

Ideas about applied theory, history, and culture have permeated the architectural discourse at least since the renaissance when Leon Battista Alberti (1404-1472) and Andrea Palladio (1508-1580) published texts in which they disseminated expert knowledge about building methods while using their own projects as idealized case studies. By the 1800s their building-centered approach to architectural theory and practice were to be transformed by writers like Friedrich Schlegel (1772-1829) and Wilhelm von Humboldt (1767-1835) into philosophical structures that would have a long-lasting influence on education in central Europe and beyond. A well-balanced humanist education stood at the center of someone like Schlegel who wrote in his Fragmente that the French Revolution, Fichte’s epistemology and Goethe’s Wilhelm Meisters Lehrjahre [Wilhelm Meister’s Apprenticeship] are the most important tendencies of the age. (Schlegel [1798] 1904, 157).

By comparing the French revolution with Goethe’s coming-of-age novel [Bildungsroman] Schlegel articulated the importance of a holistic education for a burgeoning bourgeoisie.
Humboldt had taken on the project to transform the Prussian education system six years earlier when he wrote that the true purpose of man...is the highest and proportional formation of his energy toward a whole." (Humboldt [1792] 1851, 9)

Humboldt’s approach was influenced by political and social events in the early 1800s, such as Prussia’s defeat by Napoleon in 1808 (which highlighted the failure of relying on blind obedience in decision making) and yet his earlier project had to wait until he was assigned to the Department of Culture and Public Education [Kultus und öffentlicher Unterricht] in the Interior Ministry of Prussia. (Orzessek 2017). By situating his ideas about education in the larger context of creating an independent (and independently thinking) and comparatively emancipated populace, Humbold laid the foundation for a transformative educational system that still exists today in Germany. The core of his approach to education embraces the ideas that schooling is no longer dependent on the student belonging to a certain social class and that the state’s task is larger than the education of specialists.

We want to make the argument that today, with a push for specialized education focusing mainly on STEM disciplines at the expense of the humanities, it may be time to take to heart Humbold’s perspective of a broader education that can borrow from both the sciences and the arts. Preservation education is well positioned to take on this challenge since recent developments in technology connect it squarely to the advanced sciences while its other leg relies on humanist disciplines such as history, archaeology, and the traditional design disciplines, including architecture, interior design, and landscape architecture.

In our studio work we have extended this hybrid mode of working across the arts and the sciences into our two studios as we combine traditional means (IRB-approved questionnaires, archival research, material cultural analysis, historic structures reports, interviews) and digital technologies (LIDAR scanning and processing, videography, panoramic and conventional photography) to research and analyze significant historical properties abroad, and to create web and virtual experiences that would allow the American public—which effectively owns the diplomatic sites abroad—and anyone else with a network connection to access and learn about the buildings’ complex history without physically visiting them, since, unlike museums and other institutions, the State Department properties are not physically accessible by the public.

1.0 ANALYTIC METHODS
In this paper we used three types of qualitative research methods. The first consists of case studies through which we analyze a series of student-generated representations of significant properties owned by the US Department of State abroad (the wide range of research is detailed in the Pedagogy section below). The second method involves phenomenological analysis using interviews of staff we recorded on site in London and Prague to understand the staff’s personal perspectives on working for the US federal government. The third method involves narratives generated by students using raw video from the interviews with staff that were then edited and intercut with animated photographs taken onsite of the buildings (interior, structure, and exterior), the furniture, and the art work.

2.0 INTERDISCIPLINARY STUDIOS
The two interdisciplinary studios we have taught so far in the College of Design at Iowa State University are part of a larger effort to prepare students for interdisciplinary collaboration which they will have to be familiar with when then enter the professional field of preservation as informed citizens. We consider our pedagogy to be the vanguard of a new type of cross-disciplinary case studies that has the potential to transform narrowly discipline-specific approaches. The first studio, DSN S 546 Preservation & Cultural Heritage England, International Perspectives and Design Issues, came about as part of a concerted effort to create a new historic preservation program that would draw faculty in a collaborative non-hierarchical structure of equals from four programs within our College of Design which include the departments of Architecture, Community & Regional Planning, Interior Design, and Landscape Architecture. For the near future we plan to expand this roster and start to collaborate on interdisciplinary projects with faculty from other departments both within our
College of Design (Graphic Design, Industrial Design, Arts & Visual Culture) and across the university, such as History, Anthropology, and Archaeology. The interdisciplinary studio, initiated by professor NameOfProfessor2—who has fifteen years of experience with large-scale preservation projects in addition to a Ph.D. in Design History—is our test case for pedagogical research and a potential prototype for other departments in the university to emulate. Now in its third iteration we have continuously attracted a larger number of students (18 for London in 2017, 28 for Prague in 2018, 35 for Tangier in 2019) and a larger percentage of students from different countries. Currently our international students come from Syria, Lebanon, Oman, Indonesia, China, and India. We articulate in the Pedagogy section below the impact of this diverse student body on teaching and learning.

2.1. Pedagogy
The pedagogy of preservation and cultural-heritage studios works against the grain of conventional design studios by emphasizing research and writing over generative drawing and three-dimensional modelling, which are still the mainstay of most architecture and interior design studios. Most of the teaching at the oldest US Historic Preservation program—at Columbia University—is weighted toward non-studio courses, and where those courses are studios, they involve a substantial travel component for onsite work that reinforces the importance of research in pedagogy (Dolkart 2018). Focusing on research in a design studio is still a hard sell for students who are used primarily to a production- or making-oriented environment that they know from their earlier years in an undergraduate program. This is one reason why we emphasize up front that our studio relies heavily on students choosing to engage in, and frame the scope of, their learning, i.e. the design process, which will then culminate in the final iteration of their project to be shared with our US Department of State liaison. We also stress that we expect every participant in the studio to bring their best knowledge and experience to the table and simultaneously expand his/her horizon by stretching and learning new ways of working both individually and in teams. To that end we take brief surveys at the beginning of the semester to evaluate what students know already, what they would like to know more about, and then we adjust how we match students in small teams to maximize their learning experience.

Having students in class from many different cultures makes our teaching task more difficult but also more rewarding. Students from similar cultural backgrounds tend to gravitate toward each other in class but that defeats the purpose of an interdisciplinary studio. Consequently we make sure to create small groups of two or three students for short studio projects where he have students with different nationalities, cultures, genders, and races work together. Having to collaborate with those different from oneself confronts the easy rejection of otherness head on. Iterative collaborative work on short projects helps to overcome the initial awkwardness of difference, and over the span of a four-month-long semester it creates a certain level of comfort with diversity. The resulting openness towards difference, which results in a curiosity about other countries and their customs, has so far been encouraging.

We should also acknowledge that, as instructors, we consider each new studio as an elaborate experiment where both teachers and students learn how to adjust to a fluid mode of working that frames the studio as an intersection of theory and practice. In this case the subject matter happens to be preservation and cultural heritage but the fundamental exploratory and experimental nature of how an upper-level studio works, remains the same. To that end we also believe the most effective way to learn involves a shuttling between theory and practice, between ideas and their application within both a philosophical (the minds of the students) and material construct (the studio space and its productions). The foundation of our studio can therefore be understood as an interplay between instruction and its translation into something unknown but determined to some degree by circumstance, imagination, curiosity, existing knowledge, and a readiness to learn on both sides. Travel and onsite field work is a large part of our interdisciplinary studio. So far we have travelled with students to London and Prague as part of the two implementations of our studio during the Spring semesters of 2017 and 2018. Both times we researched not only the respective US Ambassador’s residences (Winfield
House and Villa Petschek) but also toured significant historic sites in both cities, and took excursions into the region (Windsor Castle in 2017, Dresden Royal Palace in 2018), and we just completed travel abroad in February 2019 to document the American Legation in Tangier, Morocco.

2.2 Archival investigations
The first two buildings contained archives of the former owners that allowed students to examine firsthand sources in the original surroundings. In the Winfield House students studied original drawings that documented the changes of the property over the last century, and in the Villa Petschek students researched a number of Otto Petschek’s reference books he relied on for inspiration during the design phase of the building. In the American Legation the building complex contains a substantial collection of art donated by American expats who settled in Morocco. In each case, after returning with their data to the US, students began to incorporate their analyses of the buildings into a Historic Structures Report and other deliverables for the studio.

2.3 Interdisciplinary Pedagogy and Production of Culture
Since the pedagogy of a design studio already relies on the foundation of applied theory, we were only adding another layer by emphasizing the interdisciplinary focus of our studios. The above mentioned diversity of the student body does create tension but also has the potential for a transformative learning experience. Choosing small groups of two to three students with a range of characteristics means that students can’t hide, and they need to rely on each other to get the work done. In our experience this generative tension is more of a motivator than a hindrance in class. Students generated presentations throughout the semester, which helps both their research and presentation skills while making the interdisciplinary nature of those relationships a second, yet important component. We chose individuals in each group based on difference in gender, ethnicity, language skill(s), and discipline (architecture, interior design, or landscape architecture).

Based on our experience of having taught the studio now twice, we learned to structure the semester tightly, even though the participants are all fourth- or fifth-year and graduate students. During the first two weeks we introduced the students to preservation methods by assigning readings from the Secretary of the Interior website, and by having them research one of the historic State Department properties abroad. We consider this research as much a reproduction of knowledge as a production of culture, in the sense that the students grapple with new ideas about how to do research while applying skills they learned earlier in their career as designers. The pressures of a real client (the US Department of State) raise the expectations in the students about maintaining a high level of work while also encouraging them to see their contribution as part of a production of culture for anyone who can access the designed interactive websites that document their work.

2.4 Case studies of student work
Three examples of self-directed student work will demonstrate our pedagogy in the studio. The first two examples are based on initiatives by two individual students who took hold of a research topic that evolved out of each student’s interest in making the project their own. The third example is a collaboration between two students from China and one student from India. One American student who assisted in the analysis of this latter project also used it to develop his own research into one of the details depicted in the final drawing.

2.5 Case study 1
Interior Design student Joseph Danielson, who had previous training in historical preservation with professor NameOfProfessor2, studied the garden room, a premier space in the Winfield House. The garden room interior had been changed several times since the house was built in 1936, and Danielson thought that tracing the genealogy of the room to its current appearance would be helpful to future researchers and virtual visitors of the building. Through historical analysis and archival research he uncovered three major periods of change, from the 1936 boiserie-paneled interior (sold in 1952) via its existence as the Blue Drawing Room under the
Eisenhower administration (1953-1961) and the rather plain Drawing Room from 1964—during the Johnston administration—to its rebirth as the principal Garden Room with its hand-painted, recycled Chinese wallpaper, and the hand-carved pine English Rococo broken pediments over the doors (Figure 1) and matching chimney piece, all assembled by interior designer William Haines (1900-1973) who, with his partner James Shields, worked early on for such movie stars as Joan Crawford, Gloria Swanson, Carole Lombard, Marion Davies, and George Cukor. Danielson created a Revit model of the Garden Room in its three iterations and then designed a hybrid poster for our studio’s final review in which he combined all three stages of the room in one drawing. This allows viewers to understand the transformation of the space from its Rococo beginnings through the sparse post-war years into the stunning Garden Room of the Winfield House which was used to host President Obama in 2015, among many other visiting dignitaries.

![Figure 1: Digital and analog skill development: (left image) StudentName1, analysis of character-defining elements of the Drawing Room/Garden Room from 1959-1969. Reconstruction and rendering of digital hybrid model in Revit, and (Right image) StudentName1, hand-carved pine English Rococo broken pediment above doors in the Garden Room. Hand drawing in ink.](image)

2.6 Case study 2
Architecture student StudentName2’s visual interpretation of preservation is based on her research during the London field trip in 2017. She developed three posters that interpreted the existing historical sites in the city and their perception by locals and tourists. In her first constructed analysis, Historic London (Figure 2, left image), she maps out the historic sites in the city based on data she gathered from Historic England Heritage lists, realizing that 99.3% of the city’s residents live less than a mile from a listed heritage asset. In her second poster, titled Historical Observation (Figure 2, right image), she speculates why humans have been actively kept from engaging with significant cultural properties, and, if they are permitted to visit, why visitors’ knowledge about historic properties is usually limited to touring and sightseeing rather than the more in-depth knowledge gained by academic and professional researchers. In her third poster (Figure 3) StudentName2 reflects on potential future preservation methodologies where preservation efforts and documents are made easily available to educate people and to celebrate heritage properties incorporating current preservation technologies such as digital illustrations and virtual reality combined with traditional research methods. She ends her Methodology Report, written as part of the studio assignments, with the forecast that these new methodologies of preservation might turn out to be the key to social, economic, and cultural changes when considered from a global perspective.
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Figure 2: (left image) *Historic London* analysis of historic properties and their distance to Londoners, and (right image) StudentName2, *Historic Observation* of limited relationship between visitors and historic sites.

Figure 3: *Methodology Narrative* illustrating recording and representational tools used in the class to construct proposed virtual visits to sites in London.

2.7 Case study 3

Three students, StudentName3, StudentName4, and StudentName5 decided to analyze the garden façade of the Villa Petschek as part of their contribution to our Historic Structures Report. Based on existing two-dimensional CAD drawings (plans) provided by the State Department, and a series of measurements and photographs they took onsite in Prague, they developed through a series of iterations an annotated drawing of the building's garden façade (Figure 4). One other student, StudentName6, realized that one of the façade’s main details reminded him initially of a classical swag of foliage, but upon further research he proposed that it might be a depiction of the ancient Greek myth of Hercules and the Nemean Lion that symbolically guards the central balcony door on the piano nobile above the winter garden on the ground floor (Figure 5, left image and right image).
2.8 The role of technology

Martin Heidegger, in his 1953 text *Die Frage nach der Technik* [The Question Concerning Technology] articulates the potential dangers of understanding technology only as a neutral extension of human work and notes that technology brings with it a completely unique legitimacy that requires careful consideration from the human perspective (Heidegger [1953] 2002). Technology's energy independence from humans (what drives current machines are not humans but energy generated by natural resources) can also lead to a sense of inevitability that allows those who control the advance of technology to stake out control of those who depend on it, whether voluntarily or not. More recently Shoshana Zuboff's book on surveillance capitalism, while articulating the essentially colonial approach to commerce in such companies as Google and Facebook, also offers solutions to the dilemma of our dependence on both technology and the companies that apparently serve our needs but draw power from the information they gain in the process, which makes the behavior of humans more and more predictable (Zuboff 2019). Within the scope of this reality, teaching students about preservation technology requires a critical stance that acknowledges the changes that have occurred since the middle of the last century while questioning the affordances new technologies offer. Since then, technology in preservation studies has expanded from hand-measured and hand-drawn representations of existing structures and proposed changes to now include digital recording and design that has the potential to transform both the academy teaching future preservation professionals and the profession itself. Part of this critical perspective means that we teach students to learn and apply a wide range of methods to record existing structures onsite, including manual drawing and measuring in addition to digital recording using two lidar scanners (a Faro M70 and a Leica BLK360) and a Panono 360 camera. Students then use the collected data to develop three-dimensional analog and digital models as well as façade...
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Drawing and speculative hybrid representations that emerge out of an iterative shuttling between analog and digital modes of working (Figure 4).

![Figure 4: (left image) Lidar scan of Garden Room as viewed in VR desktop interface, (right image) screenshot of Winfield House website showing interactive panoramic views.](image)

Since our final deliverable for the State Department consists of a series of website prototypes, students need to translate all of their investigations and research into another mode of representation that is virtually accessible to the world. In this process of translation students become aware of how their designs are potentially viewed by representatives from a wide range of cultures around the world, and their previous collaborative work in the studio has prepared them for this challenge. The catalog of pieces that the students design during the second half of the semester, after the data-gathering and analysis period, consists of a detailed Historic Structures Report, research on historical context, chronology of use, evaluation of significance, and character-defining elements, a timeline that demonstrates the significant events related to the site, detailed façade analyses of interior and exterior structures, individual student research projects (see Figures 1-3), and at least three website prototypes with protected access until the State Department decides, after review, which one of the sites they would like to make public.

**CONCLUSION**

In conclusion we can summarize the scope of our work through another series of challenging statements and questions for which we continue to search for answers: how we communicate history (a kind of memory) and forgetting (a kind of amnesia) intersects in our studios with questions of power (important historic properties) and the absence of power (those who do not hold important positions in the hierarchy of a state or a nation—such as the support staff at the Ambassador’s Residences—yet are crucial to the everyday function of an official building representing the United States abroad). **Fluidity, impermanence, and transition** are the keywords that stand against what we conventionally think of as enduring. In response we encourage our students to design **everything** (including what we conventionally think of as re-presentation, i.e. to do graphic design), acknowledging the awkward and the refined, the introvert and the extrovert drives in us and in the designed and built environment.

Fundamentally we ask in our preservation studios: how do we conserve or preserve something for future generations? What is the difference between a real historic structure and its representation? How do we extend the temporal existence of what is designed? The first premise of the studio was that we have to care, to value what we want to preserve. Quality matters, and the process matters as much as what we end up with in the temporal realm, be it physical or digital models, an image feed, or a well designed interactive website.

‘Practice of Research’ suggests asking uncomfortable questions about one’s own approaches to design that acknowledge a contingent stance towards studio pedagogy. Allowing students to accept their own discomfort in the face of a diverse studio environment is a start, and
insisting on interdisciplinary collaboration in small groups allows students to embrace opportunities they didn’t even know existed. Emphasising the word *practice* as a verb encourages our students to experiment without overtly worrying about future results. This returns us to Wilhelm von Humbold’s approach to education that embraces not only science-based curricula but also the indeterminate meandering processes of humanist disciplines. Considering the studio as a space of non-judgemental experimentation makes this approach feasible.

In our two previous preservation studios we explored fundamental questions that ask how we communicate preservation and cultural heritage at a time when technology appears to drive much of the discourse. While we employ current tools, we also questioned what role technology plays in the recording and dissemination of preservation and cultural heritage. Given the physical and metaphysical distance between us and the objects of study (Winfield House in London, Villa Petschek in Prague, and currently the American Legation in Tangier), how we engage technology *critically* was and continues to be a vital part of the studio pedagogy.

Our work has resulted in a body of research that emerged out of applied onsite field work combined with analytic methods, archival investigations, and interdisciplinary communication to create a holistic understanding of the role historic properties abroad can play in the production of culture within an academic environment that is linked through current technology to society at large.

**REFERENCES**


Humboldt, W. v. 1851. *Ideen zu einem Versuch, die Gränzen der Wirksamkeit des Staats zu bestimmen*. Breslau: Trewendt.


**ENDNOTES**

1 "Der wahre Zweck des Menschen...ist die höchste und proportionirlichste Bildung seiner Kräfte zu einem Ganzen." (Humboldt [1792] 1851, 9)

2 This work is accessible via a student-designed interactive website at http://HistoricBuildingWebsite1 which will be demonstrated as part of this presentation.

3 The books continue to be stored in the zinc room, which had been used during the Petschek’s family relatively short stay in the house from 1930 to 1934 to store fur coats in the building.
Map the gap: iteratively bridging theory and practice to address housing insecurity in the urban environment

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ABSTRACT: According to the Robert Wood Johnson Foundation Commission to Build a Healthier America, health and well-being depend more on where we live, learn, work and play than on medical care, which accounts for only an estimated 10 to 15 percent of preventable early deaths (Brawer, R. et al., 2016). Housing insecurity, marked by uninhabitable living conditions, uncertainty regarding capacity to pay rent, and multiple relocations, threatens the physiological and mental health of individuals and overburdens infrastructure (Sandel et al., 2018). Our current research reveals that housing insecurity is exacerbated via disconnects between legal affordances, community-based organization (CBO) responsibility misconception, and a lack of resources. This paper will examine the research and development philosophies and processes which substantiate Map the Gap, a transdisciplinary, in-development mobile-Health intervention/prevention tool intended to reduce the burden of housing insecurity in Philadelphia. The tool takes its name from several efforts currently underway to consider the gap in income required for families to avoid eviction. This research group has developed an emerging framework to approach the community work required to cultivate efficient, effective relationships between Philadelphia residents and the built environment. It is anticipated that Map the Gap will play a critical role in health care and wellness promotion. In addition to enabling Philadelphia residents to access resources which improve the built environment, the human-centered accessible architecture of the Map the Gap system itself will lay the foundation for a Culture of Health, transforming determinants of health into constituents of health, and thus creating new imperatives for design of sociotechnical structures which transcend relational and environmental spaces.

KEYWORDS: Culture of Health, Urban Housing Access, Housing Insecurity, Health and Stress, Design Research for Health

INTRODUCTION

In order to improve health in this country, the health sector must work closely with those who plan and build communities, especially the community development and finance organizations that work in low-income neighborhoods to build child care centers, schools, grocery stores, community health clinics, and affordable housing. From the health perspective, our interest is less about the buildings and more about what happens in them (Lavizzo-Mourey 2012, 218).

Urban families under threat of living without an established address will experience a concurrent threat to their livelihood that can have serious health repercussions (Marcus 1995). To alter the stress levels of urban individuals, we must seek to structurally augment the ways that urban neighborhood environments drive such outcomes (Thoits 2010). A midcentury housing renewal that occurred in many urban American locales created a major housing shortage and countless living spaces that are substandard and unsuitable for urban families to have healthy lives (Jacobs 1993, 3). Within the production of architecture and the lives of many urban inhabitants lie structural inequities that lead to eviction and homelessness (Desmond 2016). To ascertain and address the possible efficient and effective relationships imperative to a city with successful and equitable housing, we ask: How can architecture and housing within the urban environment be democratized? What forms can the vocalizations
Teasing out the hidden motives in any arena where resistance to change exists builds efficacy and community capacity to change (Kegan and Lahey 2009); the urban housing environment is an especially challenging environment. This research group argues for the examination of inherent politics, policies and possible processes embedded in modern design to discover novel, equitable processes that will create change for the families that bear the burden of current processes. Exploring the transdisciplinary and trans-temporal possibilities which connect data informants, built environment care providers, processors, and recipients, enables this group to develop a community-driven design research process. This process aims to transform a legacy of inequitable development into a cyclic, iterative, democratized design process for urban families in West Philadelphia. In examining models of potential theory and possible practice translations, as well as the ethical obligations which guide design aspirations, this paper serves as a stepping stone to a transdisciplinary approach to the built and social world. The work that drives this paper stems from the desire to achieve stress reduction and enhance health for urban families (Lavizzo-Mourey, 2012, p. 218); this research group approaches stress reduction in the built environment via new solutions to change the residential environment, wherever people may live. Map the Gap, the prototype subject for this paper, is an in-development digital narratively-informed housing decision guidance tool intended to optimize utilization of existing resources (connect people to community-based organizations). The ultimate outcome is to dissolve historical tensions between landlords and tenants. The tool takes its name from urban planning and policy currently underway to consider the gap in income required for urban dwellers to avoid eviction (hraadvisors, 2019). Currently, we have found no other interactive interfaces which allow landlords and tenants to virtually navigate the realities of the housing system, nor smart-applications which advise based on individual circumstance meshed with current data.

Map the Gap is also unique in that it is intended to function as both a primary and secondary prevention tool; while it will serve to prevent homelessness associated with unrepaired rental units, it will also serve as a tool to foster self-efficacy and advocacy capacity thus reducing the risk factors for homelessness. Map the Gap serves to develop and maintain a healthy, workable system. Our plans to develop this tool have been evaluated and informed by an inter-sectoral group of experts, representing a cross-section of leaders in this area. The research group includes Public Health and Architecture practitioners and researchers with considerable experience in the urban built environment and with urban residential issues, including 20-plus years of experience in residential re-design, re-use and repair.

In terms of function, Map the Gap will connect tenants, landlords, community-based organizations, government agencies, and other resources in Philadelphia by 1) providing personalized navigation of Philadelphia's housing system, 2) facilitating communication between parties, and 3) enabling service exchange (a local currency). Map the Gap is intended to be used consistently, with users engaging with various functions at regular intervals, as well as some on a trauma-informed basis. The mobile application will contain both public and private platforms to facilitate these user-system/user-user interactions. The private platform will maintain individual data collected in bulk upon sign-up, and then derived periodically throughout use. Housing system navigation guidance will occur over the private platform, and as a function of data inputted into the private platform. The public platform will serve as a means for communication between landlords, tenants, and CBO's. In addition to providing protected chat spaces for landlords and tenants, calendars with all unit-related responsibilities including unit check-over times, rent collection, unit upkeep, repairs, and
regular meetings will be shared by all users (landlords and tenants alike) associated with each unit.

1.0 A new framework for engagement voice, guidance, channels and dynamics
Confronted with a problem as complex as racism, we cannot afford to let ourselves be constrained by the boundaries of specific disciplines (Essed 1991). We know that a child’s life expectancy is predicted more by his ZIP code than his genetic code (Lavizzo-Mourey 2012, 216).

Well-intentioned attempts to overcome historical legacies of extraction and relations fraught with unhealthy power dynamics between project teams and community participants are often poorly conceived. In addition to the subtle dynamics of community process at play in designing for poorer urban families, there is also an inherent power and privilege dynamic at play in trying to assist in their fight for urban homes and livelihood. This is illustrated by the fact that wealth and privilege related to race is protected by both public and private sector structural policies in our society. Current wealth can be directly traced to eras when institutionalized racism was in fully sanctioned operation across society (Lipsitz 2011, l. 36). For example, At least forty-six million white adults today can trace the origins of their family wealth to the Homestead Act of 1862. This bill gave away valuable acres of land for free to white families, but expressly precluded participation by (families of color) (Lipsitz 2011, l. 38).

In other words, the finish line to a stable home has never been fairly placed, and as such, solutions must take this into consideration to be successful at realizing equity in both process and outcome.

Such attempts to produce equitable housing, may appear to be ingenuine when pursued in obliviousness of this glaringly oppressive past. This becomes even more urgent when collaborative processes are not transparent and emphasized as critical to outcome production. Thus, it is essential that collaborations between project stakeholders are situated within a Culture of Health paradigm (Lavizzo-Mourey 2012). A Culture of health is defined as:

... a culture) in which good health and well-being flourish across geographic, demographic, and social sectors; fostering healthy equitable communities guides public and private decision making; and everyone has the opportunity to make choices that lead to healthy lifestyles (“What Is a Culture of Health? | Evidence for Action” 2019).

Society has come to understand that factors that are integral to poverty, such as insufficient education, inadequate housing, racism, and food insecurity, are also indicators of poor health. In our urban environment racism is driven by place in a manner that can be understood through a close study of the urban institutions that deal in wealth, mobility and education. Through the work under-taken in George Lipshitz’s “How Racism takes Place”, we can recognize that our modern-day spaces reinforce racism through institutionalization, policies, and a physical apportioning of resources through generations to present day that is driven through a paucity of resources, and a basic misunderstanding of the roots there-in (Lipsitz 2011, ll. 86–88).

Hence, space-making must occur both in a physical and social sense. Pursuing space-making within a Culture of Health framework -- thinking of space-making as a healthcare pursuit -- not only enhances the feasibility of proposed interventions but renders them of shared value with regards to community wellbeing.

At Drexel University’s urban health symposium, keynote speaker Dr. Mindy Fullilove elucidated a fundamental problem in healthcare strategy. Historically, Dr. Fullilove elaborated, we have engaged in numerous small campaigns to directly improve health: the crack baby campaigns of the 1980’s, the eat-your-veggies campaigns of the 1990’s, the anti-obesity campaigns of the 2000’s, among others (Drexel University 2017). While superficially these campaigns appear to be beneficial, evaluation reveals their lack of effectiveness in creating sustained good health can be attributed to cultural incompetence. Essentially, these campaigns failed to consider the larger environments of their target populations, and were thus incompatible with the target populations’ lifestyles, which existed as a function of inescapable structural climates. Additionally, the campaigns failed to address community priorities (e.g., eating one’s vegetables is trivial when one does not have a roof over one’s head). Nevertheless, value judgments and assumptions abounded, leaving in their wake a trail of ineffectve programs which serve as important teaching points for public health operationalization.
The Map the Gap team appreciates the criticality of redesigning healthcare strategy to address the complex, sometimes obscured, underlying social issues which determine the experience of health; the team also appreciates the need to architect interventions around collaborations which are conducive to empathetic listening, reframing of expertise, and redistribution of resources. Social and physical space-making, more specifically framed as democratic engagement with architecture, serves as a means through which to redistribute historically dispossessed resources both physical (e.g., property, money) and social (e.g., voice). To develop outcomes which are meaningful, academics must reflect on dispossessed power and embrace organizational structures and product philosophies which challenge existing oppressive power structures and redistribute resources in equitable ways. Essentially, healthy social space-making must serve as a foundation and complementary endeavor to healthy physical space-making.

The work of this group thus far has led us to propose a new model of engagement based on four main tenets: voice, guidance, channels and dynamics. As shown below, these four concepts draw on the engagement to create opportunities for mutual learning and a change in the balance of power. Most significant is the respect and value placed on lived experience as expertise in this arena, expertise that can guide the creation of new environments. This paper posits an evidence-based need for such structures and philosophies, and offers examples of ways to embody them using the Map the Gap project as a case study and the emerging framework for engagement as a guidepost.

Figure 1: An emerging Framework for Community engagement that honors the urban lived experience as a type of expertise Source: (Authors 2018)

2.0. EMBRACING A CULTURE OF HEALTH:

2.1. Third sector capacity challenge: space, collaboration, and capacity
The complexity of stress within urban housing and the associated health outcomes, call for inter-professional problem solving. These solution oriented partnerships must take place through collaboration across many sectors and disciplines, including public, private and research-oriented organizations (Murphy, Fafard, & O’Campo, 2012). Our government as an organization does not completely serve these “in need” populations especially at the metropolitan level. Thus, regional governments must look to “informal coalitions, alliances, and networks that weave together nongovernmental actors with existing units of government in metropolitan areas (Adams, 2014, p.1).” Such networks are the developing third sector, between private and public (Adams 2014). Many of the challenges that a third sector organization deals with, are related to capacity. Non-profit capacity is defined by Christensen and Gazley as follows:
Capacity is directly linked to an organization’s aptitude for reaching goals, satisfying a mission and satisfying mandates (Christensen and Gazley 2008). An organization’s capacity is essentially connected to the ability to operate successfully. Thus, an organization’s capacity is intrinsically linked to the success of their collaborative efforts within the urban built environment. From experience, this research group concludes that housing insecurity services are almost exclusively supplied by this type of overburdened third sector organization with deep challenges to its ability to initiate systems-level change. Drexel University is naturally an adaptive environment in which researchers and faculty are encouraged to bring their expertise to bear in creating change at many levels. The strategic plan for Drexel University calls for integrated community-oriented efforts on an unprecedented scale (Drexel University, 2014). This has created an environment in which faculty and students are able to engage with community partners over protracted periods of time.

Capacity and design have a complex relationship that requires an adaptive design practice. Design is adaptive by nature; as more is discovered about a problem or opportunity new tactics and answers are sought (Cross 2001). Iteration is at the heart of design, and iteration is important in this realm. To better understand how leadership in design might build further capacity, we pursue a brief examination of how Complexity Leadership (Uhl-Bien, Marion, & McKelvey, 2007, p. 299) and Adaptive Leadership (Heifetz, Linsky, & Grashow, 2009, Kindle loc. 378) might be a more influential part of the design process to expand the frame for both third sector partners and the designers who are trying to serve them. The ultimate goal is to uncover the parts of those models that have the most in common with design. Complexity Leadership Theory (CLT) (Uhl-Bien et al., 2007, p. 299) is drawn from complexity science. It is, a model for leadership that enables a flexible, creative, and learning-oriented approach to leading and is oriented to what are called Complex Adaptive Systems (CAS) (Uhl-Bien et al., 2007, p. 299).

Complex Adaptive Systems feature three overlapping roles for leaders: “adaptive leadership, administrative leadership, and enabling leadership that reflect a dynamic relationship between the bureaucratic, administrative functions of the organization and the emergent, informal dynamics of complex adaptive systems” (CAS) (Uhl-Bien et al., 2007, p. 305). CLT and CAS afford designers an opportunity to more closely assess process and find opportunities to be more effective when partnering with those in the third sector.

Those that design the spaces that we live in (e.g., architects, urban designers, engineers, and landscape architects) are taught to focus on and solve physical and service-based problems. The frame must be widened for those professions to be effective in the face of the wicked problems faced by our society. In building design, there are several phases of the process that include what is commonly known as Pre-design. Pre-design is defined by the early phases of a design process including initial problem definition and user engagement (Demkin & Architects, 2008, p. 463). The problems of capacity that have been identified by this group require an expansion of the Pre-Design process to include needs assessments, and processes outside of the usual design process. The frame used by designers is often that of reflective leaders; Donald Schon maintained that as designers employ complexity in their practice already and reflection is not far behind:

A designer makes things. Sometimes he makes the final product; more often, he makes a representation—a plan, program, or image. . .the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena (Schon, 1991, p.78).

Embedded in this practice is a reflective habit that requires an adaptive sense, and a need to change course in search of solutions. This group integrates CLT and CAS as a way to afford teams and designers an opportunity to more closely assess process and find opportunities to be more effective when partnering with those in the third sector.
2.2. Intersectional outcomes: housing, health, and policy
According to the Robert Wood Johnson Foundation Commission to Build a Healthier America, health and well-being depends more on where we live, learn, work and play than on medical care, which accounts for only an estimated 10 to 15 percent of preventable early deaths (Brawer, R. et al. 2016). Factors such as quality of housing and other environmental conditions have a significant impact on the health of a community. An untreated instance of mould in an older, unmaintained house, can lead to substandard air quality and have a lasting effect on inhabitants physiological, mental, and social wellbeing. According to the Healthy Rowhouse Project, 40% of asthma episodes are due to asthma triggers in the home. Furthermore, socioeconomic factors can compound the effects of substandard housing. Studies have shown that a caregiver’s instability, whether in regard to rental payment, multiple relocations, or homelessness, has adverse health outcomes, including child lifetime hospitalizations, poor mental health, and household material hardships (Sandel et al. 2018). The de-prioritization of housing as a constituent of health in the face of resource scarcity persists throughout the life course with devastating consequences (Bennett 2008). Tenants may find themselves at a disadvantage when attempting to deal with home disrepair. A tenant may not be fully aware of the implied warranty of habitability, which states that a landlord has an obligation to maintain habitable (safe, sanitary, and fit) premises, and that if a landlord breaks his/her obligation, a tenant may be relieved of his/her obligation to part or all of his/her rent (Pugh v. Holmes 1978). On a legal front, the majority of tenants are at a disadvantage in tenant-landlord court: In 2016, in Philadelphia, tenants in 92 percent of 22,573 cases filed in court represented themselves (Blumgart, 2017). A scarcity of financial and informational resources, as well as a historical tension between tenants and landlords, perpetuates a system wherein tenants experience disadvantages in health.

While 81 percent of landlords have legal representation, some landlords are similarly vulnerable to tenants (Blumgart, 2017). An uninformed landlord, especially one without the proper rental license, may experience financial instability. Accidental landlords, landlords who have acquired five or fewer properties without the intention of renting them, nor even necessarily being responsible for said properties, comprise much of this vulnerable population. Many have acquired properties through deceased descendants, and many rent as a means to compensate for financial hardship caused by disability. The Department of Licenses & Inspection, investigating a claim by a dissatisfied tenant, may deem a property “unfit for human habitation,” rendering the tenant homeless and depriving the landlord of a much-needed source of income (Vargas 2017). A Philadelphia Inquirer and Daily News review of 507 properties deemed “unfit for human habitation” between January 2016 and the end of May 2017 showed that 180 had rental licenses and 34 more had vacant-property-licenses; the rest had no licenses (Vargas 2017). Additionally, when income is compromised by way of unpaid rent, some landlords struggle to address repairs in their units with limited financial means. Furthermore, landlords may run the risk of violating tenant-landlord rights. Evictions are also costly to the public because evictions add even greater occupancy pressure to the emergency shelter system (City of Philadelphia 2018). The system, which is underfunded and strained, is not a navigable or sustainable one. This system is unhealthy, and accordingly must be treated as a constituent of health rather than a determinant of health. Viewing housing through the lens of a Culture of Health (Lavizzo-Mourey 2012) emphasizes equitable access and sustainability, and requires an intersectoral approach to improve outcomes at the intersection of housing and health. Accordingly, the housing system must be examined with respect to structured inequity and a systems-based approach to health. Solutions must draw together inter-sector stakeholders.

3.0. A process-oriented interdisciplinary solution
Map the Gap originated as a collaboration between graduate design and technology students and representatives from several community-based organizations during a course entitled Health and Design Research offered at Drexel University and funded through a grant with a behavioural health foundation. This course encouraged students to integrate epidemiological and design research methods to engage with built environment issues in the urban setting.
adjacent to Drexel. At the conclusion of the 10-week course term, students proposed an early-stage version of the Map the Gap tool which involved a physical toolkit intended to aid with home repair as well as a workshop series. The then took the facsimile of this toolkit to community members and experts for feedback and suggestions.

Figure 2: Final deliverable from course – toolbox for community conversations: Team examined items with community members for possible usefulness.

However, further community centered research revealed socio-structural issues which led the team to believe that the aforementioned intervention was not fit to user needs. The team then engaged in a series of expert interviews through which they worked to map out Philadelphia’s housing landscape and identify gaps which result in housing insecurity. These interviews led to iteration upon the original idea of toolkit; a digital toolkit would be more adept at addressing user needs, the team concluded. Collaborations were then forged with diverse community partners which facilitated community buy-in and proved useful when recruiting participants for two focus groups, also called community conversations, intended to elucidate participants’ experiences with the housing system, and to guide the identification of useful features for an intervention prototype. The team has worked to build out a community process that engages with participants and benefits them along the way.
The goal of this mid stage team process was to pursue co-design sessions in collaboration with community members. The team then held two information sessions about the project, and two community conversations in which community members engaged in design research activities and explored their experiences with housing resources in Philadelphia. The data garnered from the community conversations and the expert interviews mentioned here is not the subject of this paper, but informs current iterations and conclusions of the Map the Gap digital prototype, and the stance relative to this work. The team plans to engage the community again for testing in several more rounds of development prior to a launch of the Map the Gap tool.

Through both regular data input and trauma-informed data input, Map the Gap has developed multidimensional narratively-informed user profiles, and will allocate guidance accordingly. Users will begin their use of the tool by answering a series of questions to help determine appropriate remedies for home repair, such as making small fixes or getting in touch with a mediator. The interface will also suggest referrals to relevant community-based organizations and additional resources. By providing tenants and rental owners with the tools for successful corrective and preventative adaptation, much of the fall-out that strains relationships and the housing system can be avoided. The goal is to avoid loss of housing and eviction through empowering all parties to address disrepair in their homes. The tool will also enable them to take control of their health and wellness through addressing such issues as contaminants or mould through non-profit care resources that might be more difficult to find without the use of an integrated interface. Homes will no longer simply be places to reside; they will be places to grow a healthy urban family with Map the Gap and the process of home-retention will support healthy social space-making.
The Map the Gap team has made extensive efforts to relocate expertise within the design setting. Initially, an expert interview series was conducted featuring interviewees (e.g., lawyers, government officials) from whom many local residents facing housing insecurity felt disconnected. Thus, the interviewees maintained knowledge-oriented expertise rather than practice-oriented expertise. The Map the Gap academic team sought to reframe community participants as practical experts on their own communities, and to reinforce the notion that their contributions would directly determine the shape and outcome of the project. Thus, in the process of co-designing a built environment intervention, the team produced new norms for social relations and expectations for research conduct and deliverables. Today, iteration remains key to the Map the Gap process. The team seeks to prioritize the value of Map the Gap as a collaborative process (as opposed to simply an in-development product). Map the Gap’s value as a social space-making endeavour and potential for feasibility as a built environment modulator is determined by the process that underpins its development.

3.1. Community education of the team

The team received an education into the subtleties of power, race, privilege and community practice through their recent community process. This work in part has led to the framework laid out in the early part of the paper and below. As a part of the development process, an information session about Map the Gap was held in anticipation of a focus group. This information session illustrated the subtle and unique dynamics at play in such a project. This is described here in general terms in order to underscore the many fronts on which such a project can touch community members and reveal systemic issues. Repeatedly, throughout the duration of the information session, privilege and voice were situated front and center by participants who respectfully disrupted the planned talk to critique the team’s proposed intervention for epidemic housing insecurity. From participants’ input it became clear that unacknowledged dynamics and cultural differences between the Map the Gap team and potential users could seriously undermine the project. The community members gave this group the gift of their openness, honesty, and true perspective. The team took away a renewed approach that has informed further engagement, and the project moving forward. That session preceded others, and the Map the Gap hosts decided to change their approach to all following sessions. Labeling and approach was re-tuned to further meet the potential participants in a way that recognized privilege and power disparities.

The team has clarified the aforementioned framework of: voice, guidance, channels and dynamics in part from this experience, and from their combined thirty years of community engagement experience. The community in question is sophisticated and understands their environment through lived experience. The participants were generous with their time, and did receive minor incentives to participate that might help them with their homes, or small incidental inconveniences. This team worked to engage in a way that might help to shift the balance of power to the community members through the developing lens of voice, guidance, channels and dynamics whenever possible. The team was educated to operate in the following ways by these valued community voices:

The framework of voice, guidance, channels and dynamics will be the guidelines for further engagement. The framework aligns with the Culture of Health paradigm. The framework, in practice, has given participants a power to be heard within the project, and among the milieu of the project practitioners and the community. As this work continues, the team seeks to communicate and create ever more mutually beneficial community engagements that build a third community between project team, and residents.
CONCLUSION

As stated above, Map the Gap is an in-development digital narratively-informed housing decision guidance tool intended to optimize utilization of existing resources (connect people to CBO’s) and dissolve historical tensions between landlords and tenants. This team is a part of a larger research group that works to reduce stress in the urban environment to create healthy family experiences and drive success for a new generation of urban residents. We seek to promote equity, through built environment service-oriented health solutions. Our work is with non-profits, community members, architects, epidemiologists, biologists, writers, engineers, designers, and technologists. Inherently interdisciplinary, the goal is to engage across disciplinary and community boundaries in a manner that is sustained, engaged, respectful and shifts power across institutional limits as much as possible. The emerging engagement framework of voice, guidance, channels and dynamics has been synthesized from experience, and study of community driven co-design including the works of Henry Sanoff, IDEO, and many others. This novel approach seeks to include lived experience as expertise in the design process, teaching emerging designers and scholars to interfere with historically driven power and inequity structures, and create a new type of built environment practitioner – one that engages with community within a fundamentally widened frame.

The objective is to use engagement, and “radical listening”, the practice of truly hearing those one engages with (“Health In Harmony | What Is Radical Listening?” 2018)(Scott 2017), to drive a new type of health and built environment practice – one that will address health as an experience dependent on a culture which must exists beyond traditional healthcare. Third sector and non-profit partners and their capacity must be a part of this process, and the emerging partnerships here will contribute to a sustained engagement and problem solving, using a widened design frame to drive change in that sector as well. As stated above, we will re-frame housing access and the emerging drive for equity as key components of a new healthcare strategy for urban families.

Again, as a team we ask: How can architecture and housing within the urban environment be democratized? What forms can the vocalizations and internalizations of civic concern take in a historically disenfranchised community? What assumptions have historically underpinned
notions of community and institutional capacity? How have such assumptions translated into power disparities in space making? How can built environment and healthcare architecture be leveraged to de-naturalize disparities and re-socialize a Culture of Health predicated on equity, sustainability, and potential to thrive? We believe this emerging framework of Voice, Guidance, Channels and Dynamics holds the potential to explore the answers to these pressing 21st century issues.

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REFERENCES


Fieldwork in-between architecture and anthropology: The case of Marxloh - Duisburg

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ABSTRACT: Architecture and anthropology have long had similar interests regarding the built environment and its relationship to social life. While architecture has traditionally held the material aspects of the built form as its focus, seeing the built structure as an end in itself, anthropological studies considered the built form as a means to gain further insight into different sociocultural practices. Developments over the last few decades have changed the direction of both disciplines. With architecture’s break from modernism and universalism, more architects began creating buildings for culturally specific contexts (Stender, 2017). At the same time, anthropology, along with other branches of the social sciences, took a “spatial turn,” developing an interest in space, place and their human and non-human interaction with an emphasis on the performative nature of the built environment: what architecture does, rather than what is represents (Buchli, 2013). Despite different foci, the approaches of anthropology and architecture to the same subject allowed for significant methodological and theoretical overlap, and therefore potential for collaboration. In this paper, I explore this potential. In order to do so, I examine the historical links between anthropology and architecture as academic disciplines, identify religious architecture as a potential area of collaboration, and present the preliminary results of my ethnographic fieldwork in Duisburg, Germany.

KEYWORDS: Architecture, Anthropological methods, religious architecture, ethnographic fieldwork, Marxloh

INTRODUCTION

During a period of research in which I asked questions to the users of the Turkish commissioned mosques in Duisburg about the architecture of the mosque, I regularly faced interventions by my informants requesting that I stop posing questions about the architecture of the mosque. My participants argued that the essence of religion lies in individual faith, community, chartable deeds and rituals. As Verkaaik summarizes it, “the soul of the building lies in its people, not in the material of which is made” (2013, 8). But then, I asked, why spend such a large amount of money to build a mosque? Although many Muslims insist that one can perform their religious duties anywhere, it is not uncommon for poor immigrant communities in Europe to raise millions of euros to fund the construction of a community mosque. Apparently, despite the religious dogma, buildings do matter (Verkaaik 2013).

One answer to this disparity can be explained through anthropological methodology, developed after the publication of Malinowski’s influential work: Argonauts of the Western Pacific (1922). His argument is based on the idea that there exists a divergence between ideology and practice, claiming that people do not always say what they do, nor do what they say.

Architecture and anthropology have substantial common ground regarding issues such as the form of the human dwelling, spatial organization of the built environment, and their relationship to social life. Although they approach these topics with different foci in mind, recent developments have changed the direction of both disciplines. Differential approaches to the same subjects have created significant potential for collaboration.
In this paper, I examine this potential in terms of theoretical and methodological approaches. In order to do so, I first review earlier overlaps and encounters between the two academic disciplines. I argue that combining anthropology’s “spatial turn” and architecture’s break from modernism and universalism allows for an intriguing contribution. After presenting a literature review of studies in the area of religious architecture that have used anthropological methodologies, I discuss the preliminary results of my fieldwork in the mosque spaces of Marxloh in Duisburg, Germany.

1.0 ARCHITECTURE IN ANTHROPOLOGY VS. ANTHROPOLOGY IN ARCHITECTURE

The relationship between anthropology and architecture is unusual. Although anthropological literature is filled with sketches of the layouts of houses and villages, as well as cultural analyses of their spatial organization, it has been noted frequently that anthropology has historically never paid much attention to architecture (Stender 2017, Humphrey 1988). The relationship between the two disciplines was confined to the margins of mainstream debate in each field, where built environment and material structures were assumed to play a secondary role, supporting the actions and relations of their human subjects (Allen 2016). The stature of architecture, which was overlooked by anthropological inquiries in comparison to other social forms (kinship and religion) (Humphrey 1988), has in recent years started to emerge as a sub-field.

Despite complaints about anthropology’s disregard for architecture, a significant body of literature focusing on the documentation and analysis of material culture exists (Vellinga 2011). Early Anglo-American anthropology, aimed to document “hidden” and rapidly disappearing cultures, including descriptions of indigenous buildings, settlement plans and construction methods, often regarded comparatively (Horowitz 1967, Heider 1979). The existence of such a body of literature, however, does not form a structured “anthropology of architecture”, in the same way that can be said for topics such as kinship, religion and political structure. These works do show anthropologists’ interest in the role that architecture plays in the reproduction of cultures and societies (Vellinga 2011).

Such interest can be seen clearly in the French school (of social anthropology), which viewed spatial forms as representations of universal social structures (Buchli 2013). The French sociologist Marcel Mauss viewed architecture and architectural form as a key technology through which social life is (re)produced (2006). Claude Levi-Strauss launched use of the term “House Societies”, which defines the house as an institution that encompasses relations of kinship, hierarchy and physical structure, while objectifying these relations (Carsten and Hugh-Jones 1995). French sociologist and anthropologist Pierre Bourdieu’s account of the Kabyle House in Algeria analyses spatial divisions as representations of dichotomies between men/women, outside/inside, day/night or, as he coins it, “the world reversed” (1960). As Buchli (2013) and Vellinga (2011) note, these prominent studies had an impact on the field of anthropology; however, another theoretical development also had a major influence in the field. The “spatial turn” or the “material turn” in the social sciences claimed a new emphasis on things, artefacts, dwellings, spaces and even landscapes, not only as things people attach meaning to, but as things that have a performative nature, therefore actively influencing our being in different ways (Stender 2017). This development influenced later ethnographic1 accounts in the fields of architectural anthropology (Amerlinck 2001), house societies (Sparks and Howell 1999), the home (Cieraad 1999), as well as inluencing the perception and meaning of the built environment in general (Ingold 2000). These later studies concentrated on the social implications of the material structure of architecture, voicing any physical features or symbolic reading of these building forms. As Stender concludes, anthropological studies appropriated the built form as a tool to gain insight into cultural meaning or social practice, rather than as an end in itself (2017).

In contrast to social anthropologists, architects, have historically studied buildings and dwellings for aesthetic inspiration; functional, tectonic and material knowledge; and for
theoretical development. Joseph Rykwert, an American architectural historian, claims that the investigations into the “primitive hut” reemerges at times when there is a need for renewal. He views architectural form as a tool to establish proximity by bringing things and people in relation to one another, affecting the relationships of people with one another and with the built environment (1981). While French architectural theorists Eugene Viollet-le-Duc and Marc Antoine Laugier used the primitive hut as an analytical category to understand the relationships between building material, architectural form and human behavior, German architect Gottfried Semper used anthropological speculation when developing his theory of “The Four Elements of Architecture”, locating the primitive hut ethnographically in the Caribbean (Stender 2017). During this period, architecture was also utilized in the anthropological discipline of archaeology. While architecture was used as a tool of illustration and reconstruction, archaeological discoveries helped shape architectural fashions. However, this mutual attempt at linking architecture and anthropology was severed, as architecture began to answer the transformative demands of nineteenth-century industrialization. The dominant forces in the development of architecture were in the demands of production itself, not in the human domain (Jasper 2016), eventually giving rise to the “International Style”.

Accounts that have criticized the “International Style”, especially from the mid-twentieth century on, were against universalism in modern architecture as well as the perceived homogeneity produced by the global construction industry. A renewed interest in the “architecture of the common people”, and promotion of new vernacular architecture placed an emphasis on the cultural and environmental benefits of learning from local building traditions and materials (Frey 2013, Richardson 2001). While this new interest in vernacular architecture engaged with the architecture of the common people, it also triggered an interest in the study of the Other (Vellinga 2011). The architectural interest in the Other cultures, focused on the monumental and historical traditions found in the Middle East, India and Central America, was brought into scholarly focus. A renewed interest in the “the architecture of people” has solidified within in the field of architecture, meaningfully engaging with Others and their material traditions (for an early example, see Rappaport 1969). Some examples of this engagement can be seen in the work of architects such as Trevor Marchand and Dorothy Pelzer who conducted ethnographic field investigations (in Yemen and Southeast Asia respectively) into local building and construction techniques. Although a considerable body of literature on vernacular architecture exists in the architectural discourse, far less has been written about modern architecture in anthropological writing (Verkaaik 2013). Despite their differences, architects and anthropologists increasingly agree that the scope of anthropology neglects contemporary architecture.

2.0 ANTHROPOLOGICAL APPROACHES TO RELIGIOUS ARCHITECTURE

So far, I have concentrated on the theoretical overlap between architecture and social anthropology, and have shown potential areas of collaboration. Within this context, religious architecture presents an excellent opportunity for collaboration. While religion by definition brings people together, religious architecture materializes both the culture and the belief system. Going back to the question that I left unanswered in the introduction to this paper – why people put so much time and money into religious architecture if they claim it is unnecessary for religious practice – one could argue that religious buildings may not be imperative for religious purposes but have social and political importance.

In the context of contemporary mosques in Europe and North America, such interpretations can be found in the work of Dodds (2002) and Metcalf (1996), who argue that religious minorities see religious buildings as a representation of their religious identity, and link them to processes of integration and attaining power. This argument brings together what religious people say (that the building is meaningless for religious purposes) with what they do (that they build and pay for them for their sociocultural and political importance) (Verkaaik 2013). Dodds’ and Metcalf’s interpretations, however, are not entirely satisfactory as they conceptually separate the religious and political dimensions of religion in a way that may not exist for the people practicing it. According to Asad’s analysis, which argues that the dynamic
between the inner faith and outer form has marginalized the importance of ‘ritual’ in the religious experience (1993), such an analysis eventually disconnects the ritual, aesthetic and habitual aspects of religion from religious socio-political identity. In other words, it assumes that the materiality of religion, which is a part of the domain of political identity, can be distinguished from the immateriality of religion (Verkaaik 2013). The informants in my study would surely agree, that as “religion strives for immaterial beyond the material, it necessarily needs material to evoke the immaterial” (Miller 2005, 1).

The use of ethnographic approaches allows us to go beyond purely material analysis, to achieve a more comprehensive understanding of the world by incorporating architecture with symbolic territorialities and socio-political practices (Tomasi 2015). Ethnographic methods offer an alternative perspective for architectural critics who tend to focus on the function, symbolism and character of the building. Semiotic readings of architecture shift the focus from the design and construction of the building to the ways people use such buildings, and from production to consumption (Buchli 2013, Vellinga 2011). This approach does not see religious architecture as a static container of the ritual which encloses the religious interior and reflects the political exterior, but an active or live agent of religious experience, identity and community (Appadurai 1986).

Yael Navarro Yashin, analyzing the affective power of spaces and buildings, argues that religious spaces have agency as well as an impact on human experience. More specifically, such spaces can direct and limit movement, emotionally affect their visitors, and make and unmake identities (2009). Tamimi Arab’s paper, which examines the Essalam Mosque of Rotterdam, examines the affective dimension of the discourse created around this mosque. The “megamosque” discourse blurs the line between the fact and the fetish and has an affective impact (that ranges from anxiety to pride), that causes different material experiences of the mosque (2013). Tutin Aryanti’s research on contemporary mosque architecture in Indonesia refers to the performative character of religious architecture. Her research not only examines how gender conceptions permeate the architectural space of the Indonesian mosque but also regards the mosque as an active agent shaping the gender relations in and around it (2013).

Another advantage to incorporating anthropological approaches into architecture is that ethnographic methods allow us to avoid ethnocentric interpretations that make local ways of conceiving and living architecture invisible. This, in turn, allows us to locate architectural practices within the interpretive contexts where they have developed (Tomasi 2015). Eric Roose’s study on contemporary mosque design in the Netherlands illustrates this point by moving away from the architectural critical perspective that dominates the public debate surrounding the issue. Roose’s iconological approach diverges from architectural criticism that dismisses new mosques as nostalgic replicas of the Ottoman, Moghul or Mamluk traditions. Rather than interpreting them with respect to their temporal and regional style, his focus is on the design process as a symbolic-political practice. He views parties that were involved in the construction process as active political actors rather than passive agents. Roose argues that these actors do not unreflexively mix and match styles from their country of origin; rather, their choice of a certain style is an attempt to actively make a political statement (2009).

Shahed Saleem, focusing on contemporary mosque design trends and development in postwar Britain, presents a further example of anthropological work within architecture. His analysis views the design process as a process of negotiation, learning and “objectification”. While he avoids the commonly trope that European Muslims simply produce kitschy replicas of traditional Islamic building styles, Saleem argues that Muslims in Britain did not just aim to relocate a religious institution from a “home” culture to a “Western” one, but that they were driven by other concerns, such as religious disputes on mosque design, creating a familiar space for worship, and the gaze of the secular world. He concludes that these complex interactions do not reveal themselves through formal architectural analysis but can be
understood when the building process is framed as a performance that creates intragroup and intergroup dynamics (2013).

3.0 METHODOLOGY IN PRACTICE: THE CASE OF MOSQUES IN MARXLOH, DUISBURG

My current research examines Turkish commissioned mosques in the Marxloh neighborhood of Duisburg, Germany. Ongoing fieldwork involves three different mosques: Marxloher Merkez Mosque (DITIB\textsuperscript{2} organization), Marxloh Cultural Center (IGMG\textsuperscript{3} organization) and Duisburg Ulu Mosque (VIKZ\textsuperscript{4} organization). The primary goal of this work is to examine how mosque spaces in non-Islamic contexts contribute to the reproduction of Turkish-Muslim group identities, and how Turkish-German women interact with and appropriate the male-dominated space of the diaspora mosque. This paper includes preliminary results of my fieldwork, with a focus on Marxloher Merkez Mosque.

Figure 1. Marxloher Merkez Mosque, ("Merkez Moschee, Marxloh", 2011)

Marxloher Merkez Mosque (Marxloh Merkez Camii), located in the northern section of Marxloh, is the largest mosque in the city. Marxloh is characterized by its immigrant Turkish population: out of 20,500 people living in Marxloh, an estimated 65% have a Turkish background (Uslar 2017). The former DITIB mosque was established in an unused cafeteria space and was regularly overcrowded on public holidays, making it unsuitable for religious use for a community of 500 households (Ehrkamp 2007). The local DITIB, active in the area from its inception in 1984, decided that the makeshift prayer rooms were inadequate and they needed a new building. In 1997 and with the support of the local Turkish community, DITIB proposed the construction of a classical Ottoman style mosque. Being aware that such construction projects may become a source of anxiety in the district, the association’s Marxloh board of directors sought cooperation with the local municipality, the Duisburg Development Union (Entwicklungsgesellschaft Duisburg), churches, and other institutions. By 2002, an advisory council for the project was established, with representatives from political parties, churches, local associations, neighborhood residents, and businesses. DITIB’s expressed aim was transparency and openness. During the construction phase alone, the project received 40,000 visitors, who wanted to learn more about Islam and the Muslim population of Marxloh. Although in 2006, the relationship between the congregation and the city was clouded by media reports that members of the construction company were involved in right-wing circles, such incidents were almost forgotten by the time the mosque was opened in 2008 (Gorzewski 2015). Today, the Merkez Mosque functions as a religious, cultural and social meeting place, and continues to provide educational and interfaith dialogue programs to bring together people from different backgrounds.
A purely architectural analysis would present the design and construction process of the mosque, yet I argue that to be able to answer the question of how identity and gender in the diaspora permeate and influence the architectural space of the mosque, and how mosques shape these relations in turn, an ethnographic method is necessary. Over a span of 6 months, I thus collected data from participant observation, go-along observations and interviews with the female members of the mosque. I also interviewed experts involved in the construction and operation of the mosque.

Preliminary ethnographic analysis indicates three main results. The first is related to the hierarchical structure of the mosque, encountered during the initial stages of my fieldwork when I was attempting to get access to the mosque’s spaces. Although I had no problem reaching out to the community (and gaining the trust of Turkish Muslim women), I soon faced administrative roadblocks, impeding conduct of my research. Since Germany does not recognize Islam as an institution (mostly due to the fact that Islamic groups do not unite under a unified umbrella, like the Catholic Church), the mosques function through registered associations. The local board of the mosque in Marxloh fearing that my work would be “another research to harm Islam”, required written permission from the head DITIB office in Cologne as well as the Turkish Consulate. This process shows both the difference between the discourse created around the mosque (openness and transparency) as compared to the actual process, and the strict hierarchy within the mosque’s organization.

The design of the mosque included large transparent windows, which aimed for openness that was further underscored by the mosque’s self-promotion. Although at the time of its opening, Marxloher Mosque staged and performed the civic ideals of loyalty, participation, and transparency, a fact that was emphasized by the expert interviewees, the difficulty of accessing any information showed the disparity between the organization’s words and actions. Later expert interviews with the actors that took part in the mosque’s construction process confirmed that the local associations are not independent. These interviews affirmed that the DITIB head office had largely chosen the mosque’s style. Since DITIB has close ties to the Turkish government, the choice of this style followed contemporary Turkish directives, rejecting modern forms in favor of a traditional Ottoman mosque architecture. Circumventing German law, which stipulates an architectural competition for projects over a certain size, the Turkish-German architect Cavit Şahin was directly commissioned to design the mosque. In short, although at first glance the mosque might seem like a replica of the traditional Ottoman mosque, a more detailed analysis reveals social and political relations.

The second result that my analysis has yielded shows that Marxloher Mosque has become the center of a socio-spatial network. Unlike Turkish mosques, which only serve the purpose of religious practice and are familiar elements of the urban landscape, the diaspora mosques in
Germany function differently. Their importance as spaces of socialization exceed their use for religious purposes, as they help maintain the sense of community that produces identities built on both shared spaces and religion. The mosque does not exist as a single building, as over time, the surrounding land and buildings were acquired by the organization through funds raised by the local mosque community. Most of the educational and socialization functions do not take place inside the mosque proper, but in these secondary areas. Furthermore, although Marxloher Mosque is located off the main boulevard in a declining neighborhood, the existence of the mosque makes it a profitable location to live for Turkish Muslims. My informants reported that they prefer to live around the mosque, as they feel more at home living near a familiar element. They also acknowledged that people who have a prestigious social role in the mosque community live closer to the mosque, revealing the spatial hierarchy within this network of spaces. Briefly stated, the mosque complex adds another center to the neighborhood, effectively changing the area’s physical and social composition, a fact that cannot be perceived at first glance.

The last result that my analysis has shown is related to the role and participation of women in the mosque. A superficial reading of the mosque points to a space that imposes sexual segregation, with little visibility of women during prayers. The local administration likewise does not include women. My expert interviews showed, however, that women have been very active in mosque affairs, and helped bring about major changes during the design and construction phase. When the idea of building a mosque in Marxlohe was first suggested in 2006, Leyla Özmål, the integration commissioner of Duisburg at the time, came up with a plan to fund the project’s 7.5 million Euro budget. Since Islam, not recognized as a “church” by the German government, could not use the same funds as churches or synagogues do, the mosque’s construction was funded by DITIB and donations from the congregation, while municipal authorities and the EU incorporated the project into their development plans and funded the construction of the community center. While Özmål’s leadership resolved the economic problems, another woman, Zülfüye Kaykın, who served as a state secretary at the time, fought to make women part of the mosque. The initial plans of the mosque did not include a space for women, since the attendance of women was not expected. Through Kaykın’s influence, a second floor was included where women could pray. In an unorthodox move, women and men use the same entrance to the mosque. Although this decision initially drew some reactions from the congregants, after the mosque opened it ceased to be an issue. As these examples show, architectural transformations during the design process show the transformation of gender relations as well.

The spatial practices of women active in the mosque community show another dimension of gender relationships. Although women seem absent from the mosque at first glance, becoming a part of the mosque community shows how women have appropriated certain spaces in the mosque. While women make full use of the educational facilities, they have transformed part of this facility into a kitchen where they make baked goods every Friday to sell after the Friday prayer. Another area that women use is a room for the “youth branch”, which is used for occasional meetings and free for the use of the community. These interior spaces and the spatial practices that take place there show the architecture of the mosque as driven by the desire to create a familiar and relaxing place for prayer, rather than by religious disputes or political symbolism.

CONCLUSION

The examples presented in this paper show how combining architectural and anthropological research provides methodological and theoretical opportunities. Although it has been claimed that the interest of the architectural discipline stops where anthropologists enter the scene (Iberlings 2011), I argue that two have much to contribute to each other through active engagement with one another. I have identified the field of contemporary religious architecture as a subject that might especially benefit from the use of anthropological methods. Through the preliminary results of my fieldwork conducted in Duisburg, Germany, I have argued that although conventional architectural analyses are necessary to be able to understand a building, social anthropological methods can combine architecture’s materiality with religion’s
immateriality for a deeper understanding of both. Reflecting critically on how architecture is created between different actors, we understand how social relations and meaning are materialized in the built environment, allowing us to better understand the role of architecture, once built and consumed.

REFERENCES


Korn, Lorenz. 2013. “Kuppeln Und Minarette in Mitteleuropa.” In Aktuelle Probleme Vor Dem Hintergrund Der Architekturgeschichte.


ENDNOTES
1. The two terms, anthropology and ethnography are used interchangeably throughout this paper.
2. Diyanet İşleri Türk İsmâl Birliği (DITIB), the Directorate for Religious Affairs Turkish Islamic Association is an umbrella organization established in 1984. DITIB works under the Directorate for Religious Affairs, which is a part of the prime minister’s office in Turkey. The organization is responsible for delegation of imams and employees abroad and these employees have the status of civil servants of the Turkish Government (Tol, 2008).
3. Islamische Gemeinschaft Millî Görüş e.V. (IGMG) was founded in Germany in 1971 as Türkische Union Deutschland (Turkish Union Germany). Its name was changed in 1976 to Millî Görüş (National Vision) and eventually became Islamische Gemeinschaft Millî Görüş in 1994. The ideology of this group goes back to the political views of radical Islamic party which was banned from politics for violating the secular legislation. IGMG is known with its militant attitude (Tol, 2008).
4. Verband Islamischer Kulturzentren e.V. (VIKZ), Islamic Cultural Centers Association is another Islamist movement banned by the Turkish government in 1970s. This group is the European branch of the Süleymani movement, a tariqa, following centralist principles (Pedersen, 1999).
5. Personal interview with Metin Dayıoğlu, the chief engineer during the construction process.
6. Go-along technique is proposed by Margarethe Kusenbach (2003) to explore participants’ everyday
lived experiences as they interact with the built and social environment. In this technique, the researcher accompanies subjects on their ‘natural’ outings, allowing the researcher to actively explore the subjects’ experiences and their interactions with their social and physical environments. For my go-along interviews, I accompany mosque-attending woman in their social outings to understand what people say they do vs. what they do.

7. Personal interview with Necati Mert, the former president of the local mosque organization
8. Personal interview with Leyla Özmal, former integration commissioner
9. Personal interview with Zülfüye Kaykı, former state secretary
10. Personal interview with Metin Dayıoğlu
ABSTRACT: The project presented in this paper is part of a larger body of ongoing design research that investigates kinetic and responsive architectural skin systems. It explores integration of custom-made soft robotic muscles into a component-based surface. The result is a prototype of a light modular system capable of kinetic response triggered by inflation and deflation of soft robotic muscles. The project focuses on kinetics of architectural surfaces and tectonics that integrate stasis and motion. It proposes a ‘programmable’ architectural modular system that simultaneously addresses stability, dynamics and adaptability of a singular system. This prototype-based research demonstrates the possibility of transforming aggregated structures by inflating and deflating integrated soft components (pneu) within them. In particular, the project explores the capacity of pneu structures to produce a kinetic effect in architectural surfaces. By having an elastic membrane, a pneu structure responds to the change of pressure by changing its mass. The change in pressure can cause considerable physical transformation of the structure. In addition, the nature of a boundary between architecture and its larger ecology is of particular concern. The project is based on two premises. First, that architecture and the built environment in general should be more tightly bound to the dynamics of local ecologies and that strong links to the undercurrents of its surroundings (near and far) could facilitate an active response to constant changes in the environment (external and internal). Second, that responsive architectural systems could act as ecologies in themselves, allowing architecture as a discipline to recalibrate its role in a larger socio-economic context by becoming a more intelligent and operative participant – a participant imbued with foresight.

KEYWORDS: Responsiveness, active material system, architectural boundary

INTRODUCTION
A boundary is defined as a line that establishes limits of an area or a sphere of influence – a dividing line. Traditionally, we think of spatial envelope in architecture as a boundary that separates exterior and interior environments or encloses spaces, and we presume that physical and spatial boundaries are one and the same. This view of the spatial boundary is probably as old as human desire for shelter and is reflected in Frei Otto’s observation that “Architecture is man’s oldest skill in his struggle for survival in nature. It is therefore directed against nature.” (Otto, 1995, 8) However, physical phenomena extend beyond spatial boundaries. In physics, the boundary is a place of action where different energy fields transition into one another. Boundaries, therefore, could be thought of as active regions rather than surfaces of delineation (Addington and Schodek, 2005, 6).

In the 20th century, with the advent of building mechanical systems, two distinct positions towards an architectural boundary emerged: one that facilitated impermeable envelope, as seen in Le Corbusier’s Cité de Refuge, a building with sealed walls and controlled ventilation, (Banham, 1984), and the other that encouraged permeability as described in the writings of Rayner Banham, Yves Klein’s speculative projects called air architectures with walls and roofs defined by thin sheets of rapidly moving air, or Cedric Price’s, Archigram’s and Coop Himmelblau’s experiments with inflatable structures. Technological advances and a promise of technology to deliver radically different solutions fueled both positions.
As emphasized in Rayner Banham’s article *A Home is not a House*, there are two basic ways of controlling environment: building a shelter or mediating local environment by campfire. Banham points out that “a campfire has many unique qualities which architecture cannot hope to equal, above all, its freedom and variability.” (Banham, 1965, 75.) Thinking in terms of energy exchange, flow and dynamics – and consequently in terms of gradients – calls for a spatial boundary that can negotiate change and transition and not simply isolate. It was Banham’s argument for the inclusion of environmental phenomena and their variability into a design process that began to orient architecture towards adaptive environments. His ideas encompass the domain of environment and not that of an inert object or surface. Boundaries that modulate flows of heat, coolness, air or noise, exert subtle influence and support organization of people and activities differently than inert physical boundaries would. They could ‘contaminate’ design with the notion of variability, possibly leading to a richer interaction with the built environment. When the infrastructure for space organization is not only concerned with the traditional logic of the constructed environment but is informed by the logics of thermodynamic behaviors, a new notion of order and organization of space could be achieved that would increase organizational complexity, introduce emergence, and possibly result in the design of open systems. (Pavé, 2006) Energetically or kinetically active boundary has a level of agency and can, through its variability, attract, dispel or disperse users within spaces. It might unfold additional otherwise hidden layers of usable space or attract gathering by its coolness or heat (Figure 1). By gathering information from the environment, responsive boundary can serve as an effective interface between the users and their surroundings.

![Figure 1: Kinetically active responsive building skin Source: (Author 2005)](image)

In the introductory chapter of his 1970’s book *Kinetic Architecture*, William Zuk, an engineer, architect and educator at the University of Virginia, speculates about changes in design approach that are necessary to envision architecture capable of kinematic movement (Zuk and Clark, 1970, 11). He suggests that new construction techniques, materials, and technologies would have to be established. But at the same time, Zuk predicts that even though kinetic architecture will require more mechanistic and technological approach through the use of sensing technologies, new materials, and embedded computation, it may also usher a new kind of relationships between a human body and space. According to him, social relationships, as well as personal sense of space and enclosure, would be challenged. Associations between a dynamic body and dynamic space could provide a context where organization of human activities and experiences becomes more sensitive and responsive to changing needs, changing form, and phenomena.

### 1.0 BACKGROUND

The project described in this paper proposes a structure for an *active* boundary. This modular structure is built from self-similar elements and is activated by pneumatic “muscles” that can react to variety of environmental stimuli, including presence or movement of people.

Dynamic behavior of the structure is introduced by integrating active pneumatic “muscles” directly into the structure. *Pneu* is a primary form of living nature, an effective structural system, as well as instrument of form giving (Otto, 1995). Every cell is a pneu structure (Helmcke, 1977). An elastic membrane that bounds pneu structures responds dynamically to the change in pressure by changing its volume. The change in pressure and consequently volume can
cause considerable physical transformation of the structure. This transformation enables a pneu structure to produce a kinetic effect in its own structure and also in structures that are attached to it. In engineering, rigid materials are employed to fabricate precise and predictable dynamic systems, but natural systems often exceed this performance with soft and flexible bodies (Rus and Tolley, 2015).

In soft robotics, the pneu-like capacity is used to design robots that move or handle fragile objects by manipulating the inflation and deflation patterns. Their bodies are capable of large-scale deformation and high level of compliance (Marchese, Katzschmann and Rus, 2015). Some of these robots can move around obstacles or squeeze under them. The research by Harvard’s Biodesign Lab using soft robot fabrication techniques, described by Andrew D. Marchese et al. (2015), provided a starting point for the initial studies of pneu elements in this project. Other relevant studies that informed the project were related to the movement of soft actuators and their motion patterns (Bishop-Moser et al. 2012), and the complexity of this movement (Connolly, Walsh and Bertoldi, 2016). The capacity of soft robotic components to affect larger structures in which they are incorporated is of key importance for this project.

The project attempts to address two challenges present in designing dynamic and adaptive surfaces: the selection and design of an actuation system and its incorporation in surface tectonics. Therefore, on one hand, it explores a capacity of pneu structures to induce kinetic movement, and on the other, it articulates a component-based tectonic assembly that can integrate such movement. This project is informed by a history of pneumatic structures, the technology of soft robotics, and a modular design strategy (Figure 2).

**Figure 2**: Active pneumatic muscles move part of the structure Source: (Author 2005)

Inflatable or pneumatic structures have been used in architecture primarily for their lightness relative to the structural span. Between 1940s and 1970s these structures underwent a significant evolution. One of the first fully inflatable structures was a radome developed by Walter Bird in late 1940s. The exploration of air-supported structures quickly grew beyond their use as shelters for equipment or supplies. In 1960s and 1970s they were used in a variety of experimental projects in architecture, from the Fuji Group Pavilion, designed by Yutaka Murata for the 1970 World Expo in Osaka, to experiments by Coop Himmelblau, Archigram, and Haus-Rucker-Co created at the scale of a human body. Inflatable structures offered a potential to design soft, transformable spaces with new formal (and dynamic) qualities. These mobile and mostly temporary structures were acknowledging the transformational potential of inflatable forms. They brought into architecture the notions of a dynamic, changeable and soft space, with boundaries no longer defined exclusively by rigid material enclosures.

Today researchers are experimenting with even smaller scale inflatables that could be integrated into architectural surfaces and components i.e. into tectonics of a material system itself. Current experiments with elastic inflatable elements influenced by soft robotics are suggesting new trajectories in exploring dynamic spatial boundaries. The projects such as The PneumaKnit by Sean Ahlquist, McGee and Sharmin and Modular Pneu-Façade System by Daekwon Park and Martin Bechthold are integrating inflatable elements to add new functionalities of dynamics or sensing to the architectural surface. The PneumaKnit is concerned with motion and dynamic articulation of inflatable components. This is achieved by using knitted constraints that regulate expansion of the actuator and direction of its motion. The emphasis is on the material structure of the knitted constraint, which, through a variable density of its weaves, produces the surface transformation when actuators are inflated. This

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work is concerned not only with the actuator itself; equally important is its constricting surface. The material integration between the inflatable and knitted elements is a step forward in rethinking the material assembly in which constituent parts are dynamic, and perform synergistically as one material system. The Modular Pneu-Façade System is imagined as “a dynamic pneumatic interface, which can be used in building applications including responsive façade, ceiling, floor and interior screen, etc.” (Park and Bechthold, 2013). This layer of soft inflatable elements that can be integrated into a building’s skin to make them transformable and active is sensitive to human touch. Its surface utilizes capacitive sensors and conductive gel, which make it conductive to touch. Both of these experimental projects deal with a challenging question of how to integrate an active layer into an architectural assembly and speculate about architectural surface capable of interfacing information, dynamics and a user.

2.0 METHODS

The Soft Kinetics project brings together two strategies for designing adaptive architectural skins. One is concerned with the combinatorial variability of a light structure built by aggregating small self-similar components. The other one focuses on the integration and distribution of pneumatic muscles within an aggregated structure. The proposed system is a component-based material system whose properties range from rigid/stable (self-supporting) to pliable/active (dynamic). To achieve these variable properties particular emphasis was placed on the system’s morphology that arose from integrating self-similar rigid and pliable components with pneumatic muscles. This process produced a ‘programmable’ surface that can open, close or alter its basic form.

2.1. Light modular structure

The light modular structure is built using self-similar elements with a non-orthogonal alignment. It is aggregated through slot-friction connections and can be organized in a number of different configurations. The configuration of the construct is governed by the requirements for stability (self-support) and kinetics; both of these criteria are equally important to support dynamic transformations. Stability is achieved in two ways: by interlocking the components through simple slot-friction connections, and by the patterns of aggregation. The kinetic behavior is enabled by a system of pneumatic muscles, their full integration with the patterns of aggregation, and the capacity of the modular structure to allow for disruptions in pattern continuity without compromising the construct’s stability. The redundancy of connections and elements provides a structural resiliency.

Figure 3. Rigid and pliant configuration; Integration of bendable component Source: (Author 2005)

Due to the self-similar unit shape and the standardized connection between the units the structure can be built in a variety of configurations and adapted to a variety of spaces. Following the assembly pattern, two main configuration trajectories emerged: rigid (self-supporting) and pliant (flexible) (Figure 3).
Individual components can form any number of permutations, but discrete assemblies, used to govern the form of a larger construct, were generated to support change in functionality, directionality and form. These discrete assemblies were then combined into larger formations and their tectonic and spatial capacities examined. However, the system itself remains open and able to adjust to a variety of spatial/contextual conditions as well as to support part replacement. In this way, recalibration of the construct can be maintained since its parts could be reconfigured in a variety of ways (Figure 4).

![Figure 4. Combinatorial Potential Source: (Author 2005)](image)

The component shape was chosen for its capacity to produce a significant number of different combinations while maintaining the pattern that generates rigid and pliant versions. These configurations were then modeled digitally and tested physically for their behaviour. The tests resulted in a design of a new bendable component that was positioned adjacent to pneumatic muscles to facilitate bending of the regions surrounding the muscles. Ultimately, the modular structure can negotiate a change in direction (straight, angled, curved), change in thickness by smoothly transitioning from single to multiple layers (from a surface to a three-dimensional construct) and change in structural capacity (from self-supporting to bendable).

### 2.2. Pneumatic Muscles

The soft body of the *Soft Kinetics* project is imagined as a continuous and interrelated network of pneumatic muscles integrated into an assembly pattern of the modular structure. It consists of clusters of interconnected soft inflatable pneumatic muscles. They are linked by silicone tubes that allow passage of air through a number of muscles, inflating and deflating them in a sequence. When activated these clusters move entire regions of the modular structure, producing opening and closing apertures (Figure 5).

The movement of pneumatic muscles depends on the flexibility of the elastic material, and the volume of internal chambers and their geometry (Bishop-Moser et al 2012). Andrew Marchese et al (2015) list three soft robot morphologies differentiated by their internal channel structure: ribbed, cylindrical, and pleated (Marchese, Katzschmann and Rus 2015). The soft body (actuation system) of the *Soft Kinetics* project is developed using a ribbed morphology but its internal channels are produced using two different techniques: the lost wax casting, and a combination of the lamination casting and the soft lithography fabrication method. As a result, two types of muscles are produced: the central channel muscles (S, B, and V) and the distributed channel muscle (M) (Figure 6). The fabrication technique is important in achieving consistent properties of the muscles as they get reproduced; it plays an important role in achieving consistent elasticity and inner channel geometry.
The behavior of designed pneumatic muscles was explored through prototyping and iterative design and their performance observed as they were activated within a modular structure. The central channel muscles produced using the lost wax technique were resilient and durable (by not being cast in laminated fashion). Compared to the distributed channel muscle it achieved significant bending. In general the lost wax technique allows for a great variety of cavity forms since the muscle was made as a solid body and was designed that way, not in layers. The proposed central channel muscles underwent several modifications to achieve maximum bending after inflation.

The muscles were conceived as modular elements of the structure and as such could be integrated into the structure interchangeably; two muscles (S and V) were designed to integrate into the assembly grid pattern while the other two (B and M) to nest within the voids of the grid. In terms of their behavior, the central channel type muscles (S, B, V) act as linear actuators while the distributed channel muscle (M) acts as a folding hinge (Figure 6).
The muscle morphology and geometry were designed to balance the wall thickness and the volume of air channels. These two different types of muscles required different approaches to mold production. The central channel muscle molds were CNC milled, while the distributed channel mold was produced by layering laser-cut acrylic material. Both muscle types were made from silicon rubber. To direct their motion, one side was fabric-reinforced. Soft elastomer pneumatic muscles are capable of continuous deformation but the challenge is to isolate a particular bending movement within its length (Ahlquist, McGee and Sharmin 2017). For that reason, the pneumatic muscles used in this project were short and compliant with the grid pattern of the modular structure (Figure 5); their length and cluster organization, however, will be further explored in the next phase of the project, to produce asymmetrical shifts within the fabric of the modular structure.

2.3. Integration and prototypes

The “soft” body of pneumatic muscles could easily be integrated with the “hard” body of the light modular structure. The connection was achieved by embedding the modular component within the central channel muscles or by weaving the components through the openings in the distributed channel muscle. (Figure 7).

The central channel muscles integrate into the hard body of the structure by a slip joint, just like any other modular component of the system. Therefore, the soft pneumatic muscles could be positioned to displace the “hard” parts of the modular structure, working as an active connective tissue, while the overall assembly pattern was maintained. This strategy allows muscles to be asymmetrically distributed throughout the structure, concentrated in some areas, or placed sporadically in others. This is seen as a very promising direction that will be further explored in the next phase of the project. For example, larger segments of the modular structure could be dynamically altered to open and close apertures of varying sizes and shapes (Figure 8).
Several small prototypes were constructed to test various ways and combinations of muscle integration. It is in the prototypes that the clustering of muscles was explored. The clusters, consisting of three to five pneumatic muscles, were inflated in sequence. Solenoid valves controlled the inflation and deflation pattern (supply and exhaust) and their work was regulated through an Arduino microcontroller. The rate and duration of valve opening and closing was set to allow all linked muscles to inflate in a sequence; the pressure was controlled through a pressure sensor to prevent over-inflation and damage to the muscles. Muscles linked in a cluster worked as a group, affecting dynamically a designated region of the structure. The work of the "soft" body could be controlled through proximity sensors to reveal a clear view out or in, or could be regulated by light sensors to serve as a functioning shading device.

CONCLUSION

The research shows a promising way of integrating an active pneumatic layer within a light modular structure. An important aspect of this project is the smooth transitioning between stable and dynamic regions of an aggregated structure. Additional components that would facilitate that transition or compensate for motion were not necessary. Other essential features are the slot-friction connections, consistent aggregation patterns, and modular pneumatic components that integrate seamlessly into the designed patterns. The transitions between dynamic and static regions are achieved through carefully designed (and tested) component distribution pattern and varying densities of pneumatic muscle components within the aggregated construct. Some parts of the resulting structure are self-supporting, providing structural stability, while other parts permit different levels of movement without compromising the structural integrity.

The design of pneumatic muscles strives to seamlessly integrate soft and hard layers into a composite system using the same aggregation patterns. The key feature of Soft Kinetics is an actuating system that is embedded, through the geometry of its components, into the overall structural pattern of the construct, while simultaneously making the regions of that construct dynamic. This project attempts to produce additional functionality of an architectural assembly by integrating functionality and materiality of soft/dynamic and hard/structural layers to produce a dynamic architectural assembly.

The weight of the structure is an important factor; therefore more research is required to define the "blended" materiality of the modular structure as well as the durability and weight of the embedded pneumatic components. Current composite structure is made of plywood; but the use of aluminum and plastic will be explored in future iterations.

In his seminal article on "Resilience and Stability of Ecological Systems," C. S. Holling points out different ways in which we see the behavior of a system. Engineered systems or devices that perform specific tasks under predictable external conditions have their performance immediately adjusted if the variation in performance is observed. They are concerned with constancy of performance and lean towards stability. Natural systems that are constantly confronted with unpredictable external changes are less concerned with constancy and more with persistence of the relationships (Holling, 1973). An equilibrium-centered view of a system...
is static and doesn’t offer the flexibility necessary for systems with transient behavior. The project presented here is an exploration into how to incorporate variability in performance (from stable/structural to dynamic), and how those variable conditions integrate and interface with each other.

When designing active and adaptive artificial environments, whether they are intelligent facades or built environments that interface with natural ecologies, we want to establish a flow of information and energy. The adaptive built environment should behave similarly to natural systems. Therefore, we might design them by being less interested in stability as an on/off condition, and more in the zone of stability or motion, their gradient and ability to perform under constant changes.

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REFERENCES

Addressing barriers for bamboo: techniques for altering cultural perception

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ABSTRACT: The potential benefits of bamboo as a rapidly-renewable, low-carbon, sustainable building material are well established, yet bamboo remains underutilized globally due to laborious manual evaluation and fabrication techniques and deeply-rooted aesthetic stigmas in western culture. Scholarship in this area has the potential to radically redefine the usage of bamboo as a cheap and sustainable material, but in practice the widespread implementation of bamboo is limited by its cultural perception. This paper examines cultural perceptions of bamboo as a cheap and informal or kitsch vernacular material, using existing scholarship and projects to analyze existing methods and attempts in practice to either elevate or transform perceptions of bamboo through built work and engineered materials. The paper posits how new research by the authors aimed at transforming the use of solid bamboo species can radically shift the way in which bamboo is perceived, transitioning from an irregular kitsch vernacular material to a refined material system that mimics accepted conventions or invents new vernaculars.

KEYWORDS: Bamboo, Construction, Cultural Perception, Sustainability, Biomaterial

INTRODUCTION

The benefits of bamboo construction in terms of structural performance and sustainability have been known within vernacular contexts for centuries, and recent decades have seen continued development of scholarship documenting, quantifying, and lauding these and other characteristics (Van Der Lugt 2017). As a structural member, bamboo draws its strength from the density of fibers around the perimeter of its cross section and performs well in bending (Fig. 1). The question then raised is why bamboo has not been more widely implemented as a structural building material in the global construction industry—the rapid rise in popularity of bamboo flooring certainly improves sustainability but does not utilize bamboo’s impressive structural capabilities. Existing scholarship has outlined potential causes as the lack of reliable and established codes and standards for the grading of bamboo, which currently relies largely on know-how and visual grading (Trujillo and Jangra 2016), and the issues that arise from this lack of systematized documentation—architects are averse to specifying bamboo, meaning contractors do not work with it and companies producing bamboo for construction do not experience opportunities for large-scale growth (Opoku et al. 2016).

This paper describes recent work that attempts to address these issues through new approaches to structural bamboo construction. Across much of this work, the restraining factor is that the cultural perception of bamboo—particularly but not exclusively within western contexts—has not been directly addressed through the treatment of the material in a structural configuration.

The authors propose using digital means of measuring, optimizing, and routing bamboo in order to change the cultural perception of bamboo construction. The authors’ work deals specifically with Dendrocalamus Strictus—known colloquially as Calcutta Bamboo, Iron Bamboo, or Tam Vong, a unique species of nearly solid bamboo grown in Asia, Indochina, and Latin America. The comparatively thick wall of the Calcutta Bamboo allows it to be faced on one or more sides to create a flat surface through stock reduction. This faced bamboo has the potential to be perceived as a hybrid between traditional bamboo and traditional milled lumber. Through this method, the project attempts to develop a structural and aesthetic language that
calibrates the relationship between the aesthetic stigma of “live edge” bamboo and the structural benefits it inherently contains. The fidelity of bamboo as a natural material is considered and manipulated throughout the process.

1.0 METHODS
This paper establishes the cultural stigma toward bamboo, as evidenced in recent research and the treatment of bamboo in various exhibitions and through popular media. Referencing past and current research, strategies to transform the perception of bamboo in structural applications are evaluated and categorized. This creates points of comparison for the author’s project to be differentiated in its unique strategy of navigating the perception of bamboo while maintaining its demonstrated structural benefits.

2.0. CULTURAL AESTHETIC STIGMA
Known colloquially as “poor man’s timber,” bamboo carries a longstanding cultural aesthetic stigma, particularly within a western context. The perception of bamboo as an informal or unrefined material results from a combination of racism, classism, imperialism, and a lack of investment in the development of its material possibilities.

The reference to bamboo as “poor man’s timber” or “poor man’s wood” was made almost two decades ago in Grow Your Own House, in which the authors also make the claim that “…bamboo has liberated itself from this stigma as the downsides to Western culture have emerged and people are increasingly turning toward regional, sustainable technologies” (Vegesack and Kries 2000, 9). While there has been a substantial growth in interest toward sustainable technologies, to have made the claim in 2000 that bamboo had been freed of all cultural stigmas seems naive—Susanne Lucas of the World Bamboo Organization discusses the ramifications of the same “poor man’s timber” term over a decade later in her 2013 book, Bamboo (Lucas 2013, 16).
The stigma toward bamboo as an informal or low-brow material is evidenced in popular media representations of bamboo construction—ranging from depictions of primitive and uncivilized huts to the mystical healing powers of zen gardens and spa therapy. The shelter constructed by the marooned visitors of Gilligan’s Island is defined by its striping of bamboo poles in the popular sitcom aired from 1964 to 1967. Nearly every convenience of contemporary western life is recreated in bamboo, from a pool table to a pedal-powered taxi cab (Gilligan’s Island, 1964) (Fig. 2). Tiki themed restaurants, summer apparel, and poolside accessories abundant in contemporary society only reinforce such depictions. Similarly, Disneyland’s Swiss Family Treehouse was built as an ad-hoc collection of bamboo poles nested around a giant tree—and later was adapted to become and remains to this day Tarzan’s Treehouse—while the sign for the park’s Adventureland is framed in imprecisely joined bamboo members with a primitive mask mounted overhead (Fig. 3). These depictions are not always overtly negative but do work to undermine the idea of bamboo construction as anything other than temporary or a condition of circumstance—in both Gilligan’s Island and Swiss Family Robinson, the world is constructed in bamboo not by choice but by necessity given no other available materials, meaning the material of bamboo itself becomes a symbol of the protagonist’s plight. The hospitality industry likewise plays into the bamboo aesthetic, advertising beach vacations in bamboo cabins set above the water. The result of such imaging is a reading of bamboo as a shorthand for vacation, in the same way that a Swiss chalet conjures memories of a ski vacation or a log cabin implies camping in the woods away from the comforts and commodities of everyday life. The composite effect of such imagery effectively disassociates bamboo from incorporation into contemporary society.

The stigma toward bamboo is also documented in recent research. In a survey on perceptions of the use of bamboo in construction in Ghana in 2016, it was found that after lack of specification by architects, lack of bamboo processing companies, and insufficient government cooperation, the fourth highest barrier to the use of bamboo is the “Problem of social acceptability (bamboo is considered for the poor)” (Opoku et al. 2016, 86). This concern was
listed well above such items as the lack of availability of the material or the lack of knowledge and skill in how to detail and implement bamboo structures.

![Crude bamboo sign for Disney's Adventureland "Home Sweet Hut." Source: (Flickr 2018)](image)

**Figure 3:**

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**3.0. ATTEMPTS TO TRANSFORM THE PERCEPTION OF BAMBOO**

In recent years, several strategies have been implemented with varying levels of success aimed at transforming bamboo into a contemporary structural building material. These strategies can be grouped into several categories: macro-scale assemblies, unique composite joinery, elevation of material, concealment of material, and material transformation of the bamboo pole.

**3.1. Macro-scale assemblies**

Macro-scale assemblies have been attempted with various techniques of aggregating bamboo poles into large unique forms including crisscrossing, lashing, and fish-mouth assemblies. The resulting forms tend toward fluid geometries that demonstrate the capacities of new construction systems through the display of novel aesthetic qualities.

The ZCB Bamboo Pavilion constructed in 2015 in Hong Kong displays such qualities, consisting of large bamboo poles that are tied together in a traditional method (Kristof and Fingrut 2016). However, the scale of the construction is so great that the form and luminous quality of the pavilion eclipse the reading of the bamboo pole, bypassing the aesthetic quality of the bamboo and allowing it to be read simply as a set of aggregated linear members that might just as easily be made from steel or aluminum pipe.

In Archi-Union’s parametrically designed Mobius-strip pavilion entitled In Bamboo, (Chen 2018) the design blurs historic and contemporary—the form is a daring combination of two vernacular circular forms merged into a single figure eight. While the construction process engaged digital fabrication for the shaping of the glulam beams, the pavilion’s bamboo façade
is a hand hewn traditional woven bamboo screen, therefore embracing rather than challenging the traditional reading of bamboo.

3.2. Unique composite joinery
Projects implementing unique composite joinery display novel ways of creating connections for bamboo members, often utilizing a modern material such as steel or aluminum to create nodes between bamboo poles. These projects display the structural capacities of bamboo in modern construction, but display raw bamboo pole without treatment or modification without attempting to challenge its cultural perception. Instead, this strategy is often an unapologetic approach deploying modern joints and forms while the bamboo poles themselves are used as linear structural members in a relatively traditional way.

In the German-Chinese Pavilion for the 2010 Shanghai Expo, machined stainless steel nodes are juxtaposed with raw bamboo compressive members (Bamboo Pavilion 2010). The bamboo poles are read as pipes, albeit in a slightly more organic milieu. Countless other projects employ this technique, from studies by Renzo Piano for multi-axis building joints to bicycles by companies such as Boo Bikes and Calfee Designs. These bicycles similarly employ raw bamboo poles with joints made in a modern material, in this case resin-reinforced carbon fiber. In all cases, the cultural perception is largely unchanged despite the celebration of the structural performance because of the expression of the raw bamboo pole.

3.3. Elevation of material
Many widely publicized bamboo projects in the last decade have advanced the expression of the material, often using traditional construction techniques and connections but marketing and presenting the projects as high-class design. These examples typically lean heavily into the bamboo resort culture exemplified in Gilligan’s Island and Disneyland's Swiss Family Treehouse while simultaneously embracing the fluid formal language developed during the Digital Turn.

The Green School and Green Village in Bali which began construction in 2008 is a leading voice in applying contemporary design to bamboo construction, and has been widely publicized globally, bringing new attention to bamboo as a sustainable and dynamic construction material. The work does not however address the cultural stigma of bamboo within most typological applications, instead aligning itself with glamping and resort cultural archetype of the sophisticated hut. This categorization leaves the material stranded within a specific cultural association, making it difficult to transplant it to both an everyday context and a different cultural context.

Kengo Kuma’s Great (Bamboo) Wall is a house employing bamboo walls and screens with an overtly high-design sensibility (House near Badaling 2003) (Fig. 4). The project aims for a Miesian sense of space, plane, surface, and transparency, elevating the status of the material and certainly celebrating it. However, the bamboo is not meant to be understood as anything other than raw bamboo—the poles are used as-is and remain trapped within their cultural associations.

3.4. Concealment of material
In his 2016 TEDx talk, David Trujillo, chair of the Bamboo Construction Task Force at the International Network for Bamboo and Rattan, discusses the implementation of bamboo in housing and other similar structures (Trujillo 2016). After laying out clear arguments for the sustainable and structural capacities of bamboo, the example he provides as the bamboo house that global society will welcome—labelled as “Villa Diana Carolina, Ricaurte, Colombia”—has no visible bamboo at all. A label placed over the image calls out that bamboo is “concealed in the wall and roof.” This strategy sidesteps cultural perceptions entirely by removing them from sight.
3.5. Material transformation
Recent and ongoing research projects are aimed at abstracting the bamboo pole at a variety of scales through different processes while retaining the structural integrity of the material. These techniques range from flattening, unwrapping or bending the poles, to weaving, laminating or compositing boards into new shapes and forms. Some of these methods are now commonplace, such as the composited strips seen in the contemporary hardwood-replacement bamboo flooring sold worldwide, while others are less known, such as the structural composite laminated beams known as Bamboo NFINITY used to create a solar carport frame by BMW South Africa (Pablo van der Lugt 2017, 54-5). In these applications, the material transcends the connotation of “poor man’s timber,” but risks exchanging this stigma for another cultural perception of cheap engineered lumber.

Other research projects transform bamboo in even more drastic ways, such as the Truss Me furniture system designed and produced in India by Sandeep Sangaru in which the bamboo is partially split and reassembled by laminating to construct space frames with solid natural nodes and laminated braces in between. Designer Stefan Diez’s Soba bamboo furniture leaves the poles largely intact but creates innovative joints through the removal of long sections of the pole, reducing it to a belt-like dimension and allowing it to wrap around other poles to create structural connections. These approaches have also been developed through architectural research in which bamboo poles are partly split and laminated together to create space frame-like aggregations that use the natural nodes of the material as structural connections (Sonpal 2015). These projects display significant tectonic shifts in bamboo construction, suggesting entirely new vernaculars for bamboo.

4.0. APPLICATION AND CONCLUSION
Given the demonstrated benefits of bamboo construction but the drawbacks of its ingrained cultural perception, we are developing techniques to change its vernacular—either by adopting the vernaculars of wood construction or more promisingly, inventing new vernaculars that leverage the specific qualities of bamboo. Our ongoing research projects seek to advance bamboo construction via the specialized use of Calcutta Bamboo, a species with a very high wall thickness and very small hollow cavity at the center of the pole. By surfacing or facing the Calcutta Bamboo, flat surfaces are created, and the bamboo fibers take on an aesthetic quality that closely resembles some species of hardwood lumber (Fig. 5).
We are developing a material strategy and an intelligent parametric system that will enable the bamboo to be manipulated and used in this way. The system consists of several components that first evaluate the material to determine its specific geometry and qualities, then mill surfaces and specific joints in a custom 4-axis CNC mill (Fig. 6 and 7). The aim is to create an intelligent system that uses feedback from visual, noninvasive scanning to determine which piece of material is used for each specific part of a designed structure. The opportunity also exists for the designed structure to be informed and adapted by the structural and formal capabilities of the available material.

The specific structural diagram of bamboo is such that the outside perimeter of the pole is also the part with the greatest fiber density and strength (Van Der Lugt 2017, 38-9). This means that if all faces are removed to produce a fully squared piece of material—thereby making it fully recognizable to a western sensibility most familiar with lumber—the portion of the material granting the greatest structural performance is lost (Fig. 8 and 9). Rather than sacrificing the strength of perimeter, our current research aims to balance performance and aesthetics through selective facing or planking, leaving a mix of live edge and planed faces. This research is developing a set of documentation on the structural performance of Calcutta Bamboo in various combinations of faced and un-faced states. By making known the structural qualities of faced bamboo, we will be able to validate the possibility of addressing concerns of cultural perception while allowing for its implementation as a structural system. It is our goal that such activities will advance new ways of thinking and building that utilize an outstanding renewable natural material in such a way that it can be accepted and utilized globally through its perception and future acceptance into a wide array of societal and cultural contexts.

5.0. FUTURE WORK
This paper establishes the presence of tainted cultural perceptions of bamboo in various cultures globally and examines several strategies for changing the perception of the material, while proposing particular techniques for preparing and assembling the material to specifically change these perceptions. However, future research will need to gather data to substantiate the claims that these strategies will in fact change the cultural perception of the material in a predictable way. This will be done through future surveys and other methods.
Further limitations do exist in the current species of investigation. Calcutta Bamboo is a tropical species and is not currently grown in the temperate climates of America. While having a very solid cross-section, it grows to a maximum diameter of 2-3 inches. Additionally, the bamboo is very solid at the base of the plant but becomes progressively more hollow towards the top of the pole. Future development of our fabrication and material system will attempt to utilize both the more hollow and less hollow sections of the pole in order to minimize material waste. Further research will also examine and test several other species of structural bamboo that
are similarly thick-walled but grow to much larger diameters. We also plan to develop hybrid material strategies that combine ideas of faced poles with engineered laminated beams, trusses, and structural panels.

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**Figure 9:** Cross sections of faced Calcutta Bamboo. Source: (Author 2019)

**REFERENCES**


Japan-ness + suchness: seeking to seize an understanding of an ethereal elusive ethos

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ABSTRACT: Japan is in many ways a mysterious society with a rich history and complex culture. Informed by longstanding traditions and deeply-rooted values, contemporary Japan struggles to chart paths forward while retaining strong threads binding yesterday to tomorrow. Modern planning, architecture and design in Japan, and perhaps most notably in its capital city of Tokyo, in many ways illuminates the tensions that exist between the authority of the past and the promise of the future. Inspired in part by pervasive spiritual paths, fundamentally Shintoism and Buddhism, design embraces notions of ephemerality, impermanence and non-attachment. It also characterizes the pursuit and acceptance of perfection through imperfection. Wabi-Sabi and similar approaches highlight a high degree of comfort with the uncertain, the flawed and the incomplete. That said, remarkable advances in high-technology and an aggressive uptake of digital media counter this acceptance of the indeterminate, both in social and physical spheres. People are increasingly connected and informed, yet ironically disconnected and unaware. While society writ-large is shaped by intense formal and informal expectations to conform (the nail the stands out gets hammered down), it also permits ample latitude for the proliferation of subcultures and the acceptance of the extraordinary. Metabolist Architecture, for example, demonstrated an unbridled openness to utopian vision, bold departures and iconic gestures. The present research, through meta-analysis of the literature, case studies and logical argumentation, critically examines the notions of ‘Japan-ness’ and ‘suchness’ in light of current turbulence and transformations. The author, an architect and psychologist with extensive first-hand experience of Japan, considers a spectrum of dimensions that serve to distinguish and define the country and culture. Viewed through scholarly lenses that include architecture, education, spirituality and homelessness, the paper delineates and interprets the many qualities of Japan that continue to uphold its interwoven veils of mystery, sensuality, advancement and atmosphere. The paper seeks to demonstrate how architecture and urbanism in Japan embodies historic, spiritual and cultural values & practices. Using Tokyo as one window into such aspects, the author explores a variety of facets of the metropolis that illustrate those qualities that contribute to ‘Japan-ness’. Discussion includes implications/impacts to an annual study abroad program in architecture and planning whereby graduate students search for contextual understanding and cultural meaning prior to embarking on dramatic and diverse urban design projects. Designing, in a studio setting, in such a complicated and charged milieu demands a willingness to know and a commitment to connect. The deliverables of the research include the portrayal of a series of features of Japan-ness woven into an approach for understanding the conditions, complexities and characteristics of this leading nation and its incomparable culture. The systems-oriented multi-pronged tactic, and its underpinning information, proves valuable for researchers, educators, students and visitors examining, discovering and engaging Japan.

KEYWORDS: Japan, Buddhism, architecture, education, systems thinking, holism, pedagogy, culture

PRELUDE

“It is through creating, not possessing, that life is revealed.” Scudder

Japan is an enigmatic and alluring nation with a rich history that is both complex and convoluted. In many ways contemporary Japan has been shaped by a myriad of factors both
traditional and contemporary, from the honor and restraint of the samurai ways to post-war unbridled consumerism and frenzied materialism. It is a culture overflowing with contrasts and contradictions, with many aspects of life paradoxical and puzzling to outsiders. That said, there are many forces that deeply underpin the society, that profoundly shape thought and that guide action. Such forces, while often implicit and residing beneath the surface, nonetheless dictate many moves within the culture. The author has written extensively about variables of Japanese culture that define and delineate many features of the environment, the society and behavior. These explorations have ranged from research into homelessness, dwelling and the city to critical considerations of modern architecture and inherent flexibility in building design.

The present paper examines a number of aspects of Japan that contribute meaningfully to a deeper understanding of its culture. This investigation has developed over the author’s many years of conducting research (e.g., agile architecture, open building, prefabrication, homelessness, traditional arts, etc.) in Japan as well as through delivering an environmental design study abroad semester program in Tokyo, Japan’s capital city and the world’s largest metropolis. Central methods include invocation of case studies of three seminal architectural projects, intentionally drawn from dramatically different historical periods (Taisho: traditional home, Showa: Metabolist tower, Heisei: modern project). The research explores dimensions of Japanese spirituality and philosophy that serve to inform, influence and inspire these diverse projects – while concurrently illustrating common threads that give character to architecture and design. Through these case studies, together with logical argumentation and the illumination of principles of Buddhism, Shintoism and associated practices, the author reveals qualities of Japan-ness that are valuable in grasping rather ethereal constructs that undergird the society and that dictate views, define values and delimit activities. Such understanding is worthwhile to students and practitioners who endeavor to design in this enigmatic ethos.

1.0 JAPAN

“The Japanese society approaches much of life with a respect for space and a critical eye to efficiency. Take clothing, for example: kimonos are designed to be folded then stored flatly, tightly, and efficiently. The bento box for food is another example where the focus is on space: attention to delivery, designed presentation, concern for aesthetics, and no waste. Cemeteries are another example of high efficiency, effective use of room, and the appreciation for scale, mass, surface, and space. As regards design and space, Japanese culture so often places tremendous value on beautiful functionality, on quality, on keeping, on maintaining, on preserving, on innovating, and on appreciating.” Sinclair (2015)

Japan is an island nation with limited resources, restricted space and relatively high population. A major portion of the Japanese reside in one city – Tokyo. Tokyo is a remarkable urban conurbation, with intense population, compact development, extraordinary character and an exceptionally high quality of life. With a resident count exceeding that of all of Canada, the Tokyo Metropolitan Region embraces an impressive array of parts key to a well-crafted, well-designed and highly-functioning city. Tokyo is regularly acknowledged as a leading global city, with metrics underscoring abundant amenities, walkable streets, diverse neighborhoods and extraordinary attention to design + planning. From a world-class multi-modal transportation system and vibrant mixed-use communities to pedestrian-oriented fabric and design innovations, Tokyo demonstrates how an urban centre can be colossal and intricate while proving demonstrably dynamic, accessible and livable. For those looking from outside the city Tokyo proves paradoxical – it is massive in size, and incomprehensible in scope while functioning at high levels, running smoothly and relatively free from serious problems. Convenience is high, crime is low, efficiency is unprecedented, design is pervasive and a sense of community is ubiquitous. Tokyo’s success is in many regards without parallel. As an urban phenomenon it is worth critical examination, not only to cull out reasons for such achievement but also to better grasp the features and facets of the city than contribute to its Gestalt. In many regards Tokyo affords environmental design theoreticians and practitioners an outstanding exemplar for study, for experimentation, for inspiration and for best practices. While without question the context and culture of Tokyo and Japan is unique and nuanced, the
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The author contends that many lessons learned are of demonstrable value and potential application well beyond the present geographical boundaries. Japan exudes mystery with many facets of the ethos seemingly ethereal, elusive, puzzling and perplexing. Newcomers often struggle to make sense of a society that on one hand is very regimented and highly regulatory while on the other hand defies conventions and feeds the fringe. Under the societal shroud of sameness and conformity lies a kaleidoscopic milieu that permits experimentation, encourages innovation and accepts deviations. This is not only the case in fashion, entertainment and art; it also holds true for architecture.

1.1 Japan-ness

"Japanese attachment to the physical/material entity of a building has been less prominent than to the symbolic quality of its form." Bognar (2013)

In Buddhism a seeker aspires to grasp the true essence of a moment and acquire a deeper understanding of existence. The notion of ‘suchness’ conveys such attainment – an ability to discard the superfluous in order to see to the heart of a situation. Such clarity often requires hard work and repeated effort on the part of the adherent. In many ways understanding the essence of Japan – seeing beyond the tourist brochures and transcending the buzz of Shibuya – requires effort, energy and time. To comprehend ‘Japan-ness’ is to see the culture in an unvarnished manner. Such attainment, while not on the minds of most visitors, does matter for those who aim to reside, to be accepted, to work, to learn and to design in this milieu.

In the quest to appreciate Japan in deeper ways it is important to look beyond stereotypes and move beyond the superficial. In many ways such comprehension arrives not only by examining the culture but by experiencing the place, the people, the practices and the principles that comprise Japan-ness. The author has hosted many students in Japan within the structure of a semester long study abroad program. Charged with the execution of demanding design projects it becomes vital for students to quickly get beyond a bus-tour awareness of place. Students must assertively encounter the culture in ways that equip them to get deep fast – to overcome the tendencies for thin assumptions, knee-jerk responses and drive-by design in order to better understand the who, what, where, when and how of design in a foreign world.

As a part of the deep dive it is helpful to consider philosophical features of three fundamental tenets of Japanese spirituality, followed by an exploration of these features within three prominent architectural projects. The following Buddhist principles are worth considering in more detail when trying to understand Japan and Japan-ness.

1.1.1 Ephemerality

Ephemerality is in some ways the opposite of being concrete, being fixed and being set. It implies a lightness of existence and an ethereal quality. In the West our architecture often aims at being grounded, at conveying stability and communicating certainty. In Architecture schools we often witness the intense pursuit of iconic, monumental and over-bearing structures. Seldom in such settings do we see students encouraged to include changeability, to foster user-driven design roles, and to relinquish the architect’s ‘divine authority’ to create and control. In contrast Open Building, in the eyes of the author who has extensively researched this field, strives to address all of these qualities. Hence, especially in the West, the movement towards Open Building and Agile Architecture is viewed with suspicion, concern or even outright denial/dismissal. In Japan, however, such lightness of being is commonplace.

1.1.2 Impermanence

Impermanence is a core principle of Buddhism, which holds that all of reality is in constant flux. To assume that any circumstance, object or being is truly fixed is truly folly. Life is a journey of constant motion and ever-changing situations. Each moment is distinct from those preceding and those proceeding. Uncertainty is a certainty. In Western approaches to design and architecture we are most comfortable, on many counts, with total predictability. Financing models, for example, are aimed at costing out projects at a fixed moment in time based on a set bill of materials. In many cases project capital costs exclude less rigid components such
as moveable walls and furniture. Such narrow views then serve to limit any embrace of uncertainty and tend to preclude more agile, flexible models of development (including, for example, modularity and sometimes prefabrication). With skepticism abundant, and the role of architects and architecture rather entrenched in notions of permanence, it is easy to understand how the environment in North America has proven hostile to more mutable buildings. The author argues, in light of an urgent call for greater sustainability, that a deeper understanding of impermanence is important. Approaches aimed a design for disassembly, deployment of modular building systems, and empowering users to modify their spaces and places, seems timely and worthwhile.

1.1.3 Non-attachment
Non-attachment involves our ability to distance ourselves from the material world in an effort to more fully understand ourselves and our reality. In the West our obsession with consumption and consumerism (albeit now growing rapidly in the East as noted previously in the paper) make non-attachment an allusive concept. North American marketing efforts tell us that “We are what we own”. In design this translates into the role of buildings as status symbols, of products as instruments of power, and of Architecture as object. Non-attachment, as a concept of Buddhism in Japan, serves to weaken the link between the object as precious, as unchangeable and as primary. With space seen as ultimately changeable and the material world viewed as transient and detached (or detachable), architects and end-users are far more willing to accept buildings that might morph, shift, subside, reform and resurface.

1.2 Waxing philosophical
In Japan there is an important concept known as shibumi, which in essence translates as an unassuming elegance and conscious reserve. When shibumi is elevated it invokes what is called the beauty of wabi sabi. Wabi is about the wretched, forgotten and forlorn while sabi is about the ‘rust’ of age. It is arguably in the union of wabi and sabi where Japanese design becomes most compelling and aesthetics most remarkable – where the simple, the unaffected and the elegant coexist. We find this search for beauty, and the invocation of wabi sabi, deeply rooted in the traditional Japanese arts of ikebana (flower arranging), bushido (the way of the sword), and perhaps most notably sado (also referred to as chado or the way of tea). For the purposes of this paper, each of these ‘arts’ include strong temporal, and ephemeral, qualities. While preparations and reflections are inherent and valuable, it is the moment that proves especially critical. Certainly such concepts loom large in the efforts of Japanese architects and landscape architects, especially in their search to impart beauty, tranquility, mutability and meaning in an ever-escalating modern milieu of technology, urbanity and uncertainty.

One critical aspect of Japan, that informs and inspires design, is the deeply rooted spiritual history that underpins the culture. Shintoism and Buddhism are inextricably intertwined in the society, with ramifications witnessed over a spectrum of endeavours from business and the arts to education and politics. The Zen notion of mushin, or ‘no mind’, is a good example. Without a mind one is rendered without a self. Without a self one is afforded great freedom from the many trappings and seductions of common existence – inching ever closer to escape from the vicious cycle of suffering Buddhists call samsara. Ideas around and implications of ‘non-attachment’ loom large. Japanese design and architecture often seeks such release from trappings and clutter, electing instead for the simple, the austere and the unadorned. The Japanese term kanso acknowledges the importance of simplicity of design, akin perhaps to German modernist architect Mies van der Rohe’s famous dictum “less is more”.

Modern Japanese architecture, perhaps most notably in the work of the Metabolists and inspired by deeply-rooted philosophies (Kurokawa, 1995), pursued ideas of reconfigurable form and space in a new era of technological, material and societal revolution. Coupling simplicity of design and economy of means with the need for fluidity and mutability in environments, Japanese architecture has historically, and continues to, acknowledge and respond to the need for users and their built realm to exist synergistically, to transform as
conditions shift, and to be less about solidity and more about fitness. Spirituality adds substance and sets a trajectory for design pursuits in Japan.

1.3 Suchness

In Buddhism there is strong awareness of the illusion of permanence – that is, we construct and perceive our lives in a manner that suggests solidity, stability and predictability. All of this understanding of permanence however is mere folly, for the world and our lives are in constant change. What we accept now as reality is merely our best interpretation based on available knowledge, stimuli, past experiences and guesswork. Japanese culture accepts that life is ever-changing, and that a path that acknowledges the frailty & vulnerability of our journey, and the uncertainty of our path, is wise and reasonable. Zen teaches that in the midst of unpredictability, disorder and delusion one is well advised to make things as simple as possible. The goal of reducing one’s environment down to its basics, to limit exuberance and seek the most minimal essence, is indeed noble. A key objective is to cut through the glitz and glamour to grasp the essence of the circumstance, the condition and the context – to understand ‘suchness’. With the superficial left behind we grip that which seems necessary.

While we see this search for simplicity, austerity and restraint in contemporary Japanese design, from Tadao Ando’s awe-inspiring concrete churches to Kengo Kuma’s masterful collages of glass, steel and wood, it is also clearly evident in far more modest fabrications, including the constructions of the homeless. The author (Sinclair, 2010) has previously written about Japan’s informal sector, delineating the ‘temporary’ housing of the day-labour class. Such ‘architecture’ is unquestionably accepting of uncertainty, mutable in nature, light on the land, efficient in operations, and effective in the provision of shelter that protects, nurtures and provides a rightful sense of dignity.

Japanese architecture, from both historical and contemporary perspectives, has encountered strong inspiration & influence from Buddhist thought. Spiritual notions of impermanence & ephemerality (mujo) impart a sensibility into design. Such impact is seen in the employment of cardboard and paper as building materials in the projects of contemporary architect Shigeru Ban. Concepts of layering, lightness, change, transience and the transitory can also been seen in the work of Árata Isozaki, Rei Kawakubo, and Metabolist master Kisho Kurokawa (notably his Nakagin Capsule Tower in Ginza). Taro Igarashi (2005), in his article “Kisho Kurokawa: Buddhism and Metabolism”, noted that the architect’s “… global view that creation and destruction run fluidly into one another has its roots in Buddhist doctrine.” He adds that, “In the original language of Buddhism, samsara means ‘to flow’, and also means the combination of various states, expressed through the process of reincarnation.” It is clear that the work of numerous modern Japanese architects celebrates many spiritual dimensions – most impactfully of Buddhist thought -- including demonstrably the inevitability of change, a lightness of being, and the cycle of suffering common to all sentient beings.

1.4 Musashi’s Five Rings

“Harmony and disharmony in rhythm occur in every walk of life. It is imperative to distinguish carefully between the rhythms of flourishing and the rhythms of decline in every single thing” Musashi

Beyond the guidance and influence of Buddhism and Shintoism, also core to the Japanese psyche and the Japanese people is the Way of the Samurai. The Book of Five Rings was written in 1643 by Miyamoto Musashi, an acclaimed Samurai, undefeated warrior and enlightened teacher. While in the first instance aimed at aspiring students of the sword, this seminal text also had profound implications and applications for people of all walks of life struggling to find balance, success and mastery. Musashi observed that “… the true Way of the Martial Arts is to train so that these skills are useful at any time, and to teach these skills so that they will be useful in all things.” Schooled in the art of combat Musashi subscribed to two relatively simple principles on his path. Thomas Cleary, a noted translator of Musashi, emphasized “The first of these principles is keeping inwardly calm and clear even in the midst of violent chaos; the second is not forgetting about the possibility of disorder in times of order.” Considering the nature of higher education, with its sea of independent minded scholars
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struggling to cope in times of drastic change and significant upheaval, such principles seem to hold promise. No doubt there are benefits to a bold reconsideration of the culture and context within which such change might and should transpire, including the deployment of more unconventional ways of seeing, thinking and acting. In Five Rings Musashi delineates strategies for triumph & mastery, including the need for a resounding grasp of the environment and forces at play.

Through The Book of Five Rings wise Musashi paints a picture of an interconnected ethos of being that captures tenets of Buddhism, using the iconic five-tiered pagoda known as sotoba (tower of five rings). The sotoba, in its full collection of components, represents the essence of our universe and provides us with an approach (both practical and esoteric) to its deeper understanding and more skillful navigation. In an interpretation of Musashi’s classic treatise Wilson notes the sotoba is usually constructed in a prescribed manner: “a square stone at the bottom represents the Earth element, or stability and the fundamental element of physical being; next, a round stone represents the Water element, or permeation and fluidity; a triangular stone represents the Fire element, or purity and unobstructed activity; a crescent-shaped stone represents the Wind element, or growth and perfect awareness; and at the top, a stone in the shape of a mani-jewel (wish-fulfilling gem) represents the Void element, space, or in Buddhist terms, Emptiness.” Taken in its entirety, and pursued as an interwoven set of postulations on our essence, the five elements (or rings) present a path to deeper understanding, a method of transcending samsara and a vehicle to realize enlightenment or Nirvana. Our lives are always clouded with confusion and shrouded in illusion. The Way offers an approach to achieve clarity and rise above delusion – to grasp a means for negotiating existence, in its detailed moments and across its greater play, with strategy and to success.

While Musashi’s life and our times are eons apart, there are profound lessons to seize that might shape our views and guide our actions in ways much more connected, compelling and constructive than are presently in place. Contemporary education, including in the field of Architecture, while arguably not a battlefield in Musashi’s sense, is nonetheless a milieu rich in conflict, ripe with struggles and in dire need of steadiness, concord and harmony. In this sense perhaps The Book of Five Rings can offer illustration, illumination and inspiration. Looking into and grasping the lessons of The Book of Five Rings brings us closer to understanding Japan and Japan-ness.

1.5 Three complementary architectural cases

To better understand these core principles of Japanese spirituality, and by extension to more fully grasp Japanese society, culture, design and construction, it is instructive to explore how such qualities manifest in Architecture. Each of the following case studies were chosen from within unique historical periods in Japan – the Taisho (1912-1926), Showa (1926-1989) and Heisei (1989-present) eras. Each project is a well-known building that has seen strong embrace and appreciation within its time and place. Each project, in different and in similar ways, celebrates what it means to be Japanese.

Ephemerality: Yamamoto-tei | early 1920’s (Architect unknown) | Taisho
The traditional Taisho period Japanese house, Yamamoto-tei, is located in Shibamata in the Katsushika Ward of Tokyo. This unique and impressive home, standing nearby the Edogawa River, is registered as a Tangible Cultural Property. Its prominence and attraction arrives in large part due to its exceptional design quality coupled with the top-ranked Japanese Garden contained on the property. The building has been described as follows: “The wooden two-story structure of Yamamoto-tei has an area of 400m² on the first floor and 50m² on the second, and features a living room, Nagaya-mon gate, warehouse, tea ceremony room and drawing room. The living room displays characteristic shoin design elements such as chigaidana (set of staggered shelves) and akarishoji (paper screen doors for admitting light).”

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Form and materials are important in Japanese design, interplaying in balance with the significance and meaning of space. On the material side, Japan is known as a ‘wood’ culture due to the historical access to timber as a primary building material. The structural qualities of wood, with its limited spans, gave way to a post and beam construction system. The manner of building homes and temples, with complex joinery and regular grid layouts, fostered the rectilinear geometry that is so prevalent in historic Japanese architecture. From this building approach arose many aspects of Japanese design that are now well known in the West, including perhaps most significantly the interconnection and mutability of spaces, the use of infill panels (most notably the shoji screens), and the creative control of perspective to shape perceptions. Nishi and Hozumi\(^\text{vii}\) (1983) describe qualities of architecture arising through reliance on post and beam construction: “There is, moreover, a fluidity in Japanese architecture between inside and out. Though fixed walls are frequently used, the distinction between wall and door is very elastic, and whole facades in both temples and residences can be opened to the elements at will by folding open or swinging up the panels between posts or by sliding open, or even removing entirely, the wooden or paper screens.” Such historically embedded understanding of space has had demonstrable impacts on modern architecture in Japan, including on designers willingness to pursue agility.

Yamamoto-tei profoundly captures the qualities of the ephemeral so vital to Buddhist principles and practices. In true Japanese form the boundaries of space soften and disappear. Rooms that seem set quickly blur and merge. The inside and the outside intermingle. Views from the living room into the garden blend resident and landscape. The defined geometry of the architecture and the permanence of the material world are soon abandoned as spaces overlap, perceptions shift and demarcations dissolve.

**Impermanence:** Nakagin Capsule Building | 1972 (Architect: Kisho Kurokawa) | Showa

The Nakagin Capsule Building, an icon of modern architecture, stands proud in the streets of Ginza, Tokyo. Nested among the urban streets of Tokyo are some unusual and beautiful buildings by the famous Japanese Architect & Metabolist Kisho Kurokawa. His unique approach to the Metabolist movement generated a few of the most creative buildings the world has witnessed. Moreover, the Nakagin Capsule Tower, completed in the early 1970’s, is no exception (Lin, 2011). A masterpiece of Japanese architecture, the Capsule Tower design was greatly influenced by the Japanese design culture’s celebration of beauty, functionality, quality, innovation and appreciation (Sinclair\(^\text{xi}\), 2016). The 14 story apartment building comprises 140 detachable and replaceable concrete pods (300-square-feet each), stacked and rotated at varying angles. This building remains a classic representation of the Metabolist style, with all of its aspirations around agile, adaptable, recyclable and moveable modular units —it stands out as a form of liberating architecture wrapped in a cloak of modularity.
Kurokawa aimed to design a project that concurrently acknowledged and accommodated the busy lifestyle of Japanese business people. With space at a premium, and real estate at record highs in post-war booming Tokyo, the Nakagin Capsule Tower offered an innovative option. Centered on a structural notion of two service cores, a beehive of small prefabricated dwellings were fixed into place with several anchor bolts per unit. The concept was to have units swap out in a relatively dynamic and on-demand fashion. Rather than the staid and solid substance of much international architecture of the Modern Age, Kurokawa envisioned a ‘living’ building where form and composition could morph based on circumstances and conditions. The vision was one of adapting and adjusting as needs dictated. The transient nature of the project – its looseness and mutability – was in keeping with Buddhist notions of impermanence. It is interesting to note that the architect's vision was far ahead of technology’s ability to meet the challenge. Over the years not a single unit has moved or been replaced.


Located in Shinkiba, in the Koto Ward of Tokyo, Mokuzaikaikan is a beautifully-crafted skillfully-articulated building that is home to the wood association. Celebrating the warmth, resilience and texture of wood, the project is disciplined and detailed in remarkable ways. In many respects this contemporary project proves an innovative manifestation of and respectful tribute to Japan’s historically wood-based building industry. The project is in many ways humble and understated, illustrating and showcasing the power and potential of wood without being glamorous or flashy. It is through attention to detail, rigor in design and thoughtfulness in execution that Mokuzaikaikan achieves such strength and success.

Mokuzaikaikan has been described as follows: “This project involved the relocation of the offices of the Association of Wood Wholesalers in Tokyo. It serves as a showcase to demonstrate the possibilities of wood as an urban construction material. Engawa, or Japanese terraces, allow a natural breeze to enter while shutting out strong sunlight for a comfortable indoor environment. Lumber were integrated into the building's structure, and architectural
exposed concrete was cast in cedar formwork. Since the building uses a large amount of wood, great attention was given to fire safety measures. The design focused on creating spatial continuity with the use of layering and natural light.”

The project, through its humility, warmth and human scale, demonstrates the Buddhist values around non-attachment. Rather than being a centerpiece that demands attention and claims predominance, the building provides a comfortable and comforting milieu that holds and facilitates. The grain, texture, color and character of wood serve to envelope users in an unassuming manner – cultivating an environment where the users take predominance over the uses and where the contained looms larger than the container. Skillful deployment of lighting, in keeping with the messages of Junichiro Tanizaki’sxvi ‘In Praise of Shadows’, creates many intimate and sensitive moments in the building. From a Buddhist vantage point the building dissolves into the background permitting people to attend to less material-focused concerns – such as interaction with others or introspection on their own. Several traditional Japanese rooms prove the jewels of this project – each executed with great attention to scale, perception, nuance and meaning.

1.6 Studio realm

“In spiritual education the world comes alive. Living and education become inseparable. Self and the world become inseparable. Something is always happening that can be learned from. The only things that are required are openness and attentiveness: the allowing and examination of direct experience”. Steven Glazerxv (1999)

The author’s Japan-based Semester-long Senior Interdisciplinary Studio annually considers the rich, complex and multifarious urban realm of Tokyo – the planet’s largest urban settlement. Students, working in teams of two are engaged in observation and study of the city’s fabric, with an initial goal of gaining some familiarity and comfort with space and place. Following from this base overview, teams conduct more detailed analyses of selected areas of the metropolitan region, with a particular emphasis on districts and sites in proximity to major waterways and bodies (river, canal, lake, sea, etc.). Critical analyses, coupled with study of international precedents, reveal some common features and design dimensions that characterize ‘typologies’. Some typologies reflect commonly accepted space/place types (e.g., streets, squares, parks, etc.) while others charted new ground. The objective of this analytical component of the studio is to gain, as a broader cohort comprising all teams, a deeper understanding of approaches to urban design and development in the greater Tokyo area. Building from this shared understanding, individual teams then consider one or more interventions into the urban fabric, with a goal to synthesize, propose and delineate a conceptual urban design response. The intervention is not necessarily a detailed design of a building nor the shaping of a finite plan, but rather tends to demand a more holistic, creative, comprehensive and integrated urban design proposal that considers figure and ground, solid & void, streets, landscapes + buildings, and space & place at preliminary conceptual levels. The urban design responses seek a healthy balance of people/place, process/product, creativity/innovation, context/culture, integration/provocation and viability/ sustainability.

In order to deepen and enrichen the learning, and to have students create projects that are ‘of Japan’ (not merely ‘in Japan’) there is a push to immerse within and understand ‘Japan-ness’. The emphasis of the Tokyo Studio is especially on the cultural, social and environmental (i.e. sustainability) potential of explorations and interventions of and in the urban fabric. The studio explores the relationships between the public realm, architectural form, compelling landscapes, cultural identity and sense of place. The basic curricular objectives incorporate a deep and meaningful exploration and analysis of the complex fabric of Tokyo as well as taking steps to develop one or more interventions that prove challenging, effectual, meaningful and appropriate. Consideration must be given to user needs and human dimensions, including environmental perception, symbolism and meaning, ergonomics and adaptability, cultural sensitivity and place-making. To reach such objectives it is crucial for students to move beyond the point and posture of tourists in order to tap into what it means to be Japanese. From a pedagogical perspective this goal is equal to or greater than any educational aspirations on technical and professional fronts.
2.0 CONNECTING THE DOTS – GRASPING THE ETHOS
The present paper seeks to delineate a rather diverse set of characteristics and circumstances, ranging from Buddhist thought and Samurai ways to graduate education and architectural design, in an effort to link and learn. Living in Japan for the first time is both exhilarating and overwhelming. Foreigners, or gaijin, bring with them experiential baggage and pre-existing assumptions. While on one hand this ‘freshness’ is to be welcomed and harnessed, on its own it proves risky and insufficient. The Gaijin-ness must be coupled with and countered by Japan-ness. The studio pursues this balance throughout its course – an unending mission to open eyes, minds and hearts to new ways while acknowledging and building upon the strengths that come from coming from afar. In order for outside students, and professionals, to effectively design in Japan they need to comprehend and come to terms with what it means to be Japanese. To grasp such a complex and convoluted society is daunting for certain, yet essential for sure. In order to become successful in design challenges in Japan the newcomers need to see through the eyes of the other – to view the design setting and to develop any solutions via lenses of culture, values, history and spirituality.

2.1 Lessons learned | implications to education and design
As our world gets smaller, and students/professionals increasingly explore, reach and work beyond their homes, communities and countries, the pressure mounts to be responsive, responsible, sensitive and sensible. In educating architects in our current times, it is vital to prepare them for practice that transcends national boundaries, that embraces difference, and that responds in ways that prove both appropriate and effective. In order to reach such objectives educators need to consider far more than technical content, curricular conventions and book learning. In many ways the educational enterprise must assume greater risk, innovate boldly and stretch beyond current comfort. Study abroad is a crucial tool to complement the learning toolsets that we deploy in educating architects. Short-term tourist-type trips might provide some insights into novel cultures, however they tend to be superficial and not life-altering. Longer term immersion, to the contrary, affords students the chance to see with greater clarity, to feel with greater empathy and to design with more certainty. In a country like Japan, whose ways and means stand in stark contrast to Western modes and methods, it is imperative to dive deep.

2.2 Envisioning an approach
“If there is to be any order of beauty in the age of life principle, it will be in a dynamic balance that maintains its order, while always moving, roaming and changing.” Kurokawa (1995)
The present paper has examined various aspects of Japanese culture that shape the soul of the nation. In such an elusive, mysterious society it is essential to understand what drives thinking, informs values and shapes behavior. Buddhism and Shintoism loom large in any equations for comprehending the ethos. Samurai ways continue to influence thought and deed in modern Japan. Spirituality serves as a major force in the design of interiors, buildings, landscapes and cities. While this array of forces and factors is only part of a multifarious milieu, it presents a reasonable starting point for foreign students/practitioners charged with the design of spaces, places, buildings and communities in Japan. Seen from a pedagogical perspective, the present paper calls for the equal attention to matters cultural, spiritual, technical and social. In striking a balance between these four pursuits, students are better able to grasp notions of ‘suchness’ and ‘Japan-ness’ that are undeniably crucial to successful design.

3.0 Conclusions
“The essential difference between life and a machine is that a machine eliminates all idleness and ambiguity. It is constructed entirely on the basis of physical connection, functional, rational principles, and efficiency. In contrast, life includes such elements as uselessness, ambiguity, the unknown and idleness. It is a flowing interrelation continuously creating a dynamic balance.” Kisho Kurokawa (1995)
Evaluating architects in our demanding and turbulent times is increasingly a tough challenge. Pluralism proliferates, mobility heightens, communication improves and exchange escalates. That said, conflict grows, confusion spreads, differences amplify and uncertainty materializes. The education of architects needs to be reconsidered, reformed and redesigned in a manner that ensures future professionals are equipped with the theories, tools, techniques and wherewithal to cope, overcome and succeed. A part of this charge must be to wade courageously into the cultural ethos where values reside, history dwells and the future is cast. While the world is in many ways getting smaller, and global norms are on the rise, the importance and impact of the local remains high. Architects need to be versed in international standards and must capitalize the power of science -- they must also be attuned to regional qualities and respect home-grown attitudes. As Architects are called upon to design in foreign jurisdictions they should be prepared to respond in thoughtful, informed and appropriate ways. The present paper looked specifically at the country of Japan, considering how foreign architecture students and practitioners might better prepare themselves for acting in realms novel and circumstances unknown. The author delineated a number of historic, spiritual & cultural dimensions that provide substance to Japanese society and that serve to shape and guide the conception, construction and occupation of spaces and places. The Buddhist notion of ‘suchness’ and the philosophical construct of ‘Japan-ness’ stand as targets for newly-arrived students and architects, offering a means of understanding a complex ethos in ways that encourage more sensitive, applicable and efficacious design.

ENDNOTES


xi http://www.katsushika-kanko.com/yamamoto/eng/


xiii https://www.archdaily.com/778844/mokuzaikaikan-nikken-sekkei

Note: All photographs by the author.
Stakeholder theory as a paradigm for cultural production of the built environment

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ABSTRACT: Cultural production finds constant reinforcement through the built environment, yet defining what “culture” is has become an increasingly contentious in recent years. In the United States, the rise of segregated physical spaces and the accompanying social stratification in the form of gated communities and pseudo-public spaces that attract homogenous communities has been well documented. Popularly, such segregation is linked to “living in a bubble”, in which different cultural norms within a society become isolated. Despite problems associated with such isolation, such as economic stratification and social intolerance, few architects and planners have addressed how the accompanying cultural production paradigms are related to the production of the built environment, and the architect’s role in this process. This paper uses a variation of stakeholder theory to explore the consequences of our designs. Stakeholder theory, first proposed by R. Edward Freedman in the 1980s, states that in order to succeed, companies should create value for all stakeholders—customers, employees, suppliers, financiers, and the community—and not just shareholders. Extended to the process by which the built environment is created, this means that the effects of our building patterns and practices must be considered through the lens of all possible stakeholders in order to produce successful projects. The first step is to gain a fuller understanding of a project’s short and long-term social and cultural ramifications. Using a method adopted from principled negotiation in which stakeholders and their interests are identified in order to develop scenarios by which a majority of interests can be accommodated, this paper will analyze several recent building projects in the United States to assess their impact on cultural production.

KEYWORDS: Stakeholder Theory, Cultural Production, Principled Negotiation, Ethics, Participatory Design

INTRODUCTION
The built environment plays a large role in cultural production, and architects are well positioned to understand the myriad ways in which the two intersect. At the same time, increasing complexities in planning and funding projects and a growing reliance on market-driven planning processes in many communities has led to a frustrating lack of opportunity for such holistic thinking. This paper explores stakeholder theory as a means to achieve more holistic planning outcomes, which I argue can also produce more ethical results. I first introduce stakeholder theory as a concept developed for business management, and then show how this concept can be applied to built-environment production through a process taken from principled negotiation strategies. The second part of the paper applies the process through three built examples.

1.0 STAKEHOLDER THEORY

1.1 Approaches to stakeholder theory in management
Stakeholder theory was first developed by R. Edward Freeman in a 1984 book titled Strategic Management: A Stakeholder Approach. The term “stakeholder”, meaning anyone who had a stake in a firm, was adapted from the word “stockholder.” The new term was meant to expand
the group to whom management of a firm need be responsive, from those with a direct financial investment in the firm, to those needed in any way for the firm to exist, including employees, customers, suppliers and society in general (Freeman et al. 2010). Precursors to this work had been in circulation for some time; for example the economist William R. Dill recognized in 1975 that the relationship of stakeholders to firms is bi-directional: not only do firms’ decisions influence their stakeholders, stakeholders’ decisions also have an effect on a given firm. Dill thus saw stakeholders as potential active participants in strategic decision making (Freeman et al. 2010).

Within the management literature, stakeholder analyses was initially tied to questions of corporate profitability rather than questions of ethics. As such, expanding the idea of stakeholder analysis to encompass a firm’s accountability to various stakeholders remained a point of debate for years. Conservative economist Milton Friedman spoke out against social considerations in business in a 1971 essay titled “The Social Responsibility of Business is to Increase its Profits” and Stuart Slatter claimed in 1980 that companies had difficulties finding economic benefit in acknowledging stakeholder views (Slatter 1980, cited in Freeman et al. 2010). Other authors of the era, however, saw stakeholder-oriented planning processes as useful in dealing with increasing complexity in modern corporations, including social demands. At the very least, they maintained, stakeholder satisfaction would guarantee continued support of the organization. Stakeholder assessment thus increasingly became seen as an intelligence-gathering opportunity to find a business’s potential opportunities and threats (Freeman et al. 2010).

Stakeholder theory in management has evolved since the 1980s to address more than value creation and trade. Stakeholder theory now also addresses questions of ethics, responsibility and sustainability within the economics of capitalism, and it addresses the interconnectedness of the various actors involved (Freeman et al. 2010).

1.2 Applying stakeholder theory to the design of the built environment
The built environment plays an enormous role in cultural production (see Staub, 2015), and such cultural production, expressed through the design and construction of buildings and
landscapes, requires an enormous amount of capital. Although the process typically involves many firms, the parallels to activities pursued by corporations offering goods or services are strong enough that management theory, and specifically stakeholder theory as a form of addressing ethical considerations, can be considered for analyzing built-environment production.

In the business world, stakeholders, including suppliers, employees, customers, financiers, and the community, are fairly well defined. In built-environment production they are not. This is surprising, considering that national professional organizations often have a code of conduct that mentions an architect’s responsibility towards a defined set of parties. The AIA (American Institute of Architects) 2018 Code of Ethics and Professional Conduct, for example, discusses professional conduct towards clients, co-workers and employees, public officials, the community, other firms, and even the environment (AIA 2018). These groups can be considered stakeholders, both for a specific architectural firm and for the profession in general. In the AIA document, architects are instructed to avoid disrespectful, harassing, misleading or fraudulent behavior, and are proactively encouraged to perform public interest services, behave with “dignity and integrity”, mentor junior colleagues, perform environmental stewardship, and engage in civic responsibility (AIA 2018). The focus throughout the document is on ethical behavior towards a set of defined others, or, in other words, a set of stakeholders.

Despite the ideals outlined by documents such as the AIA Code of Ethics, and despite the naming of stakeholder groups – for the purpose of this paper, we will assume such ideals to be general enough to be internationally applicable – architectural firms continue to struggle with recognizing stakeholders and their accountability towards them. Widely publicized gaffes include Zaha Hadid’s reactions to human-rights violations on her international projects. Difficulties included human trafficking of laborers on a construction site in Baku and the death of over a thousand workers on construction projects in Qatar, to which Hadid claimed in a 2014 interview, “I have nothing to do with the workers …. I cannot do anything about it because I have no power to do anything about it.” (Riach 2014, Owen 2017).

Ethical quandaries abound on a smaller scale as well. Thomas Fisher’s 2010 book Ethics for Architects illustrates common issues loosely based on the AIA Code of Ethics framework, including questions such as if an employee who performs much of the firm’s pro-bono work for the community should, in an economic downturn, be fired over someone who brings in more fee-paying work, or if a conservative client who demands that only men design and oversee a project should be accommodated. Fisher’s book puts a face to the AIA’s more abstract moral code. Above all, the examples in his book make clear that many ethical questions require architects to consider the tradeoff between short-term financial gain and more durable ethical gains that cannot be easily monetized.

1.3 Stakeholders and the concept of principled negotiation

Although designers and builders might, with some analysis, be able to come up with a list of project stakeholders, few architectural programs offer training in how to determine project stakeholders and assess their interests or work with stakeholder demands. Community design centers and programs that offer participatory design studios in which students work with community members on developing project goals (Fig. 1) are generally the only ways in which stakeholders are involved in design decisions - although even here, the list of stakeholders involved is generally not comprehensive.

One approach to including stakeholder interests in a broader manner is through using techniques of principled negotiation, a negotiation method that allows participants to find win-win solutions in a decision-making situation. Principled negotiation, first presented by Roger Fisher and William Uri in 1981, uses an integrative approach to finding mutually acceptable outcomes in situations of conflict management. The approach encompasses four steps: 1) develop a list of stakeholders, 2) determine stakeholder interests, which might differ from their vocalized positions on an issue, 3) brainstorm outcomes that allow for as many stakeholder interests as possible to be met, and 4) agree on an objective means by which the outcomes
might be assessed. To illustrate this concept in a built-environment context, a conflict outlined by Dolores Hayden in the introduction to her 1997 book *The Power of Place* is instructive. In 1995, Herbert J. Gans and Ada Louise Huxtable got into a lively discussion in the op-ed section of the New York Times over the meaning of the built past. Huxtable, the Times’s architectural critic, maintained that the New York Landmarks Preservation Commission should primarily focus on preserving major architectural monuments as “a primary and irreplaceable part of civilization,” (quoted in Hayden 1995, 3). Gans, an urban sociologist, maintained that in focusing on architectural monuments, the Landmarks Preservation Commission only preserved the “elite portion of the architectural past,” and went on to suggest that, “when preservation becomes a public act, supported with public funds, it must attend to everyone’s past,” (quoted in Hayden 1995, 3).

Although Huxtable and Gans made their differing positions abundantly clear, their interests, one could argue, were not so very far apart. Both wanted the New York Landmarks Preservation Commission to maintain buildings as testimonials of the past. Both saw the public, who would learn about the history of cultural production through the preserved buildings, as an important stakeholder in this outcome. Both were surely willing to support the Landmarks Commission in this endeavor. Yet there is no evidence that they agreed on objective means by which any specific outcomes might be assessed. As Hayden points out, Huxtable and Gans used the same terms to mean quite different things:

When he said “architecture,” he meant all urban buildings, or the built environment. When she said “architecture” she meant buildings designed by professionally trained architects operating with aesthetic intent [....] When he said “vernacular” he was classifying buildings by social use […] and implying tenements, sweatshops, saloons, and public bathhouses. When she said “vernacular,” she meant that the architect was unknown […] (Hayden 1995, 4)

The Huxtable-Gans debate demonstrates what happens when negotiations break down. Principled negotiation strategies could have helped the discussion stay on track. Recognizing that both Huxtable and Gans were interested in using buildings as a form of public history and that the stakeholders were primarily the public who would both fund and benefit from having access to important landmarks, they could have examined how their two differing definitions of history might work together. For example, maintaining structures associated with the working-class who were employed by the wealthy as servants or laborers could provide a fuller picture of the interplay between workers, who were required to build and maintain the lifestyle of the city’s social elite, and their employers, who acted as architectural patrons. Instead of promoting only major architectural monuments or working-class housing and other facilities – in and of themselves interesting objects of study – the Landmark Commission could have insisted that the two together provide a contextualized version of the city’s urban history.

In the following section, I examine three examples in which cultural production of the built environment raises ethical questions that can be analyzed through the lens of principled negotiation strategies. A key part of this analysis is to compile a list of possible stakeholders and their interests. I argue that awareness of possible stakeholders is the first step in ethical decision-making, as architects become more responsive to the interests and needs of various stakeholders in the search for more holistic design solutions. I also argue that training students to recognize stakeholders and elicit their interests should be an integral part of design pedagogy. If design is recognized as an integral part of cultural production, then reaching into the community of stakeholders will enrich the design process immeasurably.

### 2.0 PROJECTS

#### 2.1 The Mercedes Benz Stadium in Atlanta

In the United States, sports are typically associated with healthy lifestyles and character building, especially for youth. Yet sports are also big business: a 2017 poll found that Americans spend over $100 billion on sports annually, with $56 billion spent on sporting events alone. In 2016, taking a family of four to an NFL (National Football League) game cost over $500 on average, including tickets, parking, and snacks (Egan 2017).
Stadia have come to reflect the intersection between cultural production and capital, in this case expressed through corporate influence. An example is the Mercedes Benz Stadium in Atlanta (which was renamed from the non-branded “New Atlanta Stadium” in 2015), designed by the firm HOK and completed in 2017 (Fig. 2). The stadium has eight triangular panels that move on tracks to allow the roof to open dramatically, while offering fans, “an immersive, technology-driven game-day experience,” including a “360 degree HD halo video board built into the roof,” as well as digital billboards allowing sponsors to display “targeted programmable content...”, a rather high-flung term for advertising (Architect Magazine 2015). The stadium’s cost was $1.4 billion, of which over $1 billion was accrued through sponsors, including the Harrah casino empire, three breweries, two winemakers, and various distillers, all of whom have purchased the right to offer branded clubs and bars within the stadium (Lefton 2017).

The main stakeholders in this scenario are the public who will frequent the venue, the teams who will play there, the people of Atlanta, and the many corporations that are using their sponsorship – a term that has come to mean monetary donations given in exchange for advertising rights – to market their products through electronic billboard advertising, fan items, and the branded naming of portions of the stadium itself. In this case, one could argue that the gambling and alcohol companies’ aggressive marketing campaigns are attempting to elevate their own reputation through a positive association with sports’ more wholesome image. With sports traditionally seen as a respectable family pastime, sponsorship allows these companies to introduce gambling and alcohol advertising to minors in a positive way that is outside the control of users. Empowering the user becomes an ethical question: should users have the right to experience the sports event without being held captive to constant corporate advertising? Although not directly under the architect’s control, pointing out how corporate branding of sports facilities has influenced fans’ sports experience is the first step towards evaluating and possibly seeking alternatives to this trend.

2.2. What to do with contentious monuments?
Confederate monuments dot the landscape of the southern United States, where their presence has become increasingly controversial. Opponents to the monuments maintain that they glorify a pre-abolitionist history of racial discrimination, while the monuments’ proponents state that the monuments commemorate the South’s struggle for self-determination. Historians, too, are divided, with some stating that Confederate memorials have historical value, and others claiming that the ideologies they represent make them too toxic to be pedagogical (SPLC 2016).
The most immediate stakeholders in this instance have interests that may be irreconcilable. Descendants of Confederate soldiers wishing to venerate their relatives, and those who see the monuments as celebrating the South’s perceived fight for self-determination are interested in keeping the monuments intact, while for many African Americans the monuments commemorate figures who were responsible for enslaving their forebearers and thus indirectly, they condone slavery itself. A third set of stakeholders is left out of this equation, however, as the monuments present a pedagogical opportunity for society at large, including future generations, about continued racial tensions that make these monuments so hotly debated.

Shifting the focus of contentious monuments and buildings from commemorating history to illustrating it lies at the heart of a similar project in Germany (Figs. 3 and 4). In Hamburg in 1936, the “76er Memorial” was erected to commemorate a local regiment of soldiers. After World War II, the sculpture, now perceived as Nazi propaganda that glorified war, became hotly debated, but was never removed. In 1985, Austrian sculptor Alfred Hrdlicka was commissioned to erect a counter-memorial against war and fascism next to the original monument. The two works, taken together, have since become part of a space that offers a powerful opportunity for pedagogy and reflection (Denkmal Hamburg n.d.).

Re-examining Confederate monuments as part of US history, planners could explore creating new landscapes to accommodate the public’s interest in learning about how history itself becomes defined. The monuments themselves would become but one display of a narrative that discusses how different groups of stakeholders perceive such relics of the Confederate past. Treating the monument sites as an opportunity for broader learning would shift them from sites of ideological ritual to spaces of broader reflection and discussion. The monuments would be contextualized and take on new meaning to accommodate an unrecognized but large group of stakeholders.

2.3. Shaping historical narratives
Colonial Williamsburg, a “living history museum” (Fig. 5) and Disney’s Epcot Theme Park (Fig. 6) both represent built environments designed to portray a carefully crafted historical and cultural narrative. Both have been repeatedly criticized for providing simplistic and inaccurate versions of cultural history designed for commercial interests and mass tourism (Levi 2005, Kratz and Karp 2003). Colonial Williamsburg has been criticized for portraying a highly edited and thus unrealistic version of eighteenth-century life in the town, a version that omits mention of the era’s sanitation problems or the role of slavery in the town’s economy (Greenspan 2002). Disney’s round-the-world Epcot display, on the other hand, has been charged with cultural conceit; portraying the United States as a modern, technologically advanced nation, while the rest of the world remains quaintly backward (Staub 2015).
The trend towards inexact replicating historical structures for marketing purposes is common in the United States. Examples include major tourist destinations such as Colonial Williamsburg as well as more mundane projects such as small-town centers built in pseudo-historical styles (Levi 2005). The trend towards historicism is not limited to publicly accessible spaces, but permeates the building industry, including contemporary housing. Seeking a marketing opportunity, since the 1970s housing manufacturers have increasingly offered historicized housing facades, indicating the popularity of architecture that offers modern amenities but looks and “feels” traditional (Harris and Dostrovsky 2008). While the market has encouraged a proliferation of traditional styles in both public spaces and private buildings, there is nevertheless a fine line between contextualism (building new structures so that they respect the physical context of older ones) and ahistorical replication.

The stakeholders when considering historicized tourist destinations such as Colonial Williamsburg and Epcot are primarily the public, who as users of the buildings seek functional convenience, educational and entertainment value, and aesthetic delight, and the investors, who seek to create architecture that will attract users who will spend money there. One can argue, however, that the user is shortchanged in this equation. The ahistorical structures provide functional convenience, entertainment value, and aesthetic delight as short-term goals, yet the longer-term goal of educational value falls pitifully short. The user is offered a version of history that is often false or misleading, while led to believe that they are experiencing something that is in the spirit of authenticity. In considering the equation of educational value for the user versus marketing value for the investor, it is clear that the scale has been tipped in favor of the latter. The result presents an ethical dilemma, as architects and designers take part in building practices that are culturally misleading.

3.0 CONCLUSION
Culturally misleading building projects often pit an investor’s short-term economic interests against the public’s long-term educational investment, a trade off that is not always recognized due to the different time scales involved. When investors “brand” a building or parts of it, the investor’s attempt to culturally influence the building process becomes more overt. In this process of cultural investment, the architect’s role is rarely examined, despite general ethical guidelines presented by professional organizations such as the AIA.

If we are to accept architects’ responsibility towards clients, co-workers and employees, public officials, the community, other firms, and the environment as an ethical imperative, then stakeholder theory as a paradigm for cultural production of the built environment allows us to more precisely assess and analyze stakeholder interests, while negotiation tactics point to how to best meet them. Architectural and design firms are businesses, and to remain viable they must stay solvent. Yet, as stakeholder theory demonstrates, fiscal concerns are no longer the only ones firms are confronted with. Milton Friedman’s 1971 article encouraging businesses to recognize only stockholders, i.e. fiscal investors, as legitimate stakeholders has been
superseded by a more nuanced approach that recognizes a broad range of stakeholders in any business venture. Short-term fiscal thinking has thus been supplanted by the recognition that sustainable business management incorporates sustainable cultural management, and that both must take into account the long game of holistic planning. When considering architecture and design firms, that long game arguably includes the reputation of the profession, as architects, planners and designers shape the built environment, and with it cultural production.

The culture of the design process starts in the professional programs that teach it. If considering stakeholders is to be an integral and consistent part of architectural and design production, then it must ideally become part of the pedagogical process. While some programs incorporate ethics education as part of their professional practice curriculum – with textbooks such as Barry Wasserman, Patrick Sullivan and Gregory Palermo’s *Ethics and the Practice of Architecture* serving as a well-sourced resource – the ideals inherent in stakeholder investment should permeate all facets of a design education.

In three of the examples analyzed above – the Mercedes Benz Stadium in Atlanta, Colonel Williamsburg, and Epcot – planners have allowed marketing interests to drive the playbook of cultural production. In the stadium example, gambling venues and liquor firms have associated themselves with the more positive lifestyle image sports provide by providing building funds in exchange for naming rights. In the Colonial Williamsburg and Epcot examples, spectators are implicitly offered the re-creation of an authentic historical experience, a claim that is, however, patently false. Recognizing that the public’s interests include not only entertainment and convenience, but also accurate cultural information, the designer’s role shifts to accommodating this accuracy.

In the case of contentious monuments, stakeholder analysis and the tenets of principled negotiation allow designers to open new avenues in a debate that has seemingly ended in an ideological impasse. When the public’s right to historical knowledge is taken into account as a stakeholder interest, contentious monuments can be reframed as didactic rather than commemorative, thus taking on a new role and purpose in civic discourse.

Acknowledging stakeholders and understanding their interests in the built environment is a first step towards more ethical cultural production. If architects are to take their responsibility regarding professional conduct towards clients, co-workers and employees, public officials, the community, other firms, and the environment seriously, they must first recognize what each of these stakeholders brings to the table.

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REFERENCES


Greenspan, Anders. "Design and Deception at Colonial Williamsburg." Journal of the National Collegiate Honors Council - Online Archive. 83 (Spring 2002). http://digitalcommons.unl.edu/nchcjournal/83


SPLC (Southern Poverty Law Center) 2016 https://www.splcenter.org/sites/default/files/com_whose_heritage.pdf


NOTES

1For example, the national organization of the YMCA, a community provider of sports programs, highlights its focus as “Youth Development, Healthy Living, and Social Responsibility”, see https://www.ymca.net.
AUTONOMOUS + SMART
ABSTRACT: To address climate responsiveness, most of the envelope strategies experimented by architects so far has incorporated automated high-tech systems, electronic sensors and actuators, increasing our energy consumption. As our climate continues to change concomitant to our reliance on non-renewable energy sources, low-tech passive façade systems require a more thorough investigation to adapt them for large-scale application. This includes an in-depth focus on sustainable building materials to generate a technologically independent, carbon-neutral building façade. Materials such as bamboo, due to its hygroscopic nature, undergo constant expansion and contraction with changing levels of atmospheric humidity. From a crafting and construction perspective, this spontaneous dimensional change is seen as an inherent drawback of working with bamboo, with attempts being made to control, or mitigate, the change. But in order to develop a passive system of responsive architecture, it is time we look at the hygroscopic movement intrinsic to bamboo as an opportunity, rather than a challenge, and integrate it within the material performance of architecture itself. This paper looks into bamboo veneer as an adaptive material to help rethink building facades as organic, breathable skins rather than a mechanized barrier between human and nature. The methodology incorporates a series of physical experiments to study the deformation of a bilayer bamboo composite consisting of a bamboo veneer bonded with a clear cellulose film. The film, being non-reactive to climate, amplifies the curving motion of bamboo, along with its return to the initial position. The module was then used to explore different façade patterns to study the opening and closing mechanism that could potentially generate maximum ventilation. The outcome of the research will consist of a working, demonstrable prototype for a no-tech adaptive façade pattern that, while undergoing a biomechanical response, will perform particular functions including shading and/or ventilation, leading to a truly material-integrated architecture.

KEYWORDS: Adaptive envelope, Responsive, Bamboo, Hygroscopy

INTRODUCTION

One of the earliest forms of adaptive envelopes that made use of embedded material properties to create a responsive architecture was the black Bedouin tent. By employing passive strategies, the fabric of the tents absorbed moisture and ensured a continuous airflow, thereby reducing air temperature through evaporative cooling. Thermal comfort was achieved throughout the interior space while ensuring little to no energy waste. This concept of climatic adaption was taken on by Buckminster Fuller in 1967 in his design for the United State Pavilion at the Montreal Expo; in a geodesic dome enveloped in computer-controlled transparent acrylic sheets that could retract themselves with changing levels of solar radiation. This development marked the beginning of a design strategy that allowed building systems to respond to external environment with the help of a technologically-imposed intelligence. Climate-adaptive envelopes were further explored in Jean Nouvel’s 1980’s creation, Institut du Monde Arabe in France. With hundreds of light-sensitive apertures that open and close with changing sunlight levels this design was one of the most innovative technological marvels of its time. However, this design approach of contemporary high-performance buildings, while offering improved internal comfort, often gets overshadowed by the associated dependency on external energy, higher cost, complex construction and maintenance issues. In order for people to survive within today’s rapidly changing climate with minimum energy depletion it is time building systems are
rethought for a more sustainable solution. Buildings are already consuming more than 40% of all energy; if building materials could be made to passively adapt themselves to the climate there is a chance that our reliance on active mechanized systems, leading to energy waste, could be brought down to a minimum.

1.0 ADAPTIVE FACADES
Loonen et al. defined climate-adaptive buildings as being characterized by their ability to repeatedly and reversibly change their features and configurations with changing climatic parameters with a view to achieving an improved building performance (Loonen 2013). Adaptive façade strategies typically follow two approaches. One is where the entire system of climatic response is mechanized with complex automated devices, and the other is where façade responsiveness relies entirely upon material behavior and material properties without the need for any intricate mechanical system. The former is identified as being an active system with extrinsic control while the latter is a passive system having intrinsic control (Loonen 2013).

The passive system, while going through continued research, has two acclaimed pilot projects so far: Doris Sung’s research pavilion in Los Angeles called “Bloom” and Achim Menges’s “HygroSkin” pavilion in Germany (Fig.1). Both these systems take advantage of a material’s inherent climate reactive properties, with temperature-reactive thermo-bimetal (Sung 2010) and humidity-reactive wood respectively (Reichert, Menges, Correa 2015). Calling the building envelope a third “skin”, Sung believes that this kind of passive responsive architecture has the potential to bring human closer to nature by incorporating an elevated sensitivity in its surface. Reichart, Menges and Correa (2014) agree with this idea of “material as a machine” and explain that material embedded actuation can eliminate any instance of technical malfunction by incorporating the atmosphere for control and actuation. While advocating for an increased interaction with environmental dynamics, they suggest materials be physically programmed, rather than superimposed with technical devices. This, as they believe, will “enable a shift from a mechanical towards a biological paradigm of climate-responsiveness in architecture”. (Reichart, Menges, 2012)

2.0 BAMBOO FOR WARM-HUMID CLIMATE
A rapidly renewable plant, bamboo is a more sustainable alternative to wood. With some species shooting up to approximately 0.6m (2 feet) per day, it is the fastest growing plant in nature. Bamboo is native to Asia, South America and parts of Africa (Fig.2).

Figure 1: Left: HygroSkin Pavilion. Source: (ICD University of Stuttgart), Right: Bloom. Source: (Alison Furuto 2012).
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The stem is hollow, except at nodes, and, when mature, can be 40m (130 feet) high. Most bamboo species become mature within 2 to 3 years.

The structural nature of bamboo, with its remarkable tensile strength, reveals that the strength and stiffness that it tends to achieve along its grain following the longitudinal direction is far greater than that in the transverse direction. Similar to wood, the major chemical constituents of bamboo are cellulose, hemicellulose and lignin. The cellulose micro-fibrils are present in an amorphous solution of lignin and hemicellulose (Tomalang et al. 1980). Any such fibrous material absorbs moisture in two forms: bound water and free water. The absorption or release of free water, occurring inside cell cavities, has negligible impact on bamboo, however swelling and shrinkage occurs with changes in bound water content, occurring inside cell walls. As bound water is absorbed the cellulose micro-fibrils expands transversely along with the lignin matrix, leading to swelling of bamboo. Similarly, as bound water is removed, shrinkage of bamboo is observed. (Dinwoodie, 2000)

Its never-ending sustainable qualities include carbon-di-oxide sequestering, reducing soil erosion, low embodied energy and low use of nutrients, extremely high tensile strength, lightweight construction and low-cost (Schroder 2011). The major drawbacks of using bamboo are perceived to be its vulnerability to moisture, leading to dimensional changes, and high cellular starch content, leading to fungal attack.

3.0 EXPLORING BAMBOO VENEER

Though the research was aimed toward a warm-humid climate, and not any particular geographic location, three locations were selected to be representatives of the climatic region namely, Florida, Bangladesh and Vietnam. Each of these regions has its own share of strengths and challenges concerning bamboo availability and constructions. While architecture constructions in Bangladesh and Vietnam have incorporated bamboo in a myriad of ways for a long time, in Florida, however, despite the easy availability and suitable climate bamboo still has not became the material of choice for many. For the purpose of the research, a number of bamboo species was explored that were native to such regions and, at the same time, were also easily available in the region where the research was being conducted. Finally, the species Phallostachys edulis (Moso) was selected for the study as it is a north-temperate bamboo species and commonly grows in the regions being studied. Moreover, being the most widely available bamboo species in the US, the ease of availability was also a major determining factor in selecting this particular type. The veneer was 0.5mm (0.02 inches) in thickness and was kiln dried by the supplier to 6-9% of its moisture content. A series of physical
experiments were conducted with the particular bamboo specimen to understand its hygroscopicity. These experiments looked into different shapes, sizes and grain angles of the veneer (Fig.3). The conclusions derived from the observations informed following experiments, thereby pushing the work forward.

3.1. Veneer behaviour study
The study began with an experiment consisting of two sets of three rectangular pieces, each of which had veneers 7", 6", 5" in length and 2" in width. Three of these had grains perpendicular to the longer dimension and three had grains at an angle of 15 degrees. After the humidity was raised from 51% to 93% it was observed that the higher the width-to-height ratio of a veneer the greater was its deformation. The deformation was also higher in pieces that were cut perpendicular to the grain direction. So the 7" long piece with grains perpendicular to the longer side showed the maximum deformation. (Fig.4)

Figure 3: Parameters for bamboo veneer experimentations. Source: (Author 2018)

Figure 4: Rectangular bamboo veneers reacting to increasing humidity level. Source: (Author 2018)
A similar experiment was conducted with triangular pieces and was observed to have a greater deformation than rectangles. The reason is that in a triangular piece as the veneer extends forward from the base toward the vertex it has increasingly less material along the grain and hence less resistance to deformation. However, when the humidity was decreased it was found that the veneer, on its own, was unable to return to its initial state, and it nearly took a period of 24 hours before it came back to its original state.

In order to have a consistent bending action throughout the length of the veneer and to allow the veneer to return to its initial position within a relatively short time a bi-layer composite unit was made with a non-reactive layer bonded to the veneer. The non-reactive layer was chosen to be a clear cellulose film 0.127 mm (0.005 inches) thick. This passive layer essentially restricts the linear hygroexpansion in bamboo, forcing it to bend. It also allowed the composite to come back to its initial state much faster. The recorded time for this was only 10 minutes. Thickness of the composite was also an influencing factor in the bending motion. Thicker veneers were observed to have more inherent stability and were able to resist the bending motion while thinner veneers were more reactive. However, reduced thickness also translates to less material strength, leading to cracking and warping under strong winds. Holstov et al. believes that thinner composites are more prone to mechanical failure due to continued bending, biological failure due to fungal and insect attack and photo-degradation of lignin in cells. (Holstov et al. 2015)

How the two layers in the composite are bonded also has a significant role to play in its responsiveness. The bonding needs to provide flexibility to the composite to ensure repeated bending and, at the same time, be stiff enough to hold the layers together under different weather conditions. Although significant researches on bio-resins continue to be undertaken, according to R.D. Adams (2005), epoxy resins are currently the most suitable adhesive in the market that provides good strength, durability and ease of curing, without effecting hygroexpansion, despite environmental concerns.

### 3.2. Generating modular patterns
Following the veneer study, the research continued with constructing various patterns of modular façade and observing the degree of opening a particular façade would generate. The intention was to arrive at a certain geometry that would produce maximum opening to allow for maximum ventilation.

The study started with two-dimensional façade systems, with a diamond shaped composite unit. The particular shape, being wider in the middle and narrower toward the two ends, forced the composite to curve faster at its ends. During this stage small perforations were laser cut throughout the body of the veneers to study the behavior of perforated versus non-perforated material and observe whether getting rid of excess material aid in the deformation process by making them more reactive. The analysis later moved on to three-dimensional module studies to give the veneers an elevation to begin with. The triangles, acting as tetrahedrons, created a much bigger opening while deforming the same amount (Fig.5). However, during this time perforated veneers were seen to deform less since the grains ended up being divided at regular intervals due to the perforations. Hence, the research went back to using non-perforated veneers with a three dimensional modular pattern.

### 3.3. Incorporating façade with the climate
Once a suitable modular pattern with a certain shape and size was selected through a number of experiments with tetrahedrons, the wind directions of each of the three chosen regions were studied to integrate them with the modules. All three regions have most of the summer winds coming in from south/south-east direction, which was utilized to further modify the façade modules (Fig.6).
To catch the south-east wind, a range of 40-50 degrees of angle from the horizontal line was determined to be incorporated into the façade structure. In order to do that, the façade was constructed in a way that the veneers would be attached to the façade frames at an angle of approximately 22-25 degrees. All three triangular pieces making up a module needed to have their deformation axis perpendicular to the base to generate maximum deflection. As the air becomes humid the veneers begin to absorb the humidity and open up to an angle within the range of 40-50 degrees at roughly 93% relative humidity level. As such, the cool south-east wind is expected to be allowed inside the space. (Fig.7)
What is interesting to note is the behavior of the triangular veneers at a micro scale. At high humidity, when the veneers reached their most ‘open’ state the maximum angular difference was observed to occur in the middle of the triangles. The veneer would begin to increase its deformation angle from the base of the triangle and arrive at a maximum difference in the middle, after which it goes up and down in its angular differences as it moves toward its apex. The observation, although unpredictable, was confirmed after repeating the same experiment multiple times. (Fig.8)

The resultant façade design would have the veneers facing inwards toward the interior space when constructed on facade that face incoming fresh air, and outwards on facades facing outgoing used air. Since the three regions have incoming air from south-east, the southern façade will have veneers angled toward the inner space, whereas the northern and western façade, mostly utilized to expel air, will have veneers angled toward outside. On a micro scale, the former creates a shaded interior from southern solar exposure and the latter creates a shaded outer façade keeping it cool throughout the day, which is essential for west facing facades in warm-humid regions. Additionally, the former case where the veneers would face inward on the southern façade will create a venturi effect, forcing outside fresh air to come inside through smaller inlets into a much bigger interior space, thereby increasing wind speed leading to a cooler and more comfortable interior.
4.0 SCALE OF APPLICATION
While the veneers are expected to act as individual units that make up the adaptive façade, it can incorporate the pieces in varying scales. When the location and the context permit, the façade can act as an adaptive one entirely and create a stunning visual effect throughout the day, for example in the case of a museum lobby or an exhibition space where the architecture itself becomes a thing to ‘see’. However, whenever the functional aspects of the façade is expected to dominate, the modules can act together as a component of certain size and shape instead of discrete units and be ‘plugged-in’ as a component itself. This will eliminate the need to construct the entire façade as an adaptive one if it gets in the way of furniture placement in the interior, and instead the particular component can be fitted in places where the wind direction is most favorable to allow a cross ventilation to take place.

![Possible scales of application of a hygroscopic façade system. Source: (Author 2018)](image)

In terms of full-scale prototyping getting the initial angle of 25° integrated into the frame proved to be a challenge, which was later accomplished by using CNC-machine. Both sides of the frames were made angular so that one side helps to attach the veneers while the other side helps in giving a direction to enhance the angular airflow. Another challenge was the transition of mechanical fixing from simple pins to screws, which, when drilled through the composite, tended to detach the active and passive layers wherever the bonding would not be consistently applied.

5.0 FUTURE RESEARCH
The unique quality of responsiveness inherent in bamboo, coupled with its easy constructability, makes it a favorable material to investigate deeper into adaptive envelopes. Understanding the different potentials of the particular research it can be carried forward by manipulating the orientation of bamboo grains on a more micro level to further control the curvature of the bilayer composite. Similarly, instead of a homogenous cellulose film, passive layers with different grain directions can be juxtaposed with those of the active layer, possibly resulting in interesting and unpredictable results. One of the limitations to working with bamboo being its vulnerability to fungal attack, exploring adhesives that can double as preservatives against fungal and insect attacks will contribute to increasing the durability of the composite. However, when the material does start to degrade it will be easily replaceable, costing very little. Their impact as waste is also very low. Due to limitations of time the exploration of façade patterns needed to be finished at a certain point in order to move ahead with the later phases of the research but there is no denying that there is potential to generate more creative and sophisticated façade patterns with better performance, particularly in response to inclement
weather including heavy rain, storm, hurricane and so on. Moreover, using a monitoring and tracking system to monitor the deflection in the composites more accurate results could be achieved. Apart from veneer deflection, material degradation, fading of color and strength of the bonded composite could also be monitored over a one-year period to assess their long-term performance. The motion sensing method to track the hygroscopic response in wood samples in real-time by Abdelmohsen et al. (2018) can be adopted to express the physical material on a computational interface to get accurate measurements.

**Figure 10:** Full scale prototyping. Source: (Author 2018)

**CONCLUSION**

Up until very recently, facades in architecture that are able to adapt themselves in response to changing climatic conditions had typically been identified with having high-tech complex automated mechanisms, using electronic sensors and actuators. The low-tech and no-tech passive strategies of adaptive façade design based on material responsiveness were still in their infancy. Passive strategies minimize energy and material use while maintaining occupant comfort. This is precisely why such methods require a greater emphasis today as we investigate deeper into the realms of Responsive Architecture. It goes without saying that using natural heating, cooling and lighting reduces building energy use. But in today’s drastically changing climate reliance on natural forces is not sufficient to maintain comfortable interior living conditions. We need building systems that have the ability to adapt to this changing environment. Extensive research has already begun exploring passive envelope systems using timber, even though bamboo, being a rapidly renewable, carbon sequestering plant, is the greenest material on the market. Bamboo is an incredibly sustainable alternative to wood that can be used to lessen our exploitation of rainforest trees. Because of its hygroscopic property it has a natural inclination to climate adaption that can be exploited to design climate-responsive façade systems with no added energy input. Native to Asia and South America and fast-growing, bamboo, as a material, has not been exposed to much experimentation as far as façade systems are concerned. As such, bamboo provides a greater potential in rethinking building facades as organic, breathable skins – rather than a highly mechanized barrier between human and nature.
REFERENCES
Impacts of dynamic glazing on office workers’ environmental and psychological responses

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ABSTRACT: Indoor environmental quality is a critical factor that significantly affects an occupant’s work productivity, environmental health, and quality of life, especially in the workplace where a competent organization, and pleasant and healthy surroundings help assure maximum productivity. However, most building environmental design components, such as façade, are static, while the outdoor environmental condition (i.e., weather) is dynamically affecting the indoor environmental quality with significant and diverse changes. This structural limitation results in potentially compromising the environmental perceptions of a building’s occupants. With the help of advanced technologies, there have been numerous efforts to implement dynamic features in modern buildings, especially dynamic structural façade components, such as electrochromic windows (called dynamic glazing). An industrial and academic research collaboration team conducted an on-site building study by collecting IEQ components in a commercial office, that was equipped with dynamic glazing. For effective comparison, an occupant environmental satisfaction study was conducted on two floors, one equipped with conventional manual blinds, and the other with dynamic glazing. The study outcomes showed that the occupants on the floor equipped with dynamic glazing reported higher environmental and psychological satisfaction/positive responses than those on the floor equipped with manual blinds. This study also revealed that environmental satisfaction and psychological perceptions could be affected by different workstation locations, such as core and perimeter zones. Therefore, these results confirmed that dynamic glazing could be effectively integrated with modern building environments to enhance individual occupants’ environmental perceptions and psychological health. It follows that this would result in higher work productivity in a commercial office workplace.

KEYWORDS: Environmental comfort; Occupant well-being; Data acquisition; Dynamic glazing; Electrochromic windows; Healthy environment; Human factor

INTRODUCTION
Among the indoor environmental quality (IEQ) components in the built environment, thermal and visual quality components have been considered as major IEQ parameters that significantly affect the occupants’ environmental comfort and work productivity, as well as physiological health conditions (Lan et al. 2011; J.-H. Choi, Loftness, and Aziz 2012; Loftness et al. 2009; J.-H. Choi and Moon 2017; Loftness et al. 2018; J. Choi, Aziz, and Loftness 2010). Due to the significant roles in the IEQ domain, many efforts have endeavored to accomplish better thermal and visual environmental qualities, based on the use of numerous design and technology advancements. In recent decades, with the help of advanced technologies, buildings have begun to have dynamic features in its environmental attributes for interior and exterior conditions (Bakker et al. 2014; Hammad and Abu-Hijleh 2010; Lollini, Danza, and Meroni 2010; Lee, Claybaugh, and LaFrance 2012). Among those technology-adopted building façade components, an electrochromic window, called “dynamic glazing”, has emerged in the high-performance building area. Due to its advancement that enables dynamically changing visual transmittance and solar heat gain coefficients, this technology has become popular in many building typologies, especially in healthcare facilities and commercial offices. Since the dynamic pattern of such smart glazing can be controlled, as a function of
solar radiation and illuminance of the outdoor condition, indoor environmental conditions, especially thermal and lighting conditions, are automatically controlled without the need for an occupants’ manual control of blinds.

However, even though lab-based IEQ performance has been conducted to validate the technical function of dynamic glazing in recent studies (Lee, Claybaugh, and LaFrance 2012; Lollini, Danza, and Meroni 2010), they primarily focused on energy performance, rather than user-satisfaction centered approaches, and there is still limited, or no research effort being made to validate the IEQ performance generated by dynamic glazing in a real office environment. Therefore, this study conducted a comparison study of occupant environmental satisfaction and psychological perceptions for two different office floors; one equipped with manual horizontal blinds and the other with dynamic glazing. Since the same group of occupants stayed in both the offices before and after their move, this research was conducted in the form of a pre- and post-study.

1.0 METHODOLOGIES

One commercial office building, located in Toronto, Canada, was selected for the field study, and two office floors were selected as the testbed. One floor (12th floor) was equipped with manual blinds, and the office on the other floor (17th) had dynamic glazing. 17 occupants worked on the 12th floor for six months and then moved to a new floor (17th floor). The survey discussed below was conducted 2 weeks before and after the move in the form of a pre-and post-study. They were conducted on April on the 12th floor and in May on the 17th floor, to minimize a seasonal variation. Fig. 1 shows an office building selected for this study, and Table 1 summarized climate conditions of the selected site in April and in May when the surveys were conducted.

This study primarily consisted of environmental satisfaction (Oxford Questionnaires) and psychological response surveys (Kansei Engineering Questionnaires), which are commercially available. The Oxford questionnaires include multiple questions that ask about an individual occupant’s thermal, lighting, air, and acoustic satisfaction, while the Kansei Engineering questionnaires are mainly about psychological perceptions that include negative and positive emotional responses to the user’s ambient environmental conditions. This study adopted the Minitab software for statistical analyses, especially for two-sample T-tests, analysis of variance, and paired T-tests for the pre- and post-analysis (Minitab 2016).

As summarized in Table 2, 12 of those 17 participants to the survey were females and five were males. Due to the significant impact of workstation location on the users’ environmental satisfaction and ambient thermal and visual conditions, the workplaces were divided into two zones: core and perimeter areas depending on the distance between the building façade and individual workstations while 15 ft was adopted as a threshold to define the zones.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Female</th>
<th>Male</th>
<th>Office location – Core</th>
<th>Office location – Perimeter</th>
<th>Total</th>
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<tbody>
<tr>
<td>12th</td>
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<td>12</td>
<td>5</td>
<td>17</td>
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<tr>
<td>17th</td>
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<td>9</td>
<td>8</td>
<td>17</td>
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<td>Low temperature (°F)</td>
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<td>Day average temperature (°F)</td>
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<td>Day average humidity</td>
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<th>Table 3. Demographic information</th>
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<td>Floor</td>
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<td>12th</td>
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<td>17th</td>
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3.0 RESULTS and DISCUSSION

2.1 Improvements in user satisfaction with lighting, daylight, and window view.
The occupants were asked regarding their satisfaction with their window view to the outside, quality of daylight, and overall lighting conditions at their workstations on both of the floors. As shown in Figure 2, the occupants' were more satisfied with those environmental components in the dynamic glazing room than in the room with manual blinds. Occupants in offices with dynamic glazing have a 29.4% higher satisfaction rate with the quality of light, a 30.6% higher satisfaction rate with overall lighting conditions, and a 35.4% higher satisfaction rate with views to the outside, as compared with the opinions of occupants in identical office locations and orientation with manually controlled blinds (all p-values <0.001).

Figure 3 summarizes the comparison results of environmental satisfaction between 12th and 17th floors. The occupants in offices with dynamic glazing reported higher satisfaction with lighting and window view, quality of light, overall lighting, alertness, happiness, and perceived productivity. In a five-point scale ((1: Very poor, 2: Poor, 3: Fair, 4: Good, 5: Excellent)), the average scores of those satisfactions are 2.8 and 4.2 on 12th and 17th floors, respectively, and it results in a 29% difference on the basis of a full 5 score. All these comparisons were identified with statistical significances (all p-values < 0.05).

2.2 Use of mitigation devices
This study found that occupants in offices with dynamic glazing used fewer mitigation devices to ensure visual comfort than those in offices with manually controlled blinds on the windows. To help control the ambient visual quality affected by daylight/electric light, we observed the following items: polarizing screens; visual blocks such as folders, books or plants; caps or hats; changes in desk position; and specialized eyewear (i.e. sunglasses, transition lenses, computer glasses. According to the survey data, occupants in offices with manually controlled blinds reported using on average 2.5 of 5 visual mitigation devices to cope with excess glare, while occupants in offices with dynamic glazing reported on average 0.4 visual mitigation devices, as summarized in Figure 4. The statistical significance was found at a p-value of <0.001.
**Figure 2.** How would you rate the window view to the outside: Quality of daylight, Overall lighting conditions at your workstation? (1: Very poor, 2: Poor, 3: Fair, 4: Good, 5: Excellent) (all p-values <0.001).

**Figure 3.** Comparison of environmental satisfactions between 12th and 17th floors

In addition, occupants in offices with manually-controlled blinds (12th floor) also reported on average 2.6 of 5 thermal mitigation devices: extra clothing/shoes; fan/heaters; temperature monitoring; hot/cold drinks; and refrigerators or kettles – to cope with temperature changes at
the window wall, while occupants in offices with dynamic glazing (17th floor) reported on average 0.9 thermal mitigation devices with a statistical significance (p<0.001). Figure 5 illustrates the significant difference of heat mitigation devices between the selected two floors.

![Interval Plot of Visual Mitigation](image1)
![Interval Plot of Heat Mitigation](image2)

In term of the frequency of the use of mitigation methods, occupants with dynamic glazing reported 71% less use of thermal and 59% less use of visual mitigation methods, as compared to the condition when they stayed in the workplace on 12th floor with manual blinds. Also 41% those in offices with dynamic glazing reported fewer breaks to take a walk than when they were in offices with manually controlled blinds (Figure 6).

![Figure 6](image3)

### 2.3 Physiological symptoms by the glare

One of the significant technical features of dynamic glazing is the glare mitigation by changing visual transmittance of the glazing. Considering the direct sunlight to the office throughout the daytime and the multi-orientation that each workstation faces, the potential visual stress caused by glare is significant. This study asked six glare-relevant questions associated with physiological symptoms. As summarized in Figure 7, there is a significant drop in the number of occupants who reported their physiological response/symptoms, such as annoyance, glare on the computer screen, drowsiness, eye fatigue, concentration, and thermal stress. On the
average, 9 to 12 among the 17 occupants reported their physiological stress and discomfort on the 12th floor, but there were only 2 to 4 occupants who stated sustained physiological conditions. On the other hand, the number of occupants who reported headaches did not change for the new office floor (i.e., 17th).

Figure 7. Comparison of physiological symptoms by the glare

2.4 Improvements in emotional responses
To investigate the emotional responses, this study adopted a survey in a five-point scale (ranging from Not at all (1) to Very much (5)). As illustrated in Figure 8, overall, occupants in offices with dynamic glazing reported 24% greater positive emotional responses and 21% lower negative emotional response than occupants in offices with manual Venetian blinds. Occupants with dynamic glazing had substantially greater positive emotional responses of energized, awake, delighted, excited and happy when compared to occupants with manual blinds. Occupants with dynamic glazing also had substantially lower negative responses of tired, boring, dark and gloomy when compared to occupants with dynamic glazing. However, the levels of upset, annoyed, distressed, frustrated, bothersome, and miserable perceptions showed limited or almost no differences between both the floors.

Figure 8. Windrose chart of positive and negative emotional responses

2.5 Environmental satisfaction enhanced in core zones
In general, core zones in offices have been frequently reported as a relatively humble space as compared to perimeter zones primarily because of limited access to nature, such as light and natural ventilation (J.-H. Choi and Moon 2017; J.-H. Choi, Aziz, and Loftness 2009; J. Choi, Loftness, and Aziz 2009). In this study, the collected dataset was grouped per
workstation location, i.e., perimeter and core zones depending on the distance between building façade and a workstation. 15 ft was selected as a threshold to define the selected two zone based on the team’s previous study (J.-H. Choi and Moon 2017). As summarized in Figure 9, the occupants in core offices with dynamic glazing reported higher satisfaction with lighting and window view, quality of light, overall lighting, alertness, happiness, and perceived productivity. In a five-point scale (1: Very poor, 2: Poor, 3: Fair, 4: Good, 5: Excellent), the average scores of those satisfactions are 0.9 and 4.2 on 12th and 17th floors, respectively, and it results in 66% increase on the basis of a full 5 scale. Also, considering the significance of productivity in office facilities, the increase of perceived productivity by 2.5 scores on 17th as compared to 12th is noteworthy. All these comparisons were identified with statistical significances (all p-values < 0.05)

![Figure 9. Comparison of environmental satisfaction in core zones between 12th and 17th floors.](image)

**CONCLUSION**

In this pre- and post- study of 17 office workers moving from offices equipped with manual venetian blinds to a different office floor with dynamic glazing statistically significant improvements were identified in user-satisfaction with lighting, daylighting and view, perceived productivity; and improved emotional responses. Occupants with dynamic glazing have significantly higher environmental satisfactions and perceived productivity than those with manual blinds by an average of 29%. On the other hand, those environmental satisfaction and perceived productivity of occupants in core zones with dynamic glazing, which have been frequently reported as humble places, were significantly higher than those with manual blinds by an average of 66%. In addition, the pre- and post-survey about emotional responses revealed 24% higher in positive emotional responses and 21% lower in negative emotional conditions in the dynamic glazing condition as compared to the manual blinds. In the physiological symptom survey, only 2 to 4 occupants in offices with dynamic glazing reported annoyance, glare on a computer screen, drowsiness, eye fatigue, concentration, and thermal stress while there were 9 to 12 occupants reporting those symptoms.

As such, this study revealed a significant impact of dynamic glazing on human physiological and emotional perceptions in workplace environments. As modern people spend a significant amount of their time indoor and their productivity becomes a key parameter in a workplace environment, the role of such technology-applied environmental control as a passive strategy is critical. In consideration of these facts, an electrochromic window, as dynamic glazing could be one of the critical candidates to be considered for modern office environments where workers’ productivity and environmental health are critical. For this purpose, this study provides intellectual values by investigating the impacts of dynamic glazing on environmental and physiological parameters of office workers.

However, despite the significant findings above, there is still a limitation to this study. First, additional samples sizes with environmental parameters to measure should be considered to support the research findings. There were only 17 occupants available per floor in this study. Also, a future study should consider ambient environmental quality such as thermal and lighting environmental elements, including temperature, humidity, illuminance, luminance, contrast and ratio, and glare that are significantly affected by dynamic glazing performance. Also, since dynamic glazing performance vary depending on seasons and times of
measurement, additional field studies are required with consideration of seasonal and daily/hourly climate conditions.

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**REFERENCES**


Bionic building concept

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ABSTRACT: This paper describes a framework for creating a structured series of levels of building automation. It is designed to allow buildings to acquire intelligence about their own systems and equipment and to gradually obtain control of themselves. This allows planners, users, owners and other actors in the planning, construction and use to view and understand the building’s operations and performance at many levels. The framework has five horizontal levels and three communication streams. Each level implies a degree of automation with the scale shifting from the mechanization at the bottom to intelligence at the top. The levels describe (bottom to top) the physical object, their representation as data, the history of the data, the processes to analyse and model the histories, and at the highest level, the ability to learn from this analysis to predict, model and plan future building behaviour. Information moves among these levels in an upstream path as well as in a downstream path. The upstream path describes how sensor information is curated to create logs that, using the IFC structure, create semantic histories. In the downstream path, the histories are measured against simulations and model-based predictions to create use-models and potential event sequences. The event sequences then become the instruction sets for the actuators and equipment in the building. Once these are carried out, the effects then feed the sensor data back upstream. In this way, a cycle of information both upstream and downstream feeds a system that can learn. The paper also describes the third stream of communication. This, at each level of the framework, shows how information given to people can be categorized in a scale of increasingly sentient perception. This denotes how the different levels allow users to perceive the building as a purely mechanistic process at the lowest level and as a sentient being at the highest level.

KEYWORDS: BIM, Intelligent Buildings, Human-Building Interface

INTRODUCTION
The idea of learning from nature is not new to architecture. The idea of a ‘bionic building’ was explored in (Yuan et al 2017) by comparing conventional building systems to analogous ones in nature. The study, however, did not go so far to discuss the implementation of the concept. This paper describes the components of how to implement the intelligent functionality of an intelligent building. The term intelligent building itself has been used since the 1980s as is discussed in (Wong et al 2005) and could be said to have gained attention as a widespread concept with Fritz Haller's 2nd Symposium in 1991. (Friedrichs 1991)

The Bionic Building Concept described here is a framework that defines several layers of building component interaction and the informational relationship between these layers. The components are also separated into distinct upstream and downstream pathways which controls the flow of information. This framework enables individual advancement of technologies in each area to proceed independently of each other while maintaining a consistent flow of information. In essence, the framework enables individual progress without having to reconfigure the entire system. The goal of the Bionic Building Concept (BBC) is to enable machine learning to develop in building control systems without having to design the intelligence from the start. By configuring the framework in this way, intelligence can emerge from behaviours and a ‘learning building’ can be developed as individual advancement in technology and/or price arise.

The paper first describes the framework and its constituent parts and how they relate to each other. This is followed by a brief description of the implementation of such a system including the training, trust and hand-over of control to the BBC system.
1.0 BBC FRAMEWORK: LAYERS AND STREAMS

The Bionic Building Concept is defined into five layers organised into two main streams of information (upstream and downstream). A third stream of information moves horizontally and represents the human-computer interface that is available at each layer of the framework. See Figure 1: BBC Framework. In essence, the BBC is a response to the question as what to do with all the sensor data created in a "real-time BIM" system (Russell, Elger 2008).

![Figure 1: Bionic Building Concept Framework](image)

### 1.1 BBC layers

The Bionic Building Concept is organised into 5 layers. While these could be mapped onto the 7-layer ISO network model (Reference), for the purposes of this paper, this mapping is ignored. The BBC Layers are labelled from bottom to top: Mechanical, Technical, Documentation, Insight and Knowledge. These layers are described in the following points.

- **Mechanical**: This layer describes the physical technical installations in a building. They are made up of two primary classes of objects: Sensors and Actuators. Sensors provide data to the system and send it upstream for processing. Examples of these are temperature, CO2, light, motion and other sensors in the building. Actuators are the mechanical devices that respond to instructions from the BBC framework. These can be vents, heating, cooling, lighting and other installations. Often, a single technical installation will contain both sensors and actuators, but for the logical description of the BBC framework, they are considered separate entities.

- **Technical**: In principle, this is the layer that converts actions into bits and bits into actions. This is kept as a separate layer from the Mechanical layer as not all sensors are solid state devices. Additionally, there is the possibility to place plausibility check at this layer in order to prevent erroneous data going upstream or to check that undesirable commands are sent to the mechanical devices.

- **Documentation**: This layer is the repository of data. It represents the bulk of the information in the system and is the basis for using machine intelligence. It is also the layer that can connect to other systems at a 'database' or ODCB level of queries and understanding. In the downstream side of the documentation layer, it describes the planned actions for the building, which will be essential during the training and trust phases of implementation.
• **Insight:** The insight layer is where pattern recognition and initial analysis of the documentation layer takes place. It is, at first a plausibility filter to find outliers and other spurious data. It also serves to highlight where potential ‘insights’ could be in the data. In the training phase, these insights will be reinforced through human confirmation thus seeding the semantic understanding of the Insight layer. On the downstream side, the Insight layer is a testing ground for potential decisions from the layer above. Different models are used to test potential actions and verified before being passed down to the Documentation layer.

• **Knowledge:** This is the highest-level layer. On the upstream side, the knowledge layer contains a semantic understanding of past events called the history. This sums up the correlations identified in the Insight layer to describe the behaviour of the building. It serves as the basis for the BBC Brain, which lies at the heart of a machine learning system. At the top of the downstream side is a component identified as the BBC Brain. This is not necessarily any one form of neural network or brute force stochastic mechanism. In principle, any artificial intelligence process can be placed in this position and indeed, it is the idea of the BBC framework to be able to exchange one process or technology for another in any part of the BBV framework.

### 1.2 BBC streams

The BBC framework has three streams of information: Upstream, Downstream and Side stream. These streams describe the flow of information from the physical position of mechanical systems to the higher-level semantic description of what has and should happen in the building. The side stream will be addressed separately as it describes how the state of the framework can be understood by a human, which has implications for the training and trust phases of the system. The streams are described as follows:

#### 1.3 Upstream information

Mechanical devices, be they doors, windows, thermostats will all have an electromechanical method to convey their position or state to the Technical layer. In some instances, this could be a camera set to look at a mechanical dial. In other instances, it could be a solid-state sensor such as an accelerometer or light sensor. In most cases, the signals will be sent to the technical layer in predefined amounts and frequency of information (i.e. a temperature reading once a minute or the state of a window upon request).

Once the information is sent to the technical layer, it is first checked for plausibility. This means that data that is out of range or consistently set at one value can identify possible failures or calibration problems with the sensors. This is vital to the ability to glean knowledge at the higher levels of the framework as filtering ‘bad’ data is time consuming and can lead to false insights. Exact procedures to deal with unacceptable data will depend on the sensor and the context. High CO2 levels should require immediate inspection to ensure occupant safety whereas reading of zero light during the daytime will need a timely maintenance, but not emergency services.

From the Technical layer, the information is sent to a log at the documentation level. At this level the data is logged according to time, position, device type, state, value and time. Ideally, each device will be tagged with Industry Foundation Class (IFC) classification so that the pathway to a semantic understanding is quicker. However, even if no IFC data is included with the data passed on to the Documentation layer, its position, type and time will allow the layer above to filter and process the data.

At the insight layer, the data is pulled up to this layer, not pushed. The insight layer is essentially a combing or ‘spidering’ of the data stored at the documentation layer. The insight layer is made of processes that scan the documentation layer looking for patterns that trigger recognition according to their algorithms. These patterns are then passed on to the layer above to create a semantic history of the building.
At the top level called Knowledge, the building’s insights or patterns are combined with other information to form the Building History. This is a combination of what did what when, what happened where when, and what happened anywhere else when. Thus, the actions of users, the actions of the building itself, as well as calendar data, weather data and any other external information deemed useful is combined into a semantic history. This history provides the high-end fodder for the Bionic Building Concept brain.

1.4 Downstream information
Starting at the top of the downstream information stream, the Bionic Building Concept brain accepts the semantic history at the top of the upstream information. The BBC brain is not designed to be any particular flavour of artificial intelligence, but interchangeable between neural networks or any other current or future variation of machine learning. At the initial phase, the BBC brain is actually a human being. There will need to be a training phase in the implementation of the system and so, for all intents and purposes, the initial BBC brain is a human one. Nonetheless, as AI increases in its scope and more buildings acquire knowledge, the assumption of the BBC brain by AI should be possible.

Decisions as to how to act and react to the information in the BBC history is passed down to the Insight layer to test against models. These models can be physical or other kinds of models. Weather predictions, the thermal transfer through the facade, the behaviour of occupants and statistical data according to calendar dates (are Mondays particularly predictable?) combine to provide an initial test of possible actions to be taken. If the models verify that the potential decisions will achieve the goals (i.e. remain in a temperature/humidity comfort corridor), these instructions are passed down to the documentation layer.

At the documentation layer, the instructions deemed appropriate by the BBC brain and tested against models are put into an event queue, which is essentially the instruction sets for each of the physical installations connected to the framework. In some cases, these will be instructions for a servo (i.e. open a vent). In others they may be instructions sent to people to carry out inspection or maintenance tasks.

1.5 Learning
Once the calendar signifies an event is due, it is passed to the Technical layer. As in the upstream flow of data, the technical layer serves as a stopgap for erroneous instructions that fall outside of acceptable ranges. The layer also checks that the devices are able to receive the data. The technical layer then passes on instructions to device or the service.

At the mechanical layer, the electrical motors then open or close vents, turn on or off lighting and signal maintenance teams to carry out their work. Signals that the event was successfully carried out then are sent back upstream to become part of the BBC history. The feedback can be instantaneous (lighting) or take days (maintenance). Indeed, the variation in timing of data and feedback is one of the biggest challenges in managing the BBC information within the framework.

1.6 Side stream information.
In addition to the upstream and downstream flow of information, there is also a 'horizontal' stream of information at each layer. The side stream information is to convey what the BBC system is doing at any given layer. This is a Human-Computer Interface (HCI) issue in and of itself, but a brief description of the principles is included here. The issue of HCI is not essential to the proper operation of the BBC system once it is up and running, but is necessary for trust that the system "knows what it is doing" in order for control to be passed on to the BBC system.

The BBC system can be understood on different conceptual premises depending on which layer it is being looked at. Each layer has a different interface that reinforces the concept of that layer. See Table 1: Building / Layer Interface Reference.
Table 1: Building / Layer Interface Reference

<table>
<thead>
<tr>
<th>BBC Layer</th>
<th>Concept</th>
<th>Interface</th>
<th>Technical Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Building as a Sentient Being</td>
<td>Avatar</td>
<td>Conversational</td>
</tr>
<tr>
<td>Insight</td>
<td>Building as a Phenomena</td>
<td>Behavioural Animation</td>
<td>Observational</td>
</tr>
<tr>
<td>Documentation</td>
<td>Building as a Resource</td>
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<tr>
<td>Technical</td>
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<tr>
<td>Mechanical</td>
<td>Building as a Machine</td>
<td>Switchboard</td>
<td>Query-Based</td>
</tr>
</tbody>
</table>

1.6 Side stream interfaces

The concept behind the side stream interfaces is that at each layer, it is necessary to understand the BBC in a different way. Starting at the highest level, the building can be considered to be a sentient being, a physical phenomenon, a resource, a set of status lights or a machine with certain states. Each concept requires a different kind of interface and while the final design of each layer has not been completely defined, the rough outline of each interface is described below.

At the highest level the building can be thought of as a sentient being. This implies that communication is possible and so the interface will have to be conversational in nature. At worst, this is the 'Star Trek' interface where people talk to the building and it responds conversationally to answer questions or inform the occupants of decisions or other pertinent information. In cases of emergency, this can be more helpful than a simple siren. In other cases, a discussion about temperature and its effect on energy efficiency could help to encourage better user behaviour in the building. In any case, when the building is considered to be intelligent, the interface must reflect this, whether the discussion take place with verbal dialogue or a chatbot-like interface.

At the Insight layer, the building can be understood to be a physical phenomenon, much like a hurricane or any other complex system with emergent properties. This allows us to model behaviour and fine-tune these models based on the accuracy of past predictions. This implies that in terms of an interface, the understanding of the building should reflect this. Thus, the HCI at this layer should provide animations or other visual representations of what has and is likely to happen to and within the building.

At the documentation layer, the building can be understood to be a resource. This means that it has certain attributes that are useable in certain numbers at certain times. Thus, the interface at this layer resembles a calendar or booking system defining which assets are used when. This interface can be used in the past in terms of histories as well as in the future in terms of planned use of the building's components. Additionally, this layer is where parts of the building combining many components (i.e. rooms) can be booked collectively.

At the technical layer, the building is depicted as a set of monitors and controls. The interface at this layer considers this to be a representation of the building's status. The depiction can be considered to be one where an overall status is possible, but then in deeper depiction upon request.

The mechanical layer sees the building as a set of mechanical components and is akin to the 'control room' effect of every component having a status (on/off, open/closed, 20%, etc.) This is the lowest technical level and simply sees the building as a machine.

Depending on the situation and the need to know which kind of information, the interface should be able to switch from one layer to the next. For example, if in a voice-controlled wish for more light, this is not possible, it should be possible to drill down through each interface to
finally discover there is a mechanical fault, if necessary. Ideally though, the desired interface will be as high in the layer hierarchy as possible.

1.7 Stream shortcuts
In addition to the upstream, downstream and side stream information flows, there are two 'shortcut' flows that should be mentioned. Firstly, at the level of the Technical layer, there is an implicit shortcut or feedback loop that filters out-of-range data either coming from or going to the physical components. Usually, these will be part of the component's internal construction, but for the purposes of the framework, constitutes a separate information shortcut loop. Secondly, there is a shortcut loop between the Insight layer and the Documentation layer. This shortcut loop is there to allow the BBC brain to test various options.

Testing options is essential for the system to be able to learn without having to actually test this in the real world. The timing of some of the events in the Documentation layer will not need to made in real-time. This means that given the time and computational capacity, the BBC Brain will be able to weigh alternatives against each other through the Insight layer and test these against each other. Until such time as an event needs to be executed in the event calendar, the BBC Brain then can search for better solutions and replace these if they are found.

Secondly, testing without actually implementing an action at the Technical layer is how the BBC system will work for its initial life. Once a building design has been planned, it is possible to create the BBC system without having it connected to an as-yet unbuilt building. Thus, given that the models are accurate and a supply of reasonably simulated data on the upstream data flow, the BBC Brain can 'run' the building for many years ahead of its connection to the actual physical building. This will be essential in the implementation phase where modelling will be tested against reality, the BBC system can be guided and trained and eventually entrusted to autonomously run the building.

Additionally, it is possible at the Technical layer to do some 'pre-intelligence'. In the human visual system, edge detection of objects is actually 'calculated' in the retina, even before it reaches the cerebral cortex. (Marr 1982). By the same token, some of the intelligence can be delegated to the lower layers. In some cases, it has been shown that given knowledge about the topology of their logical networks, sensors are able to identify themselves within a BIM model. (Moellering 2017)

2.0 BBC FRAMEWORK: IMPLEMENTATION
The Bionic Building Concept framework is set up to be modular in that technologies within the components of the framework are interchangeable so long as they respect the information streams to and from each component at each layer. This allows 'virtual' components to be used in place of any component of the system. The virtual components can be simulated data streams or even human beings. For the system, the BBC framework will still function as long as the information streams are respected.

In implementing the BBC system, there are five distinct stages in order for the building to control itself autonomously: Development, Virtual Training, Real Training, Trust Building and Autonomy. See Figure 2: BBC Implementation Phases.

2.1 Development
The BBC system is conceived so as to allow a gradual implementation of the BBC as more experience is gained by the system and more trust can be put into the system. This is also a reason for the modular framework: it allows the gradual introduction of autonomy. In the first phase, the Bionic Building Concept framework is put together and the interfaces between the modules is defined. In some cases, these are ODCB SQL queries and statements, in others, it is merely the reading of a defined data stream (i.e. sensor data). Once the components and
their interfaces have been defined, the system can be tested in whole or in part by relaying information in the different information streams.

In its initial phase (development), the most crucial part is the upper two levels where the testing of patterns is measured against predictive models. In fact, without even knowing the geometry of the building and simply using the spatial relationships, it is possible to pre-train the system and to test its components with each other. See Figure 2: BBC Implementation phases.

2.2 Virtual training
Once the geometry and other technical aspect of the building are known, it will be possible to start to train the system, although the physical aspects are not yet built, by using historical weather data, assumptions of building component performance and models of user behaviour, artificial data streams can be simulated to 'train' the system to understand and look for patterns in the documentation layer. In fact, because the streams are artificial, the reliance on actual time and periods of data being sent from the technical layer is absent. As a result, it is possible to run the virtual training at an accelerated speed, limited only by processing power and the total time available.

2.3 Real training
After the completion of construction, the technical layer will be coupled with documentation layer in the upstream information flow. This will allow the BBC brain to accept real information from the technical layer including real sensor and mechanical information. Additionally, within other components (i.e. upstream Knowledge layer: History), it will be possible to allow experience humans to adjust and fine tune the semantic information leading the BBC brain to make better suggestions. In some ways, this will beget a new kind of role or employment opportunity: the "Building Whisperer".

2.4 Trust building
Once the BBC system starts to encompass real-world and real-time information into the system, it will start to produce potential actions for the Event calendar in the Documentation Layer. By comparing these to predicted behaviour and to the experience of the Building Whisperer, it will be possible to build confidence that the building would do "what a normal person would do". Indeed, one of the challenges in building trust is to understand why the building would choose to NOT do something a 'normal' person would do. This is where the side stream interfaces become important. It is hoped that eventually, the BBC system will suggest non-intuitive actions which will result in efficiencies that humans might not have discovered. It will thus be essential to understand why this is so and the side stream interfaces will help at every level to explain the BBC's reasoning and intentions. Failing to do so can arouse suspicions as to the BBC's logic and intentions, possibly even suspecting evil ones as in some science fiction (Kerr 1995)
2.5 Hand-off phase
If the BBC System produces actions that are sufficiently consistent and aligned with expectations of building performance, it is possible then to connect the downstream information flow to the Technical layer. Once this is done the BBC system becomes autonomous and its own positive feedback loop. To be sure, the trust is not a single decision and the continual availability of the side stream HCI information will allow people to monitor the system as a whole, as well as the performance of any individual components. As has been shown, the more complex a system is, the more effort is needed to instil trust (Bartneck 2009). Furthermore, as future technologies become available, it is possible to exchange these within any component in order to improve the overall performance of the BBC system.

3.0 LEARNING AND TEACHING BUILDINGS
The first BBC system will likely be slow, obtuse and need a lot of coercion in order to become truly autonomous and trusted. However, as more and more buildings use this kind of system, a wealth of data of use, action and their effects will inform future versions and instances of the BBC system. Thus, when a new building is planned, the data from previous experience can be used to seed the virtual training phase thus accelerating the entire learning phase of the building. What is more, if new actions arise from the analysis at the Insight layer, these can be propagated to older instance of the BBC to 'upgrade' the intelligence of all systems.

By this way, it is envisioned that the Bionic Building Concept can seed and propagate best-practices of artificial intelligence and best-case strategies for managing buildings across the entire building stock. This, while interesting in itself not the reason for pursuing this. The need to radically reduce the resources required to provide habitation and shelter for humanity is under immense pressure from the side of climate protection and the sheer numbers of additional people who will need shelter in the next 30 years. The numbers state it clearly. We want to reduce by half the carbon footprint of humanity, all the while creating habitation (of good quality) for an additional 40%. The numbers mean that we need to increase our efficiency by a three to fourfold in order to meet these goals. It is likely the case, that systems like the Bionic Building Concept will provide the framework to achieve this using an incremental and interchangeable methodology of incorporating the newest technologies to improve where possible.

4.0 Outlook
The current implementation of the Bionic Building Concept is dependent on the quality of the data as machine learning can only be implemented using large numbers of high-quality data. creation of an Open-BIM policy will be essential if current artificial intelligence methods are to be used. Efforts are underway in the Netherlands to create a database of IFC information about buildings in order to meet these requirements.

REFERENCES
J.K.W. Wong, H. Li, S.W. Wang, Intelligent building research: a review, Automation in Construction, Volume 14, Issue 1, 2005, Pages 143-159,
Yanping Yuan, Xiaoping Yu, Xiaojiao Yang, Yimin Xiao, Bo Xiang, Yi Wang, "Bionic building energy efficiency and bionic green architecture: A review", Renewable and Sustainable Energy Reviews, Volume 74, 2017, Pages 771-787
ANN-based thermal load prediction approach for advanced controls in building energy systems

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ABSTRACT: The Artificial Neural Network (ANN) technology has been used in various areas. In the building industry, however, ANN is relatively less utilized due to its complexity and uncertain benefits of its application along with the costs associated with its development. This paper introduces ANN regarding its applicability and potential benefits in building operations, especially for energy savings. Thermal loads calculations are most widely used for the operation of building energy systems. An ANN model was developed to predict a large office building's cooling loads. The EnergyPlus simulation program was used to generate thermal loads data and the Python program to develop an ANN model. The initial ANN model predicted a case study building's cooling loads within the CVRMSE value of 7.3% initially, and later 6.8% after optimization, which is within the tolerance range of 30% recommended by the ASHRAE Guideline 14. This study showed the potential benefit of energy savings that can be achieved by utilizing the ANN model for accurately predicting the cooling loads.

KEYWORDS: ANN, Optimal Control, Python, Load Prediction, Learning Method

INTRODUCTION
Since the Industrial Revolution, energy usage has increased as global urbanization progresses rapidly. Researches are continuously carried out in various fields to improve energy efficiency. As such, researches on the energy conservation in both new and existing buildings have been actively carried out. In the past, high-efficiency Heating, Ventilation, and Air-Conditioning (HVAC) systems, high-performance windows, and high-insulation walls have been the focus of research (Seo, 2017, Seo and Lee, 2016). However, most of these were mostly focused on new building design and remodeling cases. In the case of remodeling, the implementations are usually high. It is required first to maximize the efficiency of the existing systems by developing optimal control strategies. Various studies on the optimal control methods of HVAC systems were conducted utilizing advanced technologies such as Artificial Intelligence (AI) controls. Artificial Neural Network (ANN) is one of the advanced AI technologies that can learn and predict future behavior of buildings based on historical data with appropriate variables. ANN-based control methods are increasingly utilized these days to solve complex problems in various fields due to its ability to learn and analyze mapping relationships including non-linear phenomena (Abiodun et al., 2018).

Recent research trends show that the ANN controls are applied to the energy systems operations in buildings. Kang et al. Implemented an ANN-based prediction model to find the optimal supply air setpoint temperature of the Variable Refrigerant Flow (VRF) system. The input variables of the ANN were indoor, outdoor temperature and humidity, cooling loads, condenser water flow rate, condenser water temperature, supply air temperature, and cooling energy consumption. Comparing the predicted value of ANN with the actual value, the Coefficient of Variance of Root Mean Squared Error (CVRMSE) was 10.3%, and the ANN-based control method saved about 28% of cooling energy (Kang et al., 2018). Reynolds et al. constructed a model combining ANN and Genetic Algorithms (GAs) to reduce building energy consumption. In order to predict the energy consumption and indoor air temperature, the training was performed by specifying the weather data, the number of occupants, and the
indoor temperature as input variables. The energy savings of 25% was observed utilizing the ANN model over the fixed-temperature control method (Reynolds et al., 2018). Afram et al. conducted an energy performance evaluation of ANN-based model predictive control against the fixed-temperature control method of residential buildings. Their results showed that the ANN-based predictive control model consumed up to 10% more cooling energy than the fixed-temperature control method in July. This is because the weather is very extreme in July and the residential building cannot hold enough cooling to shift the load to off-peak hours. However, it confirmed that the heating energy was used 70% less than the fixed-temperature control method in October (Afram et al., 2017). Deb et al. conducted a study to predict the cooling loads of public institution buildings using ANN to achieve energy savings. Two-year energy consumption data of three buildings were analyzed, and the ANN model was constructed based on outdoor temperature, humidity, solar radiation, and energy consumption variables (Deb et al., 2016). Mba et al. conducted a study to predict the room temperature and humidity in the past using ANN to reduce cooling energy in residential buildings. Two years of indoor and outdoor temperature and humidity data were collected. The ANN model predicted the indoor air temperature and relative humidity with the accuracy of about 98% (Mba et al., 2016). Many other ANN-based optimal control studies have been reported. However, most studies had focused on identifying the results of applying ANN. These studies, however, do not clearly articulate on how the AI and ANN-based control models can be developed, applied, and utilized in detail. This paper focuses on explaining the general procedure of developing the ANN-based load predicting models for the future use of optimal control of building energy systems. A case study is used to show an example of the ANN model application and its accuracy.

2.0 ARTIFICIAL NEURAL NETWORK (ANN)

2.1. Machine learning (ML) methods

There are three types of basic ML methods: 1) supervised learning, 2) semi-supervised learning, and 3) unsupervised learning. Supervised learning requires an input data set and the same number of correct answer data sets. Semi-supervised learning requires a smaller amount of correct data sets than the input data sets. Unsupervised learning uses only the input data sets. The learning method is selected according to the purpose of ML. Supervised learning is mainly used for classification, prediction and regression analyses. Semi-supervised learning is used for clustering and classification. Unsupervised learning is used for clustering, visualization, and feature extraction (Muller and Guido, 2017). Supervised learning, for example, can mainly be used for lighting on/off control, load prediction, and load calculation per unit area. Semi-supervised learning can be used to identify the amount of clothing through image analysis. Unsupervised learning can be used to classify patterns of building users. Among these, the supervised learning method is used for ANN.

ANN was proposed by Warren McCulloch and Walter Pitts, which is based on human neurotransmission structures and learning processes. When ANN is applied to the study of building thermal environment, it performs Predictive controls and Adaptive controls. Predictive control predicts the future thermal environmental conditions and system parameter values to find a way of enhancing both the thermal comfort and building energy performances. Adaptive control adapts itself by continuous self-learning, which has an advantage of outputting an accurate and stable control value by itself (Geron, 2017).

Supervised learning requires both ‘input’ and ‘correct answer’ data sets. The ‘correct answer’ datasets here mean the results that the ANN model generates for a given input data sets. For example, the case in a model for predicting the cooling loads, the input data sets are the outdoor dry bulb temperature, outdoor relative humidity, and solar radiation; the ANN model outputs are the predicted cooling loads. The learning process in the supervised learning is a process of updating the weight factors so that the error is reduced by comparing the output (or predicted) values of the ANN model with the ‘correct answer’ values. Therefore, when the specific data sets are input, the ANN model, which has been well learned by the supervised
learning, processes the patterns of the input values and generates the calculation (or predicted) results, which is determined to be closest to ‘correct answer’ data.

2.2. Structure of artificial neural network (ANN)

Figure 1-(a) shows a representative multi-layer neural network model of ANN. An ANN model consists of an input layer, one or more hidden layers, and an output layer. Figures 1-(b) and (c) show the step function and the sigmoid function, which are kind of Activate functions. There are a variety of Activate functions, but in this paper, we will only describe two of those commonly used. The Activate function is used to simulate the behavior of biological neurons. The difference between the step function and the sigmoid function is that the result is different. The step function calculates 0 or 1 as the result value, and the sigmoid function calculates the value between 0.00 and 1.00 as the result value. When designing the ANN model, it is essential to select the Activate function depending on the application. For example, the step function is used for a linearly separable problem such as an on/off control, and the sigmoid function is used for a non-linearly separable problem such as load predictions and energy consumption predictions (Kyurkchiev and Markov, 2015).

Each Neuron is connected by weight factors as shown in Figure 1-(a). Each neuron adds the product of the input values and the weight factors that are connected and pass this value to the input value of the Activate function. Also, if the input values passed to the previously calculated Activate function are not large enough to exceed a certain threshold, there will be no outputs. Conversely, if the input value given to the active function exceeds the threshold, the neuron is activated to transmit the data to the next step. In summary, we can say that ANN computes the results by analyzing the interaction between data, weight factors, and the Activate function (Moon, 2015).

![Figure 1: ANN structure and Activate function](image)

2.3. Example of ANN training method

Figures 2 and 3 are simplified illustrations of the ANN learning process shown in Figure 1-(a), which are divided into four stages to facilitate understanding. As discussed, supervised learning refers to a learning method that pairs ‘input’ and correct ‘answer data,’ where the ‘correct answer’ data is the value that the ANN model should generate as outputs for a given ‘input’ data sets. In Figure 2-(a), “Input_#” means the input value, \( w_{a,b} \) the weight factors between the nodes a and b, and node (neuron) a point at which data is gathered. Answer_# means ‘correct answer’ output to input data. Output_# is the calculated (or predicted) value from the ANN model. As discussed, the learning process is a process of updating the weight factors of the model, so that the error is reduced by comparing the output value of the ANN model for the ‘Input’ with the ‘correct answer’ of the held ‘Input’ data. Therefore, the learning is divided into feed-forward propagation to calculate the output of the ANN model and back-propagation to calculate the error and update the weight factors by reflecting on the learning process (Rashid, 2016).

Figure 2 shows the feed-forward propagation that sequentially transmits the data. Figure 2-(a) shows the initialization of the weight factors. Figure 2-(b) illustrates the process of calculating the results by multiplying the sum of the values input to each node by the Activate function.
The reason for choosing the weight factors randomly at the first stage of the ANN is that the optimal weight factors combination is different depending on the input data. In addition, since the neural network finds the optimal weight factors through the repeated learning process, it is common to randomly select all the weight factors except for setting all the weight factors to zero or setting them all to the constant of the same values.

In Figure 2-(a), Input_1 is 0.8, Input_2 is 0.6, ‘Answer’ and weight factors were randomly assigned. The Activate function was applied to the sigmoid function, and the bias and learning rate were not considered because they did not affect the learning process. Figure 2-(b) is a diagram of feed-forward propagation for calculating the output of the ANN model. As shown in Figure 2-(b), the input values to Output node 1 are Input 1 × w₁₁ and Input 2 × w₂₁, and the sigmoid function outputs 0.74 by using 1.06 that is the sum of input values. Also, Output node 2 outputs 0.61 through the same procedure.

Figure 2:

Figure 3 shows the back-propagation process for updating the weight factors. Figure 3-(a) shows the back-propagation process of calculating the ‘error’ which is the difference between the outputs of the ANN and ‘correct answer,’ and updating the weight factors to reduce the error. Figure 3-(b) shows that the weight factors are finally updated. We need to adjust the Activate function or weight factors to reduce the error. However, since adjusting the Activate function requires a relatively complicated task, most studies adjust the weight factors. In Figure 3-(a), the ANN outputs 0.74 and 0.61. They are compared with the answers 0.50 and 0.40, resulting in an error of -0.24 and -0.21. These errors are called e₁, which are used for back-propagation. For example, we input -0.24 to the e₁ in the formula \( \frac{w_{11}}{w_{11} + w_{21}} \times e_1 \) and \( \frac{w_{21}}{w_{11} + w_{21}} \times e_1 \) which update the weight factors \( w_{11}, w_{21} \) which are connected to the output node 1. As discussed, the ultimate goal of the ANN is to converge the error closer to zero. Thus we adjust the weight factors to reduce it in the learning process. Output_1 is affected by \( w_{11} \) and \( w_{21} \). Also, \( e_1 \), the error value for Output_1, affects only \( w_{11} \) and \( w_{21} \) in the back-propagation process. In this case, the denominator in the above equation is the sum of the weight factors, and the two equations are the same, but the numerator is different by \( w_{11} \) and \( w_{21} \). The sum of \( \frac{w_{11}}{w_{11} + w_{21}} \) and \( \frac{w_{21}}{w_{11} + w_{21}} \) is always 1, and the larger the weight factors is more affected by \( e_1 \). Thus, when back-propagation proceeds, the more error rate is reflected in the

Figure 3: Back-propagation process
weight factors having a relatively large value. As a result, the value reflecting the error rate is added to the existing weight factors as shown in Figure 3-(b), and the learning ends. After this process, we have completed the first learning. In the second learning, we do not initialize the weight factors, rather we repeat the process of Figure 2-(b) and Figure 3-(a) up to the number of learning iterations.

2.4. Fundamental functions of ANN

In order to implement ANN models, there are at least three functions required (Rashid, 2016).

- **Initialization**: variables, number of hidden, output nodes, number of hidden layers, learning rate, bias value setting
- **Training**: learning through training data and updating weight factors accordingly
- **Test**: outputs (or predicted values)

Besides, one additional task is required to apply the ANN to the building control field (Kang et al., 2018). First, the initialization part for selecting variables, the training part for learning based on the selected variables, and the Test & Optimization part for verifying and optimizing the ANN-based prediction models that have completed the learning. The last one is the control logic part. Through this process, ANN predicts some values, which is applied to building control logic for finding optimal control values. The control value is input to building control logic such as HVAC to apply ANN to building control. Figure 4 shows the development process of the ANN-based prediction model using Python (Muller and Guido, 2017).

![Figure 4: ANN-based load prediction logic](image.png)

The first step to construct an ANN-based prediction model is to select variables with a high correlation with the output to be predicted. The reason for analyzing the correlation of variables is to select variables through objective indicators to improve the efficiency of training. Figure 4-(a) shows the input variable selection process. For example, when constructing a model for predicting cooling loads of a building, it is important to select the input variables with a relatively high correlation by analyzing $r^2$, which represents the correlation between all the input variables that can be calculated and the cooling loads. If a variable with low correlation between input and output variables is selected, it is difficult to expect a proper prediction value even if repeated training is performed. The next step is data collection. This is because the ANN model is less adaptive when training with too few data. The sigmoid function used in this study requires a data range from 0.00 to 1.00. If you enter a larger input value, the ANN becomes saturating, which does not work properly. Therefore, through the normalization that divides the data range of the cooling load to be predicted through the selected input data and
the ANN by the correlation analysis, it should be adjusted from 0.00 to 0.99 or -1 to +1 (Rashid, 2016).

Figure 4-(b) is a flow chart showing the training part, the second part of the ANN-based prediction model. When we start training, we initialize the weight factors which are the heart of the learning. Next, add the sum of the values obtained by multiplying the input data and weight factors by each node, and bias. Input this value into the Activate function to output values (Rashid, 2016). The error rate between the result of the ANN and the ‘correct answer’ is reflected in the next training, and the error rate reduction training is repeated by the value of the epoch. Epoch means the number of training iterations. Again, the goal of learning is to obtain the weight factors at which the error rate between the output of the ANN and the ‘correct answer’ becomes the lowest.

Figure 4-(c) is a flow chart showing the test part that the third part of the ANN-based prediction model. In order to confirm the adaptability of the ANN model that has been trained through the training part, the task of confirming the error rate between the ANN output and the ‘correct answer’ of the verification data through the verification data, which is new data that was not experienced during the learning process, is called a test data or verification data. Unlike the previous learning part, the test process does not adjust the weight factors according to the error rate between the ANN results and the ‘correct answer’ and confirms the prediction accuracy rate of the ANN model that completed training process. Also, the optimization of ANN means to adjust the values of bias, learning rate, the number of hidden neurons, and the number of hidden layers, which are Hyper-parameters of the ANN model. This process is repeated until getting an acceptable error rate.

The test and optimization processes are; first, after the training part, the values of optimized weight factors and Hyper-parameters are specified in the same way as the training part. The test data is input to output the result of ANN. The next step is to confirm the predictive performance and reliability of the ANN model. To confirm these, a statistical term or Coefficient of Variance of the Root Mean Square Error (CVRMSE) is used with the acceptable tolerance ranges suggested in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guideline 14. The tolerance ranges (or error rates) mean the prediction accuracy of the ANN model compared to the ‘correct answer’ data. The CVRMSE value closer to zero % means that the better prediction performance. ASHRAE recommends the CVRMSE value of less than 30% as the error rate tolerance of time data. It includes the recommended $r^2$ value, which indicates correlation, to be 0.80 or higher (ASHRAE, 2002). If the CVRMSE value is more than 30%, the user adjusts the Hyper-parameter values and performs the optimization process by repeating a series of operations until the tolerance value becomes less than 30%, or a specific value (or goal) is reached.

There are many ways to utilize ANN technology in buildings. Typically, it can be used for optimal control to reduce energy consumption. The ANN-based optimal control uses the ANN results to the control logic part to calculate the optimal control value that uses the least amount of energy and control the building through it without compromising human comfort. This process is shown in Figure 4-(d). Also, through the ANN, optimal control can be achieved by controlling the AHU discharge temperatures, fan speeds, and chilled water temperatures by effectively predicting cooling, heating, and ventilation loads. An ANN-based optimal AHU discharge temperature control, for example, can predict the cooling loads through ANN and applies it to the control logic to calculate the optimal discharge temperatures that use the least energy under the predicted cooling loads. In addition, it can be used in areas where control is available, such as blind controls and lighting controls.

3.0 EXAMPLE OF ANN FOR LOADS PREDICTION

3.1. Tools (EnergyPlus and Python)
There are two software programs used in this study; EnergyPlus ver. 8.9 for data (or thermal loads) generation and Python ver. 3.6 for developing ANN. EnergyPlus is a simulation program...
developed by The US Department of Energy, which combines the merits of BLAST in the loads analysis part and the advantages of DOE-2 in the system analysis part. In addition, EnergyPlus uses the heat balance calculations recommended by ASHRAE (USDOE, 2018). Python is an interpreted language developed by Amsterdam's Guido Van Rossum in 1990. Python is used in practice as well as for educational purposes. Typical examples are Google's software programs and Dropbox. Python has used across the entire spectrum of social computing, including web programming, numerical computation, data analysis, object-oriented programming, graphical user interface (GUI) programming, system utility building, software development (Lutz and Ascher, 2013). NumPy and SciPy are important libraries to construct ANN models in Python. NumPy is a core Python package for performing scientific calculations, especially for N-dimensional matrix calculations. With NumPy, there is a big advantage that ANN's complex learning process can be quickly solved with simple coding. SciPy is used to deal with more complex problems such as integration, finding eigenvectors of sparse matrices, and checking the consistency of distributions using NumPy arrays. Those are mainly used for processing tasks such as optimization and data fitting (Bressert, 2013).

3.2. Simulation Modeling

A large number of datasets are required to construct an ANN-based model for loads predictions. The building thermal loads data were generated using the "RefBldgLargeOfficeNew2004" model available in the EnergyPlus program as an example. The Chicago weather condition was used. The analysis period was a cooling season (June 1 to August 31). Figure 5-(a) shows the building model and building schedule for a large office building. The model was a basement and three-story office building with an area of 46,320 square meters and Window to Wall ratio of 38%. The ASHRAE Standard 90.1-2004 was used for the selection of building materials, constructions, and window properties. The U-value of windows is 3.236 W/m²-K with the Solar Heat Gain Coefficient (SHGC) of 0.39. The U-value of the outer wall is 0.698 W/m²-K, roof U-value of 0.358 W/m²-K, and the floor U-value of 2.193 W/m²-K. To simplify the test, only the middle layer (2nd floor) data was used. Also, weekday data is only used. The room thermostat is set to 24 °C from 7 AM to 10 PM and 26.7 °C in the other hours. The data only from 07:00 to 22:00 was used with the office temperature settings of 24 °C. Figure 5-(b) shows the lighting, equipment, and occupancy schedules. All the schedules reach 90% or more during the office hours, and it can be seen that the occupancy and the equipment schedules are low only at lunchtime. In night time, the device and lighting are operated at a minimum level.

Figure 5: Simulation modeling & internal load

3.3. Selection of input variables for ANN

The datasets are divided into 1) learning and 2) verification data. The training data was only used in the training part and test data used in the test part. It is because if the same data set is used in both the training and test parts, the ANN can predict well in specific conditions, but it may not predict well when a new pattern data is used. Therefore, we implemented the Training and Test datasets by randomly dividing the EnergyPlus simulation results at 9:1 ratio to confirm the ANN adaptability to the new patterns that were not experienced in the Training.
part. In addition, input variables were selected by four variables with relatively high $R^2$ values through correlation analysis with the cooling loads as follows: Site Outdoor Air Drybulb Temperature [C] (Hourly), Site Diffuse Solar Radiation Rate per Area [W/m²] (Hourly), Site Direct Solar Radiation Rate per Area [W/m²] (Hourly).

3.4. ANN model for loads prediction

Figure 6-(a) shows the structure of the cooling load prediction model constructed for the example case. The structure of the initial model had four input nodes, two hidden layers, and 12 hidden nodes. It has one output node, and the sigmoid function was used as Activate function. The learning rate was set at 10%, which means that only 10% of the error is used to update the weight factors when the error of 1 occurs. The reason for not fully reflecting 100% of the error was that the optimal weight factors were set by using the gradient descent method. This method has advantages when it has to cope with a function with multiple parameters. This method uses a step-by-step approach to find optimal answers, so choosing a learning rate that is too high or too low will not lead to reaching the value that minimizes the error. Bias is a variable that controls how easily a neuron is activated. Epoch refers to the number of repetitions of learning. For example, when learning is performed with Epoch 100 with 1000 training data, 1000 x 100 times weight factors update is completed. Datasets to be used for ANN must match the range from 0.00 to 1.00 as required by the sigmoid function. Therefore, the range of the simulation result data from 0.00 to 1.00 was adjusted by dividing the simulation result data by the maximum value of each variable through normalization. Initial weight factors were arbitrarily specified. Figure 6-(b) is a graph comparing the 'correct answer' with the predicted value of the initial ANN model. The results showed that the CVRMSE of the cooling loads predicted by the ANN model was 7.34% compared to the “correct answer (measured data; however, simulated data in this example case),” which is within the acceptable tolerance range of 30% recommended in the ASHRAE Guideline 14.

**Figure 6: Structure of Initial ANN model and result comparison**

3.5. ANN model optimization

ANN model optimization refers to the process of finding an optimal learning rate, hidden nodes, hidden layers, and epochs to optimize prediction performance. There are no known steps to determine the values of a Hyper-parameter for any problem. Currently, the best approach is to check the results and adjust the learning rate, hidden nodes, hidden layers, and epoch values by the trial and error processes. It is repeated until the error rate comes into the acceptable uncertainty ranges proposed in the ASHRAE Guideline 14. Since the optimal parameter values vary depending on the type of data, optimization tasks can take a long time depending on the experience and expertise of the user. In this study, about ten times of optimization trials were conducted to achieve the goal of model optimization. Table 1 includes the Hyper-parameter values with the lowest CVRMSE and the possible input ranges. After the optimization process, the CVRMSE value decreased to about 6.8%. It can be confirmed that the error rate is lower than that of the earlier model although the simplified optimization is performed. The results indicate that the ANN model developed for loads prediction in the example case can be used for the optimal control of providing only necessary cooling energy to the spaces without compromising human comfort.
Table 1: Optimal ANN structure and parameter values

<table>
<thead>
<tr>
<th>Division</th>
<th>Range</th>
<th>Optimize values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Hidden Layers</td>
<td>1~n</td>
<td>2</td>
</tr>
<tr>
<td>Number of Hidden Neurons</td>
<td>1~n</td>
<td>10</td>
</tr>
<tr>
<td>Learning Rate</td>
<td>0.01~1.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Epochs</td>
<td>1~n</td>
<td>1,000</td>
</tr>
</tbody>
</table>

CONCLUSION

Many studies on AI-based building control methods have been conducted. However, most studies focused on identifying the results of applying ANN, not a detailed explanation of how they used and built the AI-based building control or optimization models.

This research focused on explaining the general procedure of developing the ANN-based load predicting models for the future use of optimal control of building energy systems to activate AI-based research. As part of AI technology, the ANN structure and learning methods were discussed along with the way on how to apply the ANN-based prediction model to building control field, including on how the ANN-based control models can be developed, applied and utilized in detail. To be specific, an ANN-based load prediction model was developed to predict the cooling loads in an example case of a large office building in Chicago. The results of the example study showed that the ANN technology has a large potential for energy savings as ANN models can be developed for the optimal control of building energy systems that require thermal loads to be able to provide the necessary energy to spaces.

Our following research will include the optimal control of building using the ANN-based load prediction model developed through this study. Detailed application methods and the possibility of ANN-based optimal control will be further discussed. Advanced studies will be conducted to compare and analyze the general control methods and ANN-based optimal control methods.

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REFERENCES


The official website of Python. Applications for Python.


Thermal preferences and cognitive performance estimation via user’s physiological responses

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1Lawrence Technological University, Southfield, Michigan

ABSTRACT: This study investigated the relationship between occupants' thermal sensation, physiological responses, and cognitive performance to quantify the priorities of the selected physiological responses for optimal productivity. In order to quantify variables for optimal productivity estimation, this study considered the following factors: 1. Local body skin temperature as an occupant's physiological responses; 2. Participants' individual factors such as gender; 3. Cognitive performance in operation span task; 4. Environmental data such as indoor temperature, wind velocity, CO2 level and indoor humidity; 5. Individual ratings of subjective thermal sensation. A series of human experiments were conducted to collect physiological responses and cognitive performance in a different room temperature conditions. The skin temperatures and environmental data were recorded in every minutes, and thermal sensation was surveyed by the Likert 7 point scale questionnaires. The operation span (OSPAN) task was used to measure working memory as a cognitive performance for occupant’s productivity. Total 39 participants’ data was collected for comparative analysis. The results revealed significant correlations between overall thermal sensation and local body skin temperatures. Also, the OSPAN score showed that it has a significant correlation with indoor temperature, thermal sensation as well as physiological responses. The OSPAN results were higher when indoor temperature was relatively low or when participant’s thermal perception was either slightly cool or cool. Most local body skin temperatures were negatively correlated with the cognitive test scores, therefore it was concluded that a little low temperature has a significant impact to promote occupant’s productivity. This study also determined the priority of local skin temperatures and gender by their impact to estimate the occupant's cognitive performance.

KEYWORDS: Thermal sensation, Physiological response, Skin temperature, Cognitive performance, Operation span

INTRODUCTION

In modern daily life, people spend 87% of their time indoors (Klepeis et al. 2001), thus the environmental quality have become an important aspect for occupant’s well-being and productivity. Most modern buildings depend on mechanical systems to provide comfortable thermal environment, based on the existing thermal comfort model, such as predictive mean vote (PMV) (ASHRAE 2013). However, these models rarely consider individual physical and psychological differences, such as gender, age, or personal preferences, which were studied and verified as significant factors for thermal comfort (J.-H. Choi and Loftness 2012). This caused various issues for the occupants in the built environment, such as occupant’s thermal dissatisfaction and low productivity.

Various engineers and scientists have tried to solve this issue from different perspectives. Some studies suggested micro-scale or personalized systems for thermal environment, focusing on individual control system (Goyal, Ingley, and Barooah 2013; Purdon et al. 2013), which showed higher occupant’s satisfaction as well as less energy consumption (Murakami et al. 2007; Veselý and Zeiler 2014). Some researchers have investigated the occupant’s physiological responses as a control factor and its relationship with indoor thermal environment (Ghahramani et al. 2016; Zhang et al. 2010b, 2010a), and the occupant’s thermal sensation...
prediction model was developed as a function of human physiological responses (J.-H. Choi and Yeom 2017a). Also, a heating or cooling control model was investigated based on the selected physiological signals (J.-H. Choi and Yeom 2017a, 2019).

Regarding occupant’s productivity, many researchers have proved that indoor thermal condition has a significant impact on the occupant’s productivity, varies by temperature (Lan, Lian, and Pan 2010; Lan, Wargocki, and Lian 2014), and others also showed the influence of indoor temperature on the occupant’s thermal sensation and productivity, such as motivation and work performance (Lan, Wargocki, and Lian 2011; Cui et al. 2013). However, these studies rarely investigated physiological responses, which has a great potential as a significant factor to predict optimum thermal sensation for the occupant’s productivity.

Therefore, the purpose of this study is to investigate the relationship between occupants’ thermal sensation, physiological responses, and cognitive performance, and to quantify the priorities of the selected physiological responses for optimal productivity in the office environment. This study, in order to quantify the physiological responses for optimal productivity estimation, considered the following factors: 1. Local body skin temperature as an occupant’s physiological responses; 2. Participants’ individual factors such as gender; 3. Cognitive performance in operation span task; 4. Environmental data such as indoor temperature, wind velocity, CO₂ level and indoor humidity; 5. Individual ratings of subjective thermal sensation.

1.0 METHODOLOGY

1.1 Experiment procedure
A series of human experiments were conducted to collect physiological responses and cognitive performance in a various room temperature conditions. The experiment was approved by the IRB (Institutional Review Board: Approval #01418) of the Lawrence Technological University (LTU), and the consent form was signed by each participant before the experiment.

The participants were mostly volunteered students and staffs at LTU, and the total number was 39 (Table 1). 80% of the participants were in their 20s (Avg.: 25.6; Min.: 15; Max.: 39; SD: 5.25), and the average BMI (Body Mass Index) was 25.29, which indicates that most participants are either slightly overweight or healthy condition. Each participant’s physical condition was initially checked by the survey, and no one reported any specific health conditions or sickness which could affect the experiment results. Each participant was requested to wear basic clothes which was Clo level 0.55 or 0.59 (long sleeve T-shirt or shirts: 0.25, long pants: 0.25, socks: 0.02, panties: 0.03, bra: 0.04). The participant’s basic information was also surveyed, such as age, height, and weight.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Temperature distribution by group (°C)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Upon arrival, the participant stayed in the waiting area for 20 minutes to stabilize their physiological conditions, where indoor temperature was controlled and maintained by central HVAC system at 22°C. The participant was asked to take the initial demographic survey and sign the consent form. The participant was randomly assigned to one of 6 experiment groups, which was 18°C, 20°C, 22°C, 24°C, 26°C, and 28°C, and independent heating and cooling system in the experiment room controlled the temperature during the experiment. Once the participant moved into the experiment room, the skin temperature sensors were attached to the participant. Total 7 local body areas were chosen from the 16 thermoregulation models.
which were chosen frequently (J.-H. Choi and Yeom 2017a; J. Choi et al. 1997; Yeom, Choi, and Zhu 2017). The local body areas used were forehead, neck, chest, arm, inner wrist, back wrist, and lower back. The Likert 7-point scale was used for thermal sensation survey (Table 2), which was based on ASHRAE PMV (ASHRAE 2013).

### Table 2: Thermal sensation questionnaire using the Likert 7-Point Scale

<table>
<thead>
<tr>
<th></th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>Cool</td>
<td>Slightly cool</td>
<td>Neutral</td>
<td>Slightly warm</td>
<td>Warm</td>
<td>Hot</td>
<td></td>
</tr>
</tbody>
</table>

Once the experiment started, the participant remained seated on a general office chair by the desk, where the laptop is located. The whole procedure took about 45 minutes, and the location and posture of the participant were maintained the same. After the initial thermal sensation survey, the participant took the operation span task (OSPA) to measure the working memory. In this task, the participant needs to read and verify the simple math problem (Yes or No) and read a word on the screen after the operation. After a random series of problems and words (maximum 6), the participant needs to recall and choose the words in correct order. Once the participant finished the OSPAN, thermal sensation survey was conducted again.

All indoor environment data and human physical data were recorded in every minute, and recorded data was analysed by various statistical methods, such as two-sample T-test, ANOVA, correlation analysis, stepwise regression, etc. Microsoft excel, Minitab, and data-mining software (WEKA) was mainly used as an analysis tool, and every analysis were conducted at 95% significance.

### 2.0 EXPERIMENT ROOM AND EQUIPMENT

The experiment was conducted in the experiment room at LTU, and the size of the room is 3m (W) x 5m (D) x 3m (H) (Fig. 1). An independent heating and cooling system with two separate nozzles was installed to control indoor temperature, and the air velocity in the room was maintained under 0.2 m/s, considering ASHRAE recommendation (ASHRAE 2013). Regular office desk and chair were located in the center of the room, and building’s central HVAC system was disconnected for the experiment. The indoor temperature of the room was monitored at four different locations for monitoring stable thermal condition, and the one on the desk was used for the analysis. During the experiments, the relative humidity was recorded around 30% and the air velocity was 0.1 ± 0.05 m/s at the level of the participant’s chest, which is appropriate, based on ASHRAE 55 standard (ASHRAE 2013).

![Figure 1: Experiment room floor plan and equipment location](image-url)
Lab quest Mini of Vernier Software & Technology was used as a data acquisition (DAQ) system to collect participant’s skin temperature as well as air velocity, which was installed in the laptop. HOBO sensors were also placed at the multiple spots of the room to record temperature and relative humidity (RH). Specifications of sensors and systems are shown in Table 3.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Model</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Air temperature</td>
<td>U12-012</td>
<td>Accuracy: ±0.35°C (from 0°C to 50°C), Resolution: 0.03°C,</td>
</tr>
<tr>
<td>Air velocity</td>
<td>Testo 405-V2</td>
<td>Accuracy: ±0.1m/s + 5%, Resolution: 0.01 m/s,</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>U12-012</td>
<td>Accuracy: ±2.5% from 10% to 90%, Resolution: 0.05%</td>
</tr>
<tr>
<td>Skin temperature</td>
<td>SBS-BTA</td>
<td>Accuracy: ±0.5°C, Resolution: 0.03°C</td>
</tr>
<tr>
<td>Data acquisition</td>
<td>Lab quest mini</td>
<td>Resolution: 13 bit, Sampling rate: 10kS/s</td>
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</table>

### 3.0 RESULTS

#### 3.1 Comparison of thermal environment and physiological responses

This study chose 7 local body skin temperatures as an occupant’s physiological responses. Every local body skin temperature showed significantly different results between each experiment group (Table 4). It is very clear that local body skin temperatures increased as indoor temperature increased, and the analysis of variance (ANOVA) proved that it is significantly different (p<0.001). Some local body spots, which is close to the core body (Chest, Back, Neck, Forehead), showed relatively higher average skin temperatures, and the arm and both wrist (Back and In) appeared lower. Among 7 local body spots, the forehead was the most stable skin temperature, and the wrist (Back) showed the largest temperature fluctuation. Table 5 shows that every local skin temperatures were positively correlated to the indoor temperature, and every results were statistically significant. The wrist (back) skin temperature had relatively stronger correlation than the others, and the back skin temperature showed the weakest correlation.

<p>| Table 4: Analysis of local body skin temperatures at each experiment group |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Forehead Mean</th>
<th>Arm Mean</th>
<th>Wrist (Back) Mean</th>
<th>Wrist (In) Mean</th>
<th>Chest Mean</th>
<th>Back Mean</th>
<th>Neck Mean</th>
</tr>
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<tr>
<td>18</td>
<td>33.0</td>
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<td>0.99</td>
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<td>2.25</td>
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<td>P&lt;0.001*</td>
<td>P&lt;0.001*</td>
<td>P&lt;0.001*</td>
<td>P&lt;0.001*</td>
<td>P&lt;0.001*</td>
</tr>
</tbody>
</table>

| Table 5: Correlation analysis between indoor temperature and local skin temperatures |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Forehead                    | Spearman R 0.496 | Arm 0.457 | Wrist (Back) 0.529 | Wrist (In) 0.459 | Chest 0.461 | Back 0.138 | Neck 0.381 |
| P-value                     | P<0.001*       | P<0.001*     | P<0.001*         | P<0.001*        | P<0.001*    | P<0.001*    | 0.001*        |

To analyze the relationship between occupant’s subjective and physiological responses, the average local body skin temperatures were analyzed at each OTS level (Table 6). No participants marked at OTS level -3 (Cold) or 3 (Hot). It is clear that local body skin temperatures increases generally when OTS increases, and every local skin temperatures...
were correlated significantly with OTS (p<0.001). The average local skin temperatures were ranged from 28.9°C to 35.2°C. The back skin temperature showed the smallest temperature variation, while the wrist (back) had the largest fluctuation. Also, the forehead, both wrist (Back & In), and the chest showed relatively constant temperature increase between each OTS level. Thus, it is safe to say that the wrist (back) has a potential as a significant factor to estimate the occupant’s optimal OTS.

Table 6: Analysis of local body skin temperature at OTS level

<table>
<thead>
<tr>
<th>OTS</th>
<th>Forehead Mean</th>
<th>Forehead SD</th>
<th>Arm Mean</th>
<th>Arm SD</th>
<th>Wrist (Back) Mean</th>
<th>Wrist (Back) SD</th>
<th>Wrist (In) Mean</th>
<th>Wrist (In) SD</th>
<th>Chest Mean</th>
<th>Chest SD</th>
<th>Back Mean</th>
<th>Back SD</th>
<th>Neck Mean</th>
<th>Neck SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>33.1</td>
<td>1.21</td>
<td>33.0</td>
<td>0.77</td>
<td>28.9</td>
<td>0.83</td>
<td>31.8</td>
<td>0.73</td>
<td>33.7</td>
<td>1.77</td>
<td>34.1</td>
<td>0.70</td>
<td>34.7</td>
<td>0.77</td>
</tr>
<tr>
<td>-1</td>
<td>33.1</td>
<td>1.84</td>
<td>31.4</td>
<td>3.53</td>
<td>29.4</td>
<td>2.57</td>
<td>31.7</td>
<td>1.66</td>
<td>33.2</td>
<td>2.07</td>
<td>33.7</td>
<td>1.82</td>
<td>32.6</td>
<td>2.19</td>
</tr>
<tr>
<td>0</td>
<td>34.0</td>
<td>1.36</td>
<td>32.7</td>
<td>1.93</td>
<td>31.1</td>
<td>2.45</td>
<td>32.3</td>
<td>2.15</td>
<td>34.2</td>
<td>1.69</td>
<td>33.6</td>
<td>2.31</td>
<td>33.7</td>
<td>1.89</td>
</tr>
<tr>
<td>1</td>
<td>34.7</td>
<td>1.07</td>
<td>33.8</td>
<td>1.35</td>
<td>32.3</td>
<td>1.68</td>
<td>33.7</td>
<td>1.26</td>
<td>34.6</td>
<td>1.48</td>
<td>34.4</td>
<td>1.63</td>
<td>34.5</td>
<td>1.38</td>
</tr>
<tr>
<td>2</td>
<td>34.9</td>
<td>0.74</td>
<td>33.7</td>
<td>0.77</td>
<td>32</td>
<td>0.98</td>
<td>33.1</td>
<td>0.74</td>
<td>35.2</td>
<td>0.61</td>
<td>33.9</td>
<td>1.39</td>
<td>33.4</td>
<td>1.15</td>
</tr>
</tbody>
</table>

ANOVA P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001* P<0.001*

4.0 COMPARISON OF COGNITIVE PERFORMANCE AND PHYSIOLOGICAL RESPONSES

To measure the occupant’s productivity, this study adapted the operation span (OSPA) tasks. It is generally used to predict cognitive performance, and have been known for its reliability and validity (Unsworth, Heitz, and Engle 2005). The OSPAN score is the sum of the sequence lengths that the participant recalled correctly, thus the higher number means the participant recalled it more in correct order. Total 18 operations were conducted in this study, and the average OSPAN score was 41.76 out of 60 (SD: 9.95).

Fig. 2 illustrates the interval plot of OSPAN score at each experiment group. It is clear that low temperature groups (18, 20, 22) shows higher score than high temperature groups (24, 26, 28). Experiment group 18 showed the highest score, and group 24 appeared as the lowest. The OSPAN score and experiment group was negatively correlated with a significant p-value (Person R: -0.171, p<0.001), and the analysis of variance (ANOVA) also verified its statistical significance between each group (p<0.001).

To analyze the relationship between OSPAN score and local skin temperature, the OSPAN score was split into two category, high and low functional group, based on the mean OSPAN score (41.76), which was used frequently (Zakrzewska and Brzezi cka 2014; Delaney and Sahakyan 2007). High and low functional group showed significant difference of the average skin temperature at every spot (Table 7). The skin temperature of the arm, back, and both wrist (Back & In) were lower in high functional group than the one in low functional group, while the forehead, chest and neck showed the opposite results. The chest skin temperature showed the largest gap between high and low functional group, and the wrist (In) skin temperature revealed the least difference.

The result of the correlation analysis between OSPAN score of each functional group and local skin temperatures are shown in Table 8. The forehead was the only local skin temperature which showed negative correlation in both high and low functional group with a significant p-value, and the arm and neck skin temperature appeared positive in high functional group and negative in low functional group with significant p-value. The others appeared differently by functional group.
4.0 DISCUSSION

5.1 Comparative analysis by gender
Various studies have revealed a significant impact of gender difference on thermal perception. This study also verified that there are clear difference in thermal perception and local skin temperature variations between male and female, which also resulted in different productivity.

In Table 9, the arm and both wrist showed higher skin temperature in male group, while female group showed higher local body skin temperature at the chest, back and neck. A similar study also showed same results in the female group, but there was a difference in the male group, where the arm didn’t show any significant difference by gender group (J.-H. Choi and Yeom 2017b). The reason could be the different experiment setting or sample size of the participants, which requires further investigation for both studies.
It is also interesting to see that the forehead, arm, and both wrist in male group showed higher skin temperature than female group for both high and low functional group with a significant p-value, and the skin temperature of female group was higher at the chest, back and neck significantly, except the back in low functional group (Table 10). Thus, it is clear that gender has a significant influence on thermal perception and physiological responses, which is also correlated with the occupant’s productivity.

Table 9: Two sample T-test of local body skin temperature by gender group

<table>
<thead>
<tr>
<th>Gender</th>
<th>Forehead Mean</th>
<th>Arm Mean</th>
<th>Wrist (Back) Mean</th>
<th>Wrist (In) Mean</th>
<th>Chest Mean</th>
<th>Back Mean</th>
<th>Neck Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>34.0</td>
<td>1.63</td>
<td>33.5</td>
<td>1.60</td>
<td>31.8</td>
<td>1.91</td>
<td>33.2</td>
</tr>
<tr>
<td>Female</td>
<td>34.0</td>
<td>1.54</td>
<td>31.9</td>
<td>2.62</td>
<td>29.5</td>
<td>2.59</td>
<td>31.8</td>
</tr>
<tr>
<td>T-test</td>
<td>0.234</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>P&lt;0.001*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Two sample T-test of local skin temperatures in high/low functional group by gender

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender</th>
<th>Forehead Mean</th>
<th>Arm Mean</th>
<th>Wrist (Back) Mean</th>
<th>Wrist (In) Mean</th>
<th>Chest Mean</th>
<th>Back Mean</th>
<th>Neck Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Func.</td>
<td>Male</td>
<td>34.3</td>
<td>1.36</td>
<td>33.7</td>
<td>2.13</td>
<td>32.2</td>
<td>1.94</td>
<td>33.5</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>34.1</td>
<td>1.53</td>
<td>31.5</td>
<td>2.83</td>
<td>29.2</td>
<td>2.93</td>
<td>31.7</td>
</tr>
<tr>
<td>T-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>P&lt;0.001*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Low Func. | Male | 33.7 | 1.80 | 33.2 | 0.71 | 32.9 | 1.12 | 31.5 | 1.84 | 33.5 | 1.48 | 34.2 | 1.30 | 33.1 | 2.77 |
|           | Female | 33.9 | 1.57 | 33.0 | 1.54 | 32.2 | 0.98 | 30.2 | 0.92 | 32.7 | 1.24 | 34.3 | 1.08 | 34.3 | 1.59 |
| T-test  | 0.010* | | | | | | | | | | | | | | |
| P-value | P<0.005* | | | | | | | | | | | | | | |

5.2 Estimation of the occupant’s optimal productivity

This study verified some relationship between occupant’s thermal perception, physiological responses, and productivity. In this chapter, human physiological responses and gender were analysed and prioritized to estimate the occupant’s productivity.

Table 11 shows the summarized results of the stepwise regression analysis of the participants and gender group on the functional group estimation. In general, the chest and back showed relatively higher impact than the others on the functional group estimation, and the combination of all valid variables reached 30.11% of accuracy. It is also interesting that there is clear difference in accuracy and most significant variables between male and female group. Female group showed significantly higher accountability than that of the male group, with a single variable or the combination of all variables. Therefore, gender should be included in the predictive model, and the chest, wrist (Back), back and arm showed relatively high influence on functional group estimation.

In the stepwise analysis, overall accuracy was 30 ~ 65%, which is relatively low. The functional group data is discrete number, while the skin temperatures are continuous, and this can be the reason of low accountability which was also mentioned in the similar study (J.-H. Choi and Yeom 2019). To address this issue, this study used J48 algorithm to develop a classification model which treats functional group as a nominal data. The accuracy was calculated by 10-fold cross validation, and Table 12 shows the results.

The arm, wrist (Back) and chest showed valid accuracy higher than 80%, and gender appeared significantly lower than local body skin temperatures. The combination of all variables can achieve 99% accuracy, however this study suggested the combination of gender and the skin temperature of the arm and wrist (back), which achieved 98.80 % of accuracy, considering practical application. It is also interesting to compare that the priority of the attributes are...
different from the similar study (J.-H. Choi and Yeom 2017b), where they developed the estimation model for the overall thermal sensation. This reveals the possibility that different sets of physiological attributes are required to estimate occupant’s thermal sensation and productivity, which need to be investigated further.

**Table 11:** Stepwise analysis results (Cumulative R-sq) for high and low functional group estimation (%)

<table>
<thead>
<tr>
<th>Step</th>
<th>All participants</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chest 19.03</td>
<td>Back 9.79</td>
<td>Chest 49.71</td>
</tr>
<tr>
<td>2</td>
<td>Back 26.35</td>
<td>Forehead 27.61</td>
<td>Wrist (Back) 58.79</td>
</tr>
<tr>
<td>3</td>
<td>Wrist (Back) 29.35</td>
<td>Arm 33.22</td>
<td>Arm 64.12</td>
</tr>
<tr>
<td>4</td>
<td>Arm 29.86</td>
<td>Neck 34.53</td>
<td>Wrist (In) 65.02</td>
</tr>
<tr>
<td>5</td>
<td>Forehead 30.02</td>
<td>Wrist (Back) 37.84</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Neck 30.11</td>
<td>Wrist (In) 38.77</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Chest 39.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 12:** 10-cross validation results of high and low functional group estimation

<table>
<thead>
<tr>
<th>#</th>
<th>Attribute</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arm</td>
<td>87.03</td>
</tr>
<tr>
<td>2</td>
<td>Wrist (Back)</td>
<td>83.38</td>
</tr>
<tr>
<td>3</td>
<td>Chest</td>
<td>83.34</td>
</tr>
<tr>
<td>4</td>
<td>Forehead</td>
<td>79.38</td>
</tr>
<tr>
<td>5</td>
<td>Neck</td>
<td>76.21</td>
</tr>
<tr>
<td>6</td>
<td>Back</td>
<td>73.74</td>
</tr>
<tr>
<td>7</td>
<td>Wrist (Front)</td>
<td>70.88</td>
</tr>
<tr>
<td>8</td>
<td>Gender</td>
<td>60.84</td>
</tr>
<tr>
<td>8+1</td>
<td>Gender + Arm</td>
<td>91.84</td>
</tr>
<tr>
<td>8+1+2</td>
<td>Gender + Arm + Wrist (Back)</td>
<td>98.80</td>
</tr>
<tr>
<td>1-8</td>
<td>Gender + 7 local body skin temperatures</td>
<td>99.76</td>
</tr>
</tbody>
</table>

**CONCLUSION**

This study investigated the relationship between occupants’ thermal sensation, physiological responses, and cognitive performance to quantify the priorities of the selected physiological responses for the occupant’s optimal productivity, through the series of human experiments including 39 participants.

In this study, it was revealed that there is a significant correlation between overall thermal sensation, local body skin temperatures, and cognitive test scores. The cognitive test results (OSPAN) was higher when indoor temperature was relatively low or when participant’s thermal perception was either slightly cool or cool. Most local body skin temperatures were negatively correlated with the cognitive test scores, therefore it is safe to conclude that a little low temperature has a significant impact to promote occupant’s productivity. Additionally, this study also determined the priority and optimum combination of local skin temperatures and gender for cognitive performance estimation. Considering practical application, gender, arm, and wrist (Back) were determined as an optimal combination for cognitive performance estimation, with 98.80% accuracy.

The result of this study can be applied to the HVAC system as a control algorithm. The results can contribute to develop personalized control system, with the help of related technologies, such as smart watch, thermographic camera, and smart fiber. However, even though the results showed significance statistically, this study was based on the participants’ data who are mostly in their 20s (Avg. 25.6), which means in their prime physical condition. Thus, larger number of participants are still required to investigate other variables, such as age, BMI, ethnicity, etc. Broader temperature range should be considered in the future study as well as subjective factors, such as thermal preference. Lastly, various types of cognitive performance test should be included to increase the validity and accuracy of the analysis results.
ACKNOWLEDGEMENTS
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REFERENCES


Murakami, Yoshifumi, Masaaki Terano, Kana Mizutani, Masayuki Harada, and Satoru Kuno. 2007. “Field Experiments on Energy Consumption and Thermal Comfort in the Office Environment Controlled by Occupants’ Requirements from PC Terminal.” Building and


ABSTRACT: Reliable quantification of energy consumption by buildings plays a key role in development of sustainable cities. However, there are methodological uncertainties embedded in the most common urban scale energy use modeling methods and tools which affect the reliability of these tools and their applicability for decision-making purposes. This article presents a novel bottom-up data-driven framework for urban energy use modeling (UEUM) to help predict energy use more precisely through utilizing disaggregated data at building level, incorporating the actual urban spatial patterns, and testing different algorithms to propose an enhanced prediction model. This framework integrates the influential factors in the model including building characteristics; i.e., height, as an urban intensity metric, urban attributes; i.e., sprawl indices, that are captured in a multidimensional way representing compactness and connectivity of neighborhoods, and occupant characteristics. A case study on 800,000 buildings in seventy-seven neighborhoods in Chicago was used to test the framework. This framework has the potential to help better understand the existing urban energy use profiles and provides a more holistic image of urban energy use at multi-scales of building, block, neighborhood, and urban levels.

KEYWORDS: Urban energy modeling; data-driven model; building operational energy use

INTRODUCTION

Buildings are the most significant contributors to urban energy use and associated emissions. In the United States, buildings operation accounts for 41% of primary energy use, and 38% of GHG emissions (EIA 2012). Achieving energy and emission reduction goals requires understanding the existing profiles of building energy use at urban scale. While urban energy use modeling and prediction are essential in urban energy management and understanding of energy performance of cities, there are a limited number of methods and tools to accurately model urban energy use in cities (Sola et al. 2018). Also, there is a lack of an integrated approach to incorporate actual urban spatial patterns with urban energy use models. The extant literature on energy performance of urban spatial patterns tends to examine energy use either at the scales of individual buildings or collection of buildings of limited typologies (Ruby and 2014, n.d.; Resch et al. 2016) that do not incorporate actual urban context effects; and at city-scale level studies (Howard et al. 2012) rely on aggregated data that do not allow energy characterization at individual building level.

The main approaches for urban building energy use modeling are classified into two main groups: top-down and bottom-up, according to their specific input, output and applied method (Swan and Ugursal 2009; Reinhart and Cerezo Davila 2016). The Top-down approach relies on aggregate energy data and does not consider disaggregated and individual characteristics of building system. Hence this model is less reliable for building level energy analysis. The bottom-up approach, identified as the dominant model, is founded upon two methos of engineering or simulation and data-driven or statistical techniques. Either simulation or data-driven techniques have their own limitations about urban energy quantification. The simulation methods often suffer from oversimplification of building and system data for the city-scale energy use estimations. They rely on a limited number of typologies or archetypes that represent buildings in a city to achieve time and computational efficiency. The interaction between the individual buildings and the city has been shown to impact the accuracy of operational energy use estimations at both building and urban scales (Zhou, Huang, and Cadenasso 2011; Reid Ewing 2010); however, it is often times overlooked. The estimation
methods are also founded upon arguable assumptions, particularly in denser and taller urban areas where urban microclimate has a noticeable impact on the building operational energy consumption (Martin et al. 2017). So the methodological uncertainties embedded in simulation methods affect the reliability of results and their applicability for decision-making purposes.

The data-driven models could present more accurate urban energy modeling if data be available and if sufficient variables are captured in the model (C. Kontokosta, Bonczak, and Duer-balkind 2016). Hence, their accuracy and reliability of results in these studies, however, depend on availability and quality of large sets of data and representative variables (C. Kontokosta, Bonczak, and Duer-balkind 2016; Hsu 2015). However, the previous data-driven studies rely on the generalized empirical data provided by building energy surveys; yet, limited number of surveys provide local energy data at building level. Previous studies (e.g. Howard et al. 2012), when conducted at city scale or a zip code level, use aggregated data and do not allow for energy characterizations at an individual building-level. Recently, as a part of disclosure law which adopted by many cities in the US, energy benchmarking was released. Energy benchmarking provides more transparency and provides disaggregated building-level energy data. However, it has limitations regarding availability for all buildings in the city. In case of Chicago, it covers less than 1% of Chicago’s buildings, which account for approximately 20% of total energy used by all buildings (“Chicago Energy Benchmarking, 2016, City of Chicago, Data Portal,” n.d.). In addition, previous data-driven urban energy models apply mostly traditional statistical techniques such as Multi Linear Regression (MLR) for urban energy prediction and explaining the association between influential factors such as urban spatial patterns and building characteristics and energy use because of its simple design and interpretability [12,78–80]. However, MLR method does not allow capturing non-linear and complex patterns.

The article presents an urban energy use modeling (UEUM) framework which employs a bottom-up data-driven approach through using disaggregated data, incorporating the localized variables in the model and applying Machine Learning (ML) based algorithms. Machine learning based algorithms allow capturing non-linear and complex features and provide higher precision level [70–72]. This model helps predict urban energy use more precisely and comprehensively through utilizing disaggregated data at building level, incorporating the localized variables in the model, and testing different machine learning techniques and algorithms. This model proposes an enhanced prediction model and provides a multi-scale analysis and visualization at neighborhood, census tract, census block, and building levels. This research also has the potential to provide insights on urban energy use dynamics across morphological patterns and helps planners and policy-makers develop more energy efficient cities. Chicago has been selected as a pilot case study to test the applicability of this framework for urban energy use modeling.

1.0. METHODOLOGY
This research develops a data-driven framework for urban energy use modeling. The conceptual framework of this research is presented in Figure 1. The framework is built upon a three-step model concept. First, the Pattern Extraction phase which studies urban spatial patterns to extract new features and incorporates localized variables in the model, and second, Prediction phase is applied to estimate urban energy use through learning the mathematical relationship between variables and tests different machine learning techniques and algorithms to propose an enhanced prediction model, and finally, the third step provides a multi-scale analysis at neighborhood, census tract, census block, and building levels. In this research, the urban energy use is outlined as building operational energy use intensity (EUI) at a city scale. The Site EUI (kBtu/sq ft) per year was used as the dependent variable. The model was run based on Log Site EUI (kBtu/sq ft) per year to properly fit the nonlinear relationships between variables. The influential factors which affect the urban building energy consumption were identified as three main groups including Building Characteristics (variables such as building type, building height, building size, and construction year), Urban Attributes (functioning as density, accessibility, connectivity and land-use mixed which are captured via
urban sprawl index), and Occupancy Characteristics (including total population, household size in residential buildings, worker density in commercial buildings, and percentage of occupied units).

Table 1. Key variables incorporated in the model.

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>Building Height</td>
<td>Number of floors</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Building Size</td>
<td>Square meter</td>
</tr>
<tr>
<td></td>
<td>Building Type</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Built Year</td>
<td>-</td>
</tr>
<tr>
<td>Independent</td>
<td>Total number of occupants</td>
<td>-</td>
</tr>
<tr>
<td>Occupant</td>
<td>Household size</td>
<td>-</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Worker density</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weekly working hours</td>
<td>hour</td>
</tr>
<tr>
<td></td>
<td>Percentage of occupied units</td>
<td>-</td>
</tr>
<tr>
<td>Urban Attributes</td>
<td>Sprawl Index (density, accessibility,</td>
<td>Unitless</td>
</tr>
<tr>
<td></td>
<td>connectivity and land-use mixed)</td>
<td></td>
</tr>
</tbody>
</table>

Conceptual Framework

1. Density
2. Accessibility
3. Land use mix
4. Activity Centering

INTEGRATED URBAN BUILDING ENERGY USE MODELING

Figure 1: The UEUM conceptual framework. Source: (Authors 2019)

To test the framework, a case study on 800,000 buildings in seventy-seven neighborhoods in Chicago was selected. The merged urban spatial and energy dataset was built upon utilizing several datasets including GIS data representing the explicit geographical location and building characteristics such as Chicago building footprints (CBF) dataset (City of Chicago n.d.); the sprawl index representing the connectivity, compactness, land use and accessibility features of neighborhood as an indicator of urban attributes in this research was built upon the U.S. Urban Sprawl Data (National Cancer Institute n.d.) developed by Ewing (Reid Ewing and Hamidi 2014; R Ewing et al., n.d.); the building operational energy dataset was built through coupling of two unique datasets including Chicago Energy Benchmarking (2016) (City of Chicago n.d.) and Chicago Energy Usage (2010) (City of Chicago n.d.) datasets. The Chicago
Energy Benchmarking dataset provides disaggregated data at building level for buildings greater than 50,000 sq.ft. While Chicago Energy Usage (2010) dataset provides energy data for buildings of all sizes with block-level geographical identification.

The UEUM workflow, as illustrated in Figure 2, proceeds as follows:

- **Data Preparation** including three steps: locate data, treat missing data, and process and clean data. After locating data as discussed, to maximize use of available information in the CBF dataset, several statistical methods including multiple imputations (Rubin 1996) was done to handle missing data; e.g. building height information by applying the valid frequency inference. The outliers as extreme observations in the building energy datasets were identified through statistical tests (Kutner, Nachtsheim, and Neter 2004) and their influential impacts on individual regression parameters were assessed through the Cook’s Distance test (Cook 1977). Finally, extreme outliers with significant influence were dropped out of the datasets. To test the model regarding normal distribution, Quantile–normal (q-norm) plot which is considered as a common normality test (Miller 1997 Of and Statistics, n.d.), p-norm and Kornel Density plots were applied.

- **Pattern Extraction** is applied through using the most promising Machine Learning clustering algorithm, k-means, (Ahmad et al. 2018; Jovanović, Sretenović, and Živković 2015; Amasyali and El-Gohary 2018a) to extract the actual archetypes/typologies of buildings with certain similarities together and learn underlying patterns. The K-means algorithm generates K clusters by dividing M points into N dimensions to minimize the sum of squares of errors within clusters (Hartigan and Wong 1979). Then localized variables such as building height typologies were added to the model. Incorporating the actual urban spatial patterns, building characteristics and urban context improve the accuracy of the city scale energy use prediction significantly.

- **Prediction** compasses the train model, validate, compare and predict energy consumption for all buildings in the city where the energy use data is not available based on the enhanced model. The energy use prediction as a regression problem approximates a mapping function from input variables; e.g. building characteristics, urban attributes, and occupant characteristics and building operational energy consumption as the output variable. Six machine learning models were trained including Multiple linear regression (MLR), Nonlinear Regression (NLR), Random Decision Forest (RDF), Classification and Regression Trees (C&RT), K-Nearest Neighbors (K-NN), and Artificial Neural Networks (ANNs), which are among promising data-driven techniques (Ahmad et al. 2018; Jovanović, Sretenović, and Živković 2015; Amasyali and El-Gohary 2018a) on the merged dataset.

- **Validation** process was done to achieve solid results. The cross-validation method as a most effective validation technique (Torabi Moghadam et al. 2018; Amasyali and El-Gohary 2018b) based on Random Sub-sampling was applied to avoid biased results. Data was split to train and test of 80% / 20%. Then the models were compared regarding their prediction performance based on the most widely used evaluation metrics including the Mean Absolute Deviation (MAD), Mean Square error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE). These performance metrics are computed by measuring the errors between the predicted and actual values that means the lower the values of MAD, MSE, RMSE, and MAPE show the better performance of the model. As the final step, the results are compared and an enhanced prediction model was proposed and validated against aggregated city-level data.

- **Visualization** was done through developing of a GIS web-based platform which allows communication and visualization of the urban energy use predictions at multi-scales including building, block, neighborhood, and city levels.
2.0. RESULTS

The Figure 3. presents the performance evaluation of the prediction models applied in this research including the Multiple linear regression (MLR), Nonlinear Regression (NLR), Random Decision Forest (RDF), Classification and Regression Trees (C&RT), K-Nearest Neighbors (K-NN), and Artificial Neural Networks (ANNs) algorithms. The most common predictive model evaluation metrics: Mean Absolute Error (MAE), Mean Square error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) were employed to assess and compare the performance of the models. These metrics are calculated based on measuring the errors between the predicted and actual values. Therefore, the lower the values of MAE, MSE, RMSE, and MAPE show the better performance of the model. The results suggest that among the six algorithms modeled in this research, K-NN provides the best predictive performance with MAE of 0.08; while MLR provides the weakest predictive model with MAE of 0.22. The results show that the K-NN model performs best. The other algorithms provide results better than MLR but no significant differences observed between RDF, ANNs, C&RT models and MLR model. The result suggests that MLR model enables the energy use prediction fairly well with no significant difference, compared to RDF, ANNs, C&RT which are computationally expensive and time-consuming models for energy use prediction at city level.

R2, the coefficient of determination, is a measurement metric of how well the regression model describes the observations and shows the percentage of variations that are explained by independent variables (Ohtani 2000). In the MLR model, the R2 value of 0.28, indicates that the model explains 28% of the variance in building operational EUI for buildings in Chicago. MLR as a common method for energy use prediction which has been employed widely in the previous studies (C. E. Kontokosta 2015), shows a R2 value of 0.28, indicating that the model explains 28% of the variation in energy use of the buildings in the model. R2 for other models (NLR, RDF, C&RT, K-NN, and ANNs) was calculated based on actual vs. predicted energy use values, shown in Figure 3. While among these models, K-NN significantly provides an improved prediction model with R2 of 0.75 that shows K-NN is able to explain 75% of the variation of energy use of the buildings in the model. It should be noted that the R2 is used to explain the linear association between variables and it fails to capture such association in nonlinear models. Here R2 is used only for comparison purposes between the linear and nonlinear models which we used the developed equation from the nonlinear models through predicting energy use values and plot them against the actual values on y-axises and then estimated the R2 values for each model. Then the improved model was applied to predict...
energy use for around 820,000 buildings in the city. The model evaluates the energy performance of the city in a multi-scale resolution analysis which maximizes the use cases and allows for a more comprehensive energy decision-making and policy (Figure 4).

3.0. DISCUSSION
The results of this research suggest that the urban energy prediction accuracy can be increased significantly by using disaggregated data at building level and incorporating the actual urban spatial patterns. Also, the more advanced machine learning methods enable an improved prediction model. The findings of this study also provide empirical evidence on how spatial characteristics of neighborhoods impact the urban energy performance. The results of this study on the combined urban energy and spatial pattern dataset across neighborhoods in Chicago show the impact of the three major energy use determinants incorporated in the model including building characteristics (building height, type, size, and age); urban attributes representing sprawl dimensions; and occupant characteristics (total occupants, household size, worker density, weekly working hours, and percentage of occupied units) were found to be statistically significant at 95% confidence level, as measured by p-value of below 0.05. However, there are other energy use determinants such as socioeconomic and behavioral factors and other important building factors such as renovation year and building systems have been excluded from this research because of lack of data availability. This highlights a limitation in this research. Considering other influencing factors could contribute to more comprehensive low carbon urban policies and could be explored by future research.

CONCLUSION
The UEUM framework developed by this research is able to predict energy use at multiple scales of building, block, neighborhood, and city scales. This model captures the urban building operational energy use. The results of this research suggest that urban energy prediction accuracy can be increased by using disaggregated data at building level and incorporating the actual urban spatial patterns. Also, the more advanced machine learning methods enable an improved prediction model. Among the six promising machine learning algorithms tested in this research, K-NN showed the best predictive performance. The finding of this study also provides empirical evidence on how spatial characteristics of neighborhoods impact the urban energy performance. As this research continues, in another article we intend to examine the association between variables in the model in detail. This framework has the potential to provide a more accurate and holistic image of urban energy use and the impact of different design decisions on energy consumption and to help designers, planners, and policymakers better understand the existing urban energy use profiles and project the environmental impacts associated with alternative scenarios of urban development.
<table>
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<th>MAE</th>
<th>MSE</th>
<th>RMSE</th>
<th>MAPE</th>
<th>R²</th>
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<td>0.18</td>
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<tr>
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<tr>
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<td>0.15</td>
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<tr>
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<td>0.210</td>
<td>0.075</td>
<td>0.14</td>
<td>0.053</td>
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</tr>
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</table>

The machine learning models:
- Multiple Linear Regression (MLR)
- Nonlinear Regression
- Random Decision Forest (RDF)
- Classification and Regression Trees (C&RT)
- K-Nearest Neighbors (K-NN)
- Artificial Neural Networks (ANNs)

The most widely used predictive model evaluation metrics:
- Mean absolute Error (MAE)
- Mean Square error (MSE)
- Root Mean Square Error (RMSE)
- Mean Absolute Percentage Error (MAPE)

The coefficient of determination:
- R-squared (R²)

**Figure 3:** The performance evaluation of the prediction models. Source: (Authors 2019)

- Building Level
- Census Block Level
- Neighborhood Level
- Urban Level

**Figure 4:** Multi-Scale Building Energy Use Modeling and Analysis. Source: (Authors 2019)
REFERENCES


Environmental and economic implications of building envelope design

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ABSTRACT: There is a wealth literature on operational energy consumption of buildings and how building skins contribute to that. Little is known about the life-cycle environmental impacts of building skins and it is not clear if the operational energy savings that are achieved by improvement strategies in building skin (such as more insulation, external shading devices, PV systems) would indeed result in lower environmental impacts from a life-cycle perspective. Even less clear is how economic and life-cycle environmental impacts of buildings would vary by the changes in architectural design parameters. In the present study, we quantify the variations in operational energy, environmental impacts and costs as a result of change in building skin design and construction parameters. We will examine building envelopes in low-rise office buildings from economic and environmental perspectives. For this purpose, 91 different design combinations of a building envelope are considered with different thermal resistance values of wall, wall-to-window ratios, window types, and frame materials. We then use Environmental Life Cycle Assessment (LCA) to study the variations of design combination with respect to global warming, acidification, eutrophication, and smog formation. Simultaneously, Life-Cycle Cost Analysis (LCCA) is applied to examine the cost changes in design combinations. Then, regression analysis is conducted to find the association between design combinations and changes in environmental impacts and cost fluctuations.

KEYWORDS: life-cycle assessment (LCA), life-cycle cost analysis (LCCA), building envelope

INTRODUCTION

Buildings are constructed with construction materials that entail high levels of embodied energy consumption over their life-cycle. Indeed, construction materials are responsible for about 6% of total primary energy consumed in the U.S. Since 1979, a focus of architectural practice and scholarship has been to find ways to reduce operational energy use of buildings which is the largest contributor to primary energy consumption. With the increased energy-efficiency of buildings, embodied energy is now regaining interest, especially that the improvement of design and construction for operational energy efficiency often leads to increased embodied energy. As an example, multiple-glazed windows have higher thermal resistance and therefore are more efficient in blockage of heat transfer and savings of operational energy, as compared with single-glazed windows, but higher amount of energy is used in manufacturing process of multiple glass panes. Limited number of studies explore the tradeoffs and synergies between building skin design, operational energy, embodied energy and other impacts on the environment.

1.0. LITERATURE REVIEW

Environmental Life Cycle Assessment (LCA) is the main methodology used for estimation of embodied energy and environmental impacts of products, processes, and buildings. The LCA methodology consists of four major phases of goal and scope definition, inventory modeling, impact assessment and interpretation of results. Process-based LCA, Economic Input-Output (EIO) LCA, and their hybrid LCA variants are major LCA techniques. In environmental process-based LCA, the environmental inputs (materials, energy) and outputs (waste, emissions) associated with each phase in a given product’s life-cycle are identified, quantified and aggregated for the entire life cycle of the building (Heijungs & Suh 2002). The inputs and outputs are then converted into various categories of environmental impacts such as global
warming, eutrophication, and acidification (Heijungs & Suh 2002). The EIO LCA method applies the US economy models and associates the monetary value of products to their environmental impacts (Hendrickson et al 2005). The hybrid methods take advantage of the methodological and data availability opportunities presented by each of the previous methods. Finally, a less known LCA method is ecologically-based LCA (Zhang 2010) that is based on an integrated ecological-economic model of the US economy and considers the role of ecosystem services (biogeochemical cycles, disease regulations, etc.) too. Most LCA studies in the field of built environment tend to rely on process-based LCA.

The environmental impacts of building envelopes have been studied by several studies in the past. Kim (2011) conducted an LCA study on a transparent composite façade system (TCFS) and compared its environmental impacts with those of a glass curtain wall system. The research suggested that TCFS has a superior performance with regard to life cycle energy use and CO2 emissions (Kim 2011). Otteléa et al (2011) used LCA to compare the environmental impacts of non-vegetated brick walls, vegetated brick walls, and living wall systems in Netherlands. They showed that the living wall systems offered relatively lower environmental impacts, as compared with other systems. Stazi et al (2012) used an integrated energy-LCA analysis on a solar/Trombe wall and optimized energy and environmental life-cycle performance by considering parametric variations of wall materials, thickness, frame material, and glazing type. They concluded that the variation with concrete as wall material and aluminum as frame materials entails high environmental burdens.

2.0. METHODS

We used environmental life-cycle assessment (LCA) methodology to assess the life-cycle impacts on the environment. The functional unit for the LCA study was defined to be a building envelope of 1632 square foot (151.6 square meter) covering equal south and north façade areas of a low-rise office building. The system boundary for the LCA study includes the entire life-cycle of the building envelope from raw material extraction to manufacturing, construction, occupancy, and recovery/demolition.

We considered 91 design alternatives to a reference case based on variations in six design parameters. The design parameters of interest include insulation material type (Fiberglass batt, Fiberglass batt + expanded polyurethane), wall’s R-value (ranging from 11-21), window frame material type (fiberglass, wood vinyl, aluminum), glazing type (double-glazed, triple-glazed), and window-to-wall ratio (10-60%) on north and south facades. The operational energy consumption of each design alternative was estimated using eQuest 3.65 as energy simulation software and based on ASHRAE 90.1 assumptions to meet the energy code requirements. The operational energy performance results were then fed into the LCA software. Athena Impact Estimator (Athena IE) was used as the LCA software for life-cycle inventory modeling and impact assessment. Global warming potential (GWP) was the specific environmental impact category of interest.

The construction costs for the 91 design alternatives simulated in the paper were calculated using the 2015 Q3 RSMeans Online Construction Cost Data for new commercial buildings, localized for the Seattle (Washington state, USA) metropolitan area (RSMeans 2015). Wall components were classified following the CSI Master Format 2014. The required solid wall material quantities, and window surface area, were calculated based on the window to wall ratios and building dimensions specified for each of the design combinations studied. The resulting window surface area was then converted into individual 3’x5’ single hung window units. Cost estimates were computed based on the material, labor and installation equipment unit costs for the components used and the total quantities required of each. Labor costs are based on prevalent open-shop (non-union) productivity and man-hour cost for the various trades involved in the construction of the building envelope, while material costs are based on the procurement costs including associated delivery cost to the job site in the Seattle metropolitan area. Table 1 shows the detailed unit costs of materials used in design alternatives including the labor and installation costs.
In the next phase of the research methodology, the effects of building skin design parameters on the changes in operational energy, global warming potential and cost were estimated. Multiple regression analysis was used as the statistical analysis technique with Stata SE as the tool for this purpose.

In this phase, first the data were explored visually in order to detect outliers and influential observations. Outliers are observations in a sample that deviate “markedly” from the rest of the observations in the sample (Grubbs, 1969); their presence in a model can skew the results of analysis. Influential observations are those observations having such extreme impact on the results that their inclusion in the model jeopardizes generalization of the results (Ting, 2004). The scatterplot matrix of the variables in the regression model was visually examined for outliers. These observations were excluded from the analysis.

Then, a bivariate regression model was run to test the bivariate relations between variables. Since the dependent variables in the model (i.e., energy use, global warming potential, and cost) are simultaneously affected by several design variables, multiple regression analysis was used to measure the effects on dependent variables. We then empirically examined the multiple regression model for other outliers/influential cases. Two statistical measures were applied for this purpose, including DfFit and studentized residuals. The model was re-run using the remaining cases in the model. In the next step, this model was examined for violation of other regression assumptions including non-linearity, non-normality, multicollinearity, heteroscedasticity, and misspecification. Non-linearity occurs when the relationship between independent and dependent variables is not linear. Non-normality refers to non-normal distribution of residuals. Multicollinearity occurs when the independent variables in the model exhibit near-perfect correlation with each other. Heteroscedasticity refers to the lack of equal variance of the residuals for independent variables (Miles & Shevlin, 2001) and is closely associated with non-normality. Misspecification happens primarily as a result of failing to include a major variable in the model, or including an irrelevant variable. Figure 1 illustrates the multiple regression methodology.
3.0. RESULTS
The regression analysis results for operational energy use, global warming potential and cost are shown in Tables 2, 3, and 4, respectively. The tables also report standardized beta coefficients for the regression results which help compare the effects of independent variables.

As shown in Table 2, the association between south WWR and operational energy use is negative; that is, increase in south WWR reduces energy use. More specifically, each unit increase in south WWR decreases energy use by -1.003. On the other hand, increase in north WWR increases operational energy use. The results also suggest that the effects of all design variables on operational energy use are statistically significant (p-value<0.05). R-value seems to be an exception which demonstrates a p-value of 0.08. This could be explained by high correlation between R-value and other variables in the model. The effects of all variables on operational energy use are negative, except for north WWR and changes in frame material which represent a positive effect. The adjusted R-squared of 0.6151 suggest that more than 61% of variations in operational energy use can be explained by five variables in the model.

Table 3 reports the multiple regression results for global warming potential. The results show that increase in north WWR and south WWR, and using high-performance windows reduce the global warming potential. This occurs mainly because the increase in WWR would lead to lesser use of insulation in the building envelope. Most insulation materials are energy-intensive with high global warming potential. The effects of the three variables are significant statistically. However, the effects of R-value and frame material on global warming potential are not significant in the sample studied by this research. The adjusted R-squared of 0.2106 suggest that about 21% of variations in global warming potential of the case-study building can be explained by the five variables in the model. This figure is not high enough and implies that there are other major variables affecting global warming potential that have not been included in the model.

Table 4 reports the results of multiple regression on cost variable. The variable with greatest effect on cost is window type as high-performance windows are often associated with increased construction cost. It is important to note that the cost factor studied here is not life cycle cost of the project, rather initial construction cost. The higher costs of high-performance windows can be balanced by the energy-related cost savings over the life span of the building. The results also show that south and north WWR both represent negative effects on cost; that is, increase in south and north WWR reduces the cost of the project. This could be explained by significant amount of construction materials (e.g. insulation, brick veneer, gypsum board,
etc.) that would not be needed by increase in WWR. Among the design variables in the model, wall R-value and frame materials also have a positive effect on cost; i.e., they lead to increase in costs. The adjusted R-squared of 0.860 suggest that more than 86% of variations in construction cost can be explained by WWR, R-value (i.e., insulation), windows and frames.

**Table 2. Multiple Regression Model with Operational Energy as Dependent Variable**

| Variable     | Slope Coefficients | Standard Error | T     | P>|t| | Beta  |
|--------------|--------------------|----------------|-------|-----|-------|
| South WWR    | -1.003             | 0.240          | -4.17 | 0.000 | -0.274 |
| North WWR    | 1.158              | 0.240          | 4.82  | 0.000 | 0.316  |
| Window type  | -8.152             | 0.844          | -9.65 | 0.000 | -0.634 |
| R-value      | -0.242             | 0.089          | -2.70 | 0.008 | -0.177 |
| Frame mater. | 1.614              | 0.496          | 3.25  | 0.002 | 0.213  |
| Constant     | 198.744            | 2.286          | 86.91 | 0.000 |        |

**Table 3. Multiple Regression Model with Global Warming Potential as Dependent Variable**

| Variable     | Slope Coefficients | Standard Error | T     | P>|t| | Beta  |
|--------------|--------------------|----------------|-------|-----|-------|
| South WWR    | -9.151             | 2.906          | -3.15 | 0.002 | -0.296 |
| North WWR    | -8.418             | 2.906          | -2.90 | 0.005 | -0.272 |
| Window type  | -29.515            | 10.210         | -2.89 | 0.005 | -0.272 |
| R-value      | -2.057             | 1.085          | -1.90 | 0.061 | -0.178 |
| Frame mater. | 8.415              | 6.006          | 1.40  | 0.165 | 0.132  |
| Constant     | 1994.227           | 27.643         | 72.14 | 0.000 |        |

**Table 4. Multiple Regression Model with Cost as Dependent Variable**

| Variable     | Slope Coefficients | Standard Error | T     | P>|t| | Beta  |
|--------------|--------------------|----------------|-------|-----|-------|
| South WWR    | -2.682             | 0.533          | -5.03 | 0.000 | -0.198 |
| North WWR    | -2.682             | 0.533          | -5.03 | 0.000 | -0.198 |
| Window type  | 31.077             | 1.874          | 16.58 | 0.000 | 0.656  |
| R-value      | 2.874              | 0.199          | 14.42 | 0.000 | 0.570  |
| Frame mater. | 9.935              | 1.102          | 9.01  | 0.000 | 0.356  |
| Constant     | -45.318            | 5.074          | -8.93 | 0.000 |        |

Comparison of standardized Beta coefficients revealed that improving glazing material (triple-glazed versus double-glazed) has the highest effect on operational energy use, followed by WWR on north and south facades. Results also show that the association between operational energy use and south WWR is an inverse association while its association with north WWR is positive. The results also showed the increase in north WWR, south WWR and wall’s R-value would lead to lower life-cycle global warming potential. Using aluminum frames also can increase the GWP potential, although the results seem to be statistically insignificant.

**CONCLUSIONS**

We empirically studied the effects of 5 design variables including south WWR, north WWR, R-value, window type, and frame materials on operational energy use, global warming potential,
and cost in a low-rise office building using process-based LCA and regress analysis. The use of multiple regression analysis allows to capture and isolate the effects of multiple design parameters on the changes in operational energy use, GWP and cost. The results revealed that the independent design variables including north WWR, south WWR, glazing type, R-value and frame material type have a statistically significant effect on all dependent variables; i.e., operational energy use, GWP and cost. The effect of insulation material type on dependent variables, however, was not significant statistically, mainly because of its high correlation with the R-value. The results also reflect the complex relationship between operational energy and global warming as one variable could increase one while decreasing the other.

While the research result can be useful to the research and professional communities, caution should be taken in interpreting the results and generalizing them to other contexts. The results reflect the climatic and geographical context of Seattle in Washington State. Other locations have different climates and manufacturing and transportation practices which would affect the operational energy use and life-cycle environmental impacts of buildings. Also,

REFERENCES
eQuest. 2015. eQuest, the Quick Energy Simulation Tool. http://www.doe2.com/equest/
Life in a high-rise: surveying opinions and expectations on social housing in Turkey

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ABSTRACT: What does encourage people to spend their time outdoors of their residences? Is it the weather? Is it the enclosure? Is it the safety of their neighborhood? Currently, the Turkish government faces social and spatial disintegration in urban areas. Different ethnicities, beliefs and income levels in the cities divide society. In the last decades, the Turkish Mass Housing Administration - known as TOKI – has altered the silhouette of old low-rise dense neighborhoods with tall apartment buildings. Moving into vertical developments, low-income populations deal with new urban lifestyles. In the past, picturesque streets and little squares with full of activity allowed inhabitants to hang around with family and neighbors. In the present, the TOKI developments are characterized as possessing anonymous areas, that are the unplanned remains of the towers’ footprints. Have these urban and architectural circumstances exacerbated the lack of social cohesion in communities all around the country? Through a case study in a TOKI project in the city of Gaziantep – in southeastern Turkey, this research illustrates the current conditions of indoor and communal ground-level areas of this project. Interviews and observations make evident the need to energize these communities exploring climate-responsive design alternatives. Such solutions would alleviate the outdoor thermal stress in this hot and dry climate (particularly in summer). This paper aims to review the current conditions of social housing in Turkey, and the significance of communal outdoor spaces. Survey data makes evident that interaction between people can be enhanced by placing well-defined outdoor. Through a more pleasant range of temperatures and shading regions, communal outdoor areas help communities improve experiences inhabiting and sharing these spaces with others. They stimulate urban vitality, and shape well-defined neighborhoods with participatory and well-aware residents.

KEYWORDS: survey, urban form, communal outdoor spaces, social housing, Turkish Mass Housing.

INTRODUCTION

Many publications and researches in social sciences, environmental studies have criticized different aspects of Mass Housing Administration in Turkey. One of these criticisms is about the high-rise typology that TOKI proposes. In the results of slum clearance in cities -as a part of “urban regeneration” process- housing demand has been purportedly solved through TOKI’s vertical towers for nearly 35 years in Turkey. While criticisms mention about the human scope of relocation, forcing people to move into towers from low-rise neighborhoods. These people have to change jobs, schools, and neighbors leaving their houses. Exploring what people currently living in TOKI residential developments think is the core of this study.

In this sense, this research uses interviews as a main part of the methodology. A survey conducted in a TOKI development in Etiller neighborhood - the case study of the research- helps to figure out what their opinions are. This experiment displays the relation between theory and practice and answers these questions:

- Are residents of Etiller neighborhood Project really struggling to adopt this high-rise development?
- Do they prefer a single-story house than a high-rise TOKI environment?
- How these people can calibrate the social implications of relocation?
- Do outdoor spaces of the project provide a well-defined and functional area for social interaction?
- Is it easy to create a community in a TOKI high-rise environment?
How is the satisfaction level of TOKI residents about living in the project?

Findings help to understand the reasons of need of a community. The importance of an appropriate physical space is obvious when you want to make people go outside, share space and time and be aware and a contributing participant member of this community. Overall, the objective of this paper is to review the current conditions of social housing in Turkey, to stress the importance of a quality communal outdoor areas.

Collected data help to understand demographics of a low-income community and their evaluation about the high-rise typology that is new for them. For that purpose, the paper is designed in three parts. The first part reviews the urbanization process of Turkey and governmental solutions for housing demand. The second part studies a project of the Turkish Mass Housing Administration (TOKI) through a survey conducted in August 2018. The paper is concluded with general guidelines and advises with the light of survey results and observations at the site.

1.0. Urbanization process and solutions to informal settlements in Turkey

Since the 1940s, rural migration has increased the demand on mass housing in Turkey. According to Turkish Statistical Institute (TUİK), every year two hundred thousand people immigrated to the urban areas between 1950 and 2008. 12.5 million people which is 29% of the urban population live in informal settlements in Turkey. These numbers mean that serious inadequacies in social and technical infrastructure are the results of illegal housing (Turk and Korthals Altes 2010, 26-32). Still today, Turkey faces the effects of a rapid urbanization. Cities cannot answer to the housing problem of people, since the unprecedent immigration surpasses the capacity and resources to provide a formal dwelling production, hence, municipalities cannot provide enough infrastructures and slum areas extended quickly (Senyapili 1998, 301-316).

Like in many other countries, slum areas in Turkey are fragmented and erased. Their residents have been relocated. Their neighborhoods have been torn down in urban public lands under the name of “urban redevelopment” as a political tool which impacted the legislative regulations in Turkey in the 1980s. As a solution to control informal settlements in the periphery of cities - known as “gecekondu” in Turkish (Karpat, 1976), governmental initiatives have developed housing solutions by establishing a Mass Housing Authority called TOKI. In the last 35 years, this entity has replicated the model of large-scale high-rise typologies all over the country. Thought to alleviate the housing deficit, these interventions have broken the urban continuity, have isolated neighborhoods and have transformed the traditional lifestyle of people that have moved into vertical structures.
ENVIRONMENTAL STEWARDSHIP

In 1984, with the law number 2985, TOKI was created with the purpose of providing financial support for new projects, the clearance and transformation of slum areas (Dulgereoglu-Yuksel et al. 2009). TOKI has looked for mass housing alternatives for low and middle-income groups, gathering public funds for urbanization. Since that moment, this agency has developed more than 600,000 units in renewal projects around the country (TOKI 2017). Its models include social housing, disaster housing and slum transformation projects (Devrim 2016, 316-326). Regulations passed in favor of TOKI between 2003 and 2008 has provided financial benefits and power. For instance, “65,808,839 m² of land were transferred to TOKI” by allowing the institute to build projects on state-owned lands (Akcan 2015, 359-378)

Concentrated on the main cities, large scale real-estate projects have emerged through investments of private construction companies and subsidized by local governments. Under the scenario of an earthquake destruction, TOKI agency has gained power as a main actor in housing sector (Bozdogan et al. 2012, 848-858). Public-owned lands started to be used for mass housing projects. However, the repetition of the same architectural typology with the use of the same tunnel formwork shows that quantitative and qualitative user needs haven’t been properly analyzed and this is a problem (Tomruk, 2009). Limited layout plans made these residential projects lacking functional and aesthetic diversity, while limiting the possibility of different unit size and usage of local natural forces. In this sense, its projects have been criticized for having living areas that overheat in summer and are underheated in winter. Their fenestration and wall assemblies are built under budget restrictions and without clarity about their compliance with thermal standards.

2.0. CASE STUDY: ETILER PROJECT

Throughout a review on social housing projects of TOKI, the most common plan type is identical 4-unit plan configuration. Therefore, in this paper, one of the TOKI projects in Etiler neighborhood is selected as an archetype (Fig.4). This project, built for low income groups in the city of Gaziantep, is studied to display the demographics, residents’ evaluation and future expectation about their houses. People, whose former dwellings were demolished during a gecekondu clearance of three districts (Turktepe, Etiler and Ozdemirbey), moved into these high-rise towers after the completion of the project in 2012.
Etiller Project comprises six tower blocks in an 18,506 m² site. Residents who first moved into these towers in 2012 were chosen by TOKI agency and local municipalities according to the criteria of economic status. As part of this research, the community living in this project was surveyed to know its opinion about the quality satisfaction with indoor areas and outdoor communal spaces. Interviews were carried on August 2018. Visits were scheduled on working days between 10 am and 5 pm. A group of 143 residents representing their households (out of 288 number of families) decided to participate in this survey. Statistics about the gender gives the number of nonworking women of this development. Only 18 participants out of 143 are male. In each unit, the interview was planned to last from 10 to 12 minutes. During this time, a resident answered to a set of 33 questions. Also, according to the orientation of the units, residents were asked about their windows operation (Fig. 5). These statistics about users provide a reference for future alternatives beside proving data of user profile of this specific project.

The obtained questionnaires represent a distributed sample of the project. Answers from the different towers (6), stories (12), and orientations (8) were reported (Fig. 5). The project has 288 identical housing units. Each one has two bedrooms, one living room, one kitchen and one bathroom, and one balcony as a transitional space. 58% of all interviewees are the first occupants of their units. Majority own their apartments. Since the area is scarce for many residents, most of them, which are owners, tend to make some changes in plans. Therefore, the survey explores the family sizes living in this project under a same residential layout. Statistics give an important clue about the demand of variety in housing units. If the number of large families (more than 4 members) is considered, it is obvious that 2-bedroom units of Etiller Project do not meet the spatial needs of those big families.

Related to the size of families, a larger distribution is found. Instead of having a unique apartment type, families with 1-7 persons have to live these same 2-bedroom units (built area of 82 square meters). However, the most common family type contains 4 or 5 members (21% and 25.9% respectively). Larger families occupy more than 16% of apartments. (Fig. 6). Overall, outdoor spaces seem to be the only choice for these families not just to interact but also to alleviate the overloaded use of apartments at times of the day. Similarly, statistics about number of children that live in Etiller Project are useful to determine the scale of social organization (such as formal and voluntary associations) that the neighborhood needs to.

Understanding the family as a growing entity, the survey investigates the previous residence that these households had before arriving into this mass housing project. As a common answer, it was obtained that larger families were living previously low-rise informal developments. Nearly 40% of families with more than five members lived in one-story residences before arriving to the TOKI Project. The adaptation to living in a smaller unit, without open private spaces, and without major climatic possibilities, represents the problems of these families when moving into a high-rise building.

Figure 4. Etiller TOKI Project, Gaziantep. Source: (http://www.gaziantephaberler.com)
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Results show that 73% of interviewees lived in 1 or 2-story buildings in the past (Fig. 7). Only 4 out of 143 people used to live in buildings more than 5 stories. However, small families which have more available domestic areas also complain about the tower surrounding areas. These are non-functional spaces that end in most of the times as surface parking plots. Most of surveys express that as a main consequence of living on high-rise residential building is the community’s disintegration. Residents believe that this is originated by the absence of central spaces that can serve as communal services such as recreational, cultural and social areas.

The TOKI mass housing projects have been characterized by a low retention rate by families who really seek other long-term residences. It is a common aspect that families that inhabit in TOKIs after a couple of years of dwelling in these buildings look for a more appropriate residence that meet their needs. As a priority, families intuitively look for projects of smaller scales. Therefore, one of the most certain answers when families are questioned about their expectations for a residence after the TOKI is connected to the desire of living in mid-rise developments (Fig. 7).

The following part of the survey is related to natural ventilation questions. For instance, questions about ventilation methods of users helps this study to understand their adaptability level. In this TOKI project, 16% of families declared that they had an air conditioning unit in one of their rooms. However, only 6% of those uses the AC unit as a cooling method when the summer mean temperature is between 29 to 34 Celsius degrees. This pattern explains residents’ tolerance level to hot temperatures compared to people who depend on mechanical ventilation. Opening windows to enhance cross winds through the units is the most used method for cooling in this context.
alternative. When asked about pointing the windows used for ventilation purposes, answers explain the trends in window operation and schedules in day and nighttime.

In each unit of this project, there are four window openings (one per each room) on two façades. Each block has 14.5% of opening area which is 536.5 m². The exterior wall area of a tower is 4615.9 m². While two bedrooms and the living room have one operable window, there is not any windows in the kitchen. However, a balcony door is the only opening in this space. During daytime more than 95% of families use the balcony door for cross ventilation. Overall, it is the most used opening for both daytime and night ventilation. As predicted, windows in bedrooms are being opened more at nocturnal time. However, they are also used in mornings and afternoons by more than 65% of families. (Fig. 9)
Considering these results, it is seen that nearly 35% of families modify balconies and enclose them by PVC profiles and glass panes. However, they continue to use this opening for cross ventilation. Survey data shows that air movement desire on the indoor environment is averaged on “no change” with 80% of families for hot period of a year when average outdoor temperature changes from 29° C to 34° C (Windfinder). This unpredicted result emphasizes the strong connection of residents’ thermal sensation adaptability with outdoor temperatures in this region.

Example of a survey question: *Did you close your balcony with PVC profiles? If yes, please indicate the reason(s)?*

“The house is small, and the balcony as well. We cannot put a table to sit with somebody. So, we closed it with a PVC window frame. Now, we are using it as a storage”.

The scale between -3 and 3 indicates that satisfaction level about indoor areas in units and outdoor spaces. 57% of 143 residents are very dissatisfied in outdoor areas when this number is lower for unit satisfaction. While only 1% of people feel very satisfied for indoor and outdoor environment, nearly 50 percent of interviewees defines their perception as slightly dissatisfied.

Thermal Sensation and Clothing Value for winter and summer are explained through Figure 12. In winter, the predominant trends show that nearly 75% of people expresses ‘warm’ as a Thermal Sensation. In summer, 38.5% of people define their thermal sensation cooler than neutral which only 1.4% of residents expresses as.
CONCLUSIONS
This paper reviews the current conditions of social housing in Turkey while bringing the residents' evaluation up through a case study and interviews. Slum clearance through “Urban Renewal” operations and quality of TOKI projects as new dwellings for people, are controversial topics among architects, urban planners and academics in Turkey. A review of the issue via surveys shows that TOKI buildings have a limited possibility on spatial diversity. Constantly, residents complain about lack of community and social life which according to opinions is a consequence of outdoor discomfort. Resolving the housing problems of the Etiler Project residents through a participatory process can help to provide a better understanding of their expectation. It is essential for implementable and sustainable possibilities in new TOKI projects.

In the TOKI project, surveys demonstrated deficiencies in ventilation abilities, resulting in indoor discomfort. TOKI urgently needs to improve the quality of mass housing, not only for structural durability but also for social and environmental sustainability by providing more habitable residential areas to deal with extreme climates. This group of residents also complained about large amount of unused ground spaces, it exemplifies the scale of TOKI interventions through on state-owned lands. It questions if it is possible to come up with different typologies to create communities.

Large scale intervention in urban areas by TOKI should be reconsidered. Architects should be able to propose lower density design proposals with adequate communal areas. These features would better fit into the urban dynamics of Developing Countries.

Perimeters of connected blocks create access points for pedestrians by providing an access and transforming a closed private interior into a semi-public transitional space. These communal gardens provide an intermediate space between streets and built environment. These recognizable domestic spaces will bring dynamism. Also, using a midrise typology will help to recover the link between street and dwelling which does not exist in TOKI towers.
In light of these survey data and the resultant literature on resident satisfaction, this research recommends that the following new principles in order to ensure higher satisfaction of residents in TOKI providing well-being for adults and children.

1. Building Type:
   - Instead of using 12 stories, similar densities (people/hectare) could be obtained through configuration of 3 to 5 stories. As interviews show a mid-rise typology with communal outdoor areas can be easier to keep the connection with outdoor environment.
   - Even small-scale modifications of building geometry and typology can influence habitability of residential areas. The integration of communal areas into the built environment as transitional spaces, may provide a shaded meeting point for pedestrians to gather socialize. When these well-defined and functional outdoor spaces have attractions to public use and give users reasons for crisscrossing paths, people start using them voluntarily. Thus, strong community connections may randomly occur. Therefore, spaces between TOKI towers stop presenting themselves as large voids.
   - Residents’ expectations about a space for social and cultural activities proves the need of communal services such as a daycare would help children of the community.

2. Outdoor Spaces:
   - Vehicular access should be rearranged to have better recreational area. The current urban layout does not allow people to have pedestrian-friendly routes and provide safety for children by carrying vehicular roadwork from inside to outer parts of the project away from where people gather.
   - Public spaces and amenities enhance social mixing and upgrading the quality of space. If the zoning allowed the residents to incorporate small businesses on the ground floor, commercial part of the project can help to have livelier outdoor space by calibrating the social implications of relocation.

3. Indoor Environment:
   - Results show that a residential project should provide different unit types for various family sizes.
   - Since buildings do not have any mechanical conditioning for cooling, especially in this hot and dry climate, residents struggle to obtain comfortable indoor environments. Without success, they try to enhance the air movement though their units as a manner.

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**CLOTHING VALUE**

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**Figure 12.** Winter/summer indoor sensation and clothing preferences. Source: (Author 2018)
to reduce temperatures. Thus, openings which are located in adjacent facades in the Etler Project should be located on opposite facades to increase the performance of cross ventilation.

- Transitional spaces such as balconies, terraces, courtyards and galleries could be reinterpreted to improve passive conditions.

When urban activist and New York historian Jane Jacobs explains what makes a community and what makes a city livable, she indicates an active, involved and aware neighborhood. She talks about safety as a basic notion comes from "eyes on the street". She mentions the importance of urban vitality which also comes from residents’ participation. However, as she mentioned, if people don’t have any reason to use streets, you can’t make them use (Jacobs 1961, 105-109).

LIMITATIONS

This research does not include residents of all TOKI projects in Gaziantep and can thus not be generalized to all of hot and dry climate regions of Turkey. Interviews with residents have included a broader understanding and concern for the many issues that surround this TOKI development.

REFERENCES


TOKI www.toki.gov.tr
www.windfinder.com/windstatistics/gaziantep
The untapped potential of passive energy housing developments

Craig S. Griffen
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ABSTRACT: Recent reports paint a dire picture of the potential worldwide effects of climate change. Since our buildings’ energy consumption plays a significant role in the production of greenhouse gases, many more energy-efficient buildings could affect a major reduction in carbon production. Single-family developer housing represents a high percentage of US construction at close to a million starts per year. Yet, the typical subdivision is designed with little to no regard for orientation to sun, wind and thermal envelope efficiency. Since single-family homes consume around 80% of residential energy use, a million passive energy house starts per year could have profound effects on our energy use but most architects appear uninterested in suburban housing design. This segment of the market is prime opportunity for applying passive energy strategies on a massive scale. So with the looming specter of climate change, why do most architects and builders seem apathetic to the suburbs and continue to disregard this opportunity despite the potentially catastrophic results? This research/design project questioned: If passive solar houses have been around for decades, why are there few passive single-family housing communities, and why haven’t they made the leap in scale? The research component investigates the historical reasons for the disconnect between architects, large housing developments and passive energy. Based on the findings, the design component proposes a variety of model house types, based on the Charleston House typology, and subdivision designs, both in the suburbs and as urban infill, as potential present-day strategies for extending the strategy to the massive scale. The research produced two governing questions that informed the design solutions: 1. How do we apply passive energy strategies to the pre-manufactured developer house? And, 2. How do we make passive houses marketable in a well-established industry?

INTRODUCTION
Most scientists agree, if not already too late, that to slow the effects of climate change will require enormous changes to the way we produce and use clean energy. In our built environment, to achieve measurable success in integrating sustainable energy systems into buildings will likewise require application on a sizeable scale. However, wind and solar sources supply only a small percentage of power for building energy systems that still rely heavily on fossil fuels. In terms of construction volume, single-family developer housing starts account for a huge percentage of construction each year. (US Census Bureau reports levels...
ENVIRONMENTAL STEWARDSHIP

of over one million starts per year for the past several years)\(^1\) And more recently, suburban style developments have been constructed on large tracks of vacant land in large cities. With the vast majority of new house construction produced by these large housing development companies, this segment of the market is prime for applying passive strategies on a scale great enough to have a significant impact on energy use. Yet developers typically build entire subdivisions with little to no regard to orientation to sun and wind and most architects appear uninterested in becoming involved with suburban housing design. The increase in quantity of passive house construction is laudable, but at the current small volume it will not have a measurable effect on our environment. However, a million passive house starts a year could have profound effects on our ecosystems. With the looming specter of climate change and the potentially catastrophic impact, can architects ethically continue to ignore the problem as it grows into a major environmental concern? This design/research paper investigates the reasons for this disconnect between architects, large housing developments and sustainable energy, and then identifies potential design strategies for improvement.

1.0. THE LACK OF DEMAND FOR SUSTAINABLE SUBURBAN HOUSE CONSTRUCTION

Rethinking suburban design is an enormous challenge because many suburban neighborhoods have been designed, developed and managed precisely to avoid change and limit uncertainty. …the issues remain just as relevant, except the houses have gotten bigger and more wasteful and the environmental imperatives more urgent.\(^2\) Why have developers stayed out of the passive energy housing market and what would it take to convince them of the feasibility of sustainable single-family housing? At the same time, while there is a high demand for single-family homes, why is there not a strong demand among buyers for sustainable suburban housing? Two major fears among both developers and clients are resistant to change and cost. The construction industry (at least in the US) is notorious for using the same construction techniques again and again with little desire for innovation. This is especially true in the suburban house market. "Is there anything made in America that’s less innovative than the single-family home? While we obsess over the new in terms of what we keep in our houses...we’re incredibly undemanding of the houses themselves." Change is a financial risk to developers because the new techniques have not proven themselves through repetition and are more vulnerable to unseen cost fluctuations. Lightweight wood-frame designs are replicated across the country, regardless of location and climate, because they are cheap and efficient to build. Following an “if it ain’t broke, don’t fix it” attitude, builders have little incentive to take risks so “If the buyer wants it, give it to him.”

Proponents of energy efficient housing agree that initial costs of showcase “green” houses are more expensive but there is strong evidence that the savings in energy bills over time will more than pay off for additional first costs. But speculative builders who sell their houses immediately upon completion are not the future owners/occupants, so are less concerned with future operational costs. Unfortunately, seeking the bottom-line and suspicion of new techniques make reducing initial costs and maximizing profit the main goal. "Initial cost will always be important and many of the showcase projects have a short-term flaw in that it has generally been perceived by the wider construction industry that there must be a monetary penalty when demonstration developments are transferred, in a somewhat diluted form, into the more affordable mass market”.\(^5\) So the wariness is understandable.

A harder question to answer is why don’t more home buyers demand higher energy efficient houses? In a recent on-line article titled Ask The Agent: What Home Features Are Most In Demand When Buying Or Selling?\(^6\), many real estate agents across the country gave a predictable reply that the focus was on location and luxury amenities: “I noticed that buyers really love when properties are move-in ready with the decked out kitchens, bathrooms and hardwoods floors.” However, several agents did mention that in addition to those desires, there is a newer demand for energy efficiency: "Buyers and sellers are starting to demand amenities that are energy-efficient, low emission and cost-effective like tankless water heaters,
solar panels, Nest-type thermostats, low-water toilets and the like.” So the demand for energy efficiency may be increasing among home buyers, albeit slowly.

In addition to developers and buyers, our legal environmental energy codes in this country are not very demanding. With a few exceptions, most municipalities follow the far-from-stringent ASHRAE 90.1 or similar minimum level of energy efficiency. So if “...neither building codes nor buyers demand that homes be energy efficient. And given the lack of incentives to go green, most builders prefer to do what they know, rather than master new — and more demanding — building techniques and materials.” Until the public demands it or the government requires it, builders will have little incentive to change.

1.1. Architects’ apathy towards the suburbs

With blithe inconsistency, architects and architectural scholars point to the seemingly undesigned sprawl of suburbia and say, “Don’t blame us, we had nothing to do with it.” This avoidance is precisely the problem.

Another question is why aren’t architects, who are some of our best sustainable construction advocates, more involved in suburban housing? There are many well-trained professionals who could lend their expertise in passive systems but many architects have washed their hands of developer housing seeing it as beyond hope or beneath their status. The “…the bias against suburbia remains strong among designers and critics, whether it manifests as tirades against sprawl or utter indifference. Unless they’re wooed by an Apple or a Facebook, top-tier architects rarely work in the ’burbs.” Suburban development accounts for approximately 75% of all new construction in recent decades so therefore presents great opportunities on a very large scale, yet it is still shunned by most architects. Suburbia seems to have an image problem among architects. In 1950’s post-war America, the suburbs were seen as a land of opportunity for design and planning, but no longer. PAU architect’s current website includes a list titled “What We Do” to describe their scope of services, as well as another, less typical one: “What We Don’t Do,” which identifies “Single-Family Suburban Homes; Suburban Subdivisions, Malls, and Office Parks; Work for Autocratic/Dictatorial Nations; Work for Nations or Corporations with Unacceptable Labor or Environmental Practices; Correctional Facilities; Casinos/Facilities for Slot-Machine Gambling; Facilities that Manufacture Arms.” To place suburban homes and subdivisions in the company of tyrants, weapons, gambling and prisons, speaks volumes about their reputation in the eyes of some architects.

To be fair, many architects have addressed the problems of suburbia. Most of that work has centered on increasing density, promoting mass transit and reducing the immense waste of land and infrastructure through planning means like zoning code and land-use reform. In Retrofitting Suburbia, Dunham-Jones and Williamson provide many methods and potential solutions for redeveloping suburban environments into denser more urban sustainable places. Compact developments address sustainability well at the macro level by reducing carbon emission through less road and utility construction, decreasing car use, promoting walking, using mass transit, etc. But the individual suburban house has received less consideration.

The big-picture ideas and national movements are by now well-known—transit-oriented development, New Urbanism, Smart Growth, and so on. And yet the suburban reformers, focusing almost always on the scale of systems, have rarely paid sustained attention to suburbia’s essential component, its irreducible unit — the freestanding single-family house.

Increasing density is a critical move, but could we continue that line of thought to focus on the energy consumed/wasted by each individual house. Some architects argue that single-family homes are not a sustainable use of land and resources; preferring multi-unit housing as a better approach. But single-family homes consume around 80% of residential energy use. To affect change on a massive scale requires a willingness to confront the big issue. Although unpleasant to many architects, the continual demand for detached single-family suburban housing is an issue that needs greater attention to investigate how to make this enormous number of homes energy sustainable. To continue to ignore the issue is an ethically questionable decision.
1.2. The solar suburban house and subdivision – a (very) brief history
During and right after the war, hundreds of solar houses were built across the United States, most using passive radiation to reduce heating load. Typically these designs featured a narrow plan and an all-glass façade, in order to allow solar rays to penetrate deep into the house in the winter, and also a carefully designed overhang, in order to deflect the summer heat.15

Figure 3. Post-war Solar Homes
Figure 4. Village Homes, Davis, CA, Passive Solar Community

Although rare, the passive solar suburban house is not a recent development. While there was much experimentation in the 1960’s and 70’s, the origins are earlier. After World War 2, oil was in short supply so there was a search for new forms of energy including solar. However, these solar houses were not very effective and required continual maintenance which, when combined with newly discovered oil, doomed this first generation of solar houses.16 So while passive solar houses have been around for decades, more extensively in Europe, they exist only as individual cases or in small groups. Few large passive single-family housing communities exist, and none close to the scale of a suburban development containing hundreds of houses. Davis Homes community built in California in the early 1970’s is one of the truly rare examples of a passive solar oriented subdivision but very few followed their lead. This paper explores why passive energy systems are not part of US suburban developer housing and which issues might be preventing the leap in scale. These ideas were then tested through potential design solutions on the scale of both an individual prototype Passive Suburban Developer House (PSDH) model and a community master plan. Out of the research grew two major questions. First, how do we apply passive energy strategies to the pre-manufactured suburban house, and second, how do we make passive houses marketable in a well-established industry?

2.0. THE CHALLENGE OF MAKING DEVELOPER HOUSES PASSIVE
Not so long ago homes were designed to make the most of their surrounding climate and terrain. Vernacular forms like the shotgun, in places like New Orleans, served a purpose that went far beyond aesthetics — they encouraged natural cooling by improving cross-ventilation. ... Houses were sited and windows placed to maximize or minimize sun exposure as needed 17

With the advent of central heating, air-conditioning and electric lighting, houses could ignore the sun and wind conditions of a site and depend on solely mechanical means for thermal comfort. Current developer housing is designed and sited with little to no relation to the direct solar gain, wind movement or daylight. Streets of a typical subdivision are often laid out in a pattern of gently curving drives and dead-end cul-du-sacs with the houses oriented towards the street regardless of which cardinal direction they face. A prime challenge is how to adapt
and site these non-directional houses to maximize natural passive environmental benefits. To also take advantage of the sun and wind requires orienting the house in a specific direction.

2.1. Orientation towards sun and wind
The first step to make a house energy efficient is to use Passive House thermal performance principles of continuous well-insulated walls, an airtight envelope, and high-performance windows. Since most of these requirements deal with material performance standards, they can be applied to most styles of houses including developer housing. Developer houses typically use small double-hung windows of relatively the same size on all sides that do not adjust for the varying solar demands on the four faces. While this reduced glass area is good for minimizing heat loss (same for the Passive House) it also limits direct sunlight, restricts views and separates inside and outside space. Therefore, the PSDH model varies slightly from the Passive House by opening up more window area towards the sun and the exterior on the south side.

A passive solar house wants to stretch out in a long east-west direction to expose many rooms to the southern sun. But a heavily glazed façade facing the street or close to neighbors would be detrimental to privacy and the use of curtains would negate the solar gain. An open south façade works better if it can face a private yard space. The result is to exchange the large front and back yards of a standard subdivision house for one big side yard, a house type similar to the Charleston House of a long, side-yard facing building with a gallery along the south wall. In the PSDH, main living spaces are located along the sunny south side overlooking the side yard with service spaces located on north with few windows. Since all houses are oriented the same general direction, the heavily glazed south walls look across a landscaped yard at the predominantly solid north wall of the neighbor, thereby maintaining privacy. A gallery and the deep roof eaves extend out from the wall to provide for shade in the summer. The public street-side entries are best located on the narrow east or west elevations that require fewer windows and therefore provide greater privacy. Renee Chow has already demonstrated how the urban fabric pattern of the Charleston typology can be a sustainable solution for increasing density and reducing suburban sprawl. This strategy becomes more attractive with the addition of passive energy strategies.

To minimize the need for air conditioning and artificial lighting, the PSDH should make use of natural ventilation and daylight for their health and psychological benefits. The deep-plan developer house with its closed rooms and small windows does not allow for efficient cross ventilation and greatly restricts daylight to only spaces along the perimeter. The linear, open-plan form of the PSDH, allows for an efficient cross breeze and a two-story stairway with northern clerestory windows vents warm air out high. The clerestory which runs the length of the atrium brings abundant soft northern daylight into the core of the house to compliment that already provided by the extensive southern glazing. With two stories on the south and one-story service functions on the north, the house forms a wedge shape that deflects cold winter winds over the house and creates a protected outdoor space on the south.
3.0. THE CHALLENGE OF MAKING PASSIVE HOUSES DEVELOPABLE

Passive Suburban Houses can’t have an effect on the environment if they don’t sell in great numbers so they need to be attractive to a broad spectrum of buyers. The typical developer house presents a nostalgic image of the traditional house as a symbol of home. Developers aren’t pushing one style over the other. They say they will build whatever style sells; that they are only giving the client what they want. So, any design for passive suburban developments must be financially feasible and aesthetically marketable to a massive audience.

3.1. Conveying the image of ‘home’

A Passive House whose only goal is to maximize energy efficiency is at risk of becoming a data-driven machine that while efficient, will have little appeal to the public as a cherished family home. The image of house as home is deeply imbedded in the public psyche as evidenced by the long-time popularity of the historical pseudo-colonial style house. The challenge is how to retain this image of home without resorting to outdated historical pastiche; something architects understandably detest. But the modern house that appeals to designers is not as appreciated by the developer house-buying public. Looking at the traditional styles of developer homes that are purchased today, it becomes evident there are certain common defining characteristics that are desired by buyers. While the counterfeit historic language of false gables, pasted on brick, and screwed-on plastic shutters are less appropriate, incorporating structural sloped roofs and sustainable building materials make it possible to convey the image of home in a more authentic way.

3.2. Making it cost effective

Many of these radical homes can be characterized as showcase developments, which employ all manner of state-of-the-art techniques, as well as sound, basic passive solar principles, to produce often expensive, prestige homes designed to demonstrate what is possible. The theory is that money will be saved over the lifecycle of the building. The better performing building materials needed to create passive house envelopes also drives up their initial cost. Since developers shy away from increased initial expenses, passive house construction should be cost effective to be adopted and marketable. There are many examples of high-end architect-designed custom sustainable houses that are very efficient in terms of energy use but not in terms of construction cost. Their one-off design makes them too expensive for the developer market. As Allison Arieff asks,

Devoting this much R&D and software development to so few homes feels akin to installing a $250,000 solar array on a garden shed. Why not devote that energy to transforming cookie-cutter developer homes?

The developer housing industry has developed successful methods for pre-packaging building elements to reduce labor and material costs. This strategy can be extended to passive houses. To be economically feasible, these houses should not be site-built, but should utilize Modular and Prefabricated Construction techniques to be competitive. One current solution is the use of prefabricated panelized building components such as those manufactured in the US by the Ecocor company, that are shipped to the site and erected by cranes to shorten construction time and save material and labor costs. Another firm, Go Logic, has developed reproducible...
designs for prefabricated passive Go Homes that are in styles similar to what suburban buyers want. While these examples show that passive homes don’t need to be expensive one-off designs, they are all located on large rural sites so the next challenge is to apply this idea to the developer subdivision.

3.3. Planning passive neighborhoods

“In general, the planning profession is not concerned with or particularly well trained in the physical performance of buildings, yet decisions made at this stage can radically affect the performance of passive solar designs.”

Since passive solar houses generally need to be oriented the same way, there is a risk of creating repetitive, monotonous neighborhoods if all houses face the same direction south. A street grid oriented to the cardinal points with mostly north-south running streets, is the most efficient. Although the grid is a successful urban strategy it is less desired in suburbs where relentless grids can create look-alike neighborhoods that lack a sense of identity and place. Therefore, initial planning is critical. Likewise, there is a need to avoid repetitive house styles. Developer housing subdivisions are often created using only 2-3 house designs and a small palette of materials.

Passive Houses have become so thermally efficient with their insulation they will still effectively capture enough solar gain if oriented to within 20 degrees to either side of true south. This 40 degree swing creates enough flexibility in house siting from a strict north-south orientation to allow for gently curved and angled streets, which when combined with pocket parks and green spaces, relieves a relentless grid. PSDH’s don’t make sense without sustainable land use as well. Typical suburban sprawl master plans use large half-acre lots; more land than usually needed by the owners. The Charleston House model, with its large side yard, allows for smaller 1/6 to ¼ acre lots. The increase in density can nearly double the number of houses in a subdivision (from 45 to 86 in the site analysis shown) while maintaining the same overall amount of public green space and creating walkable, livable neighborhoods. With more houses to sell per acre the developer can offset any increased capital costs with an increase in total home sales. To avoid repetition of house styles, several house models should be designed to accommodate diverse family structures and sizes. These models would use the same basic plan but very in scale, color, materials and features; excellent candidates for mass customization. A large number of combinations would help provide initial variety and owner modifications over the ensuing years would provide additional character and neighborhood identity. Richard Pendranti Architects, who works with Ecocor, has already created a portfolio of basic passive house models that can be adapted to the individual client. Like with the prefabricated Go Home, the next step is to jump up to the scale of the subdivision.
CONCLUSION, AND NEXT STEPS
Passive houses already exist that are attractive, affordable and non-repetitive so the next challenge is how to make the jump in scale to large suburban and urban housing developments to increase the positive effect of energy savings. But are we at the point yet where we can make that jump? To test the feasibility of these ideas I needed the feedback from someone in the industry who knows the market well. Therefore, I submitted my house and subdivision designs to Tim Gehman, an architectural executive for a national Fortune 500 homebuilder, for review and comment. While he was personally supportive of the idea, he felt there would still be many hurdles in changing the very imbedded status quo of suburban home buyers. First is the legal problem of in increasing density. Many zoning boards are reluctant to change codes to allow additional lots per acre as it could overburden roads, schools, infrastructure, traffic, etc. But the biggest challenge may be that suburban home buyers still don’t demand energy efficient housing. As he states:

“Real-estate is valued by location, square footage and bedroom/bath count. Attractiveness matters as an opener, but doesn’t drive a yes or no, and annual maintenance and energy usage are an afterthought at best for most buyers. That's a systemic long-term behavior, how do you change it?”

For the great majority of today’s buyers, bottom-line cost and lot location still far outweigh issues of requests for energy efficiency and until they do, builders will have no incentive to change. There are a growing number of buyers who are concerned with the sustainability of our environment and would prefer an energy efficient house, but they are mostly younger first-time buyers who can not afford the price for their first purchase. But the increasingly palpable effects of climate change are causing a corresponding increase in the public’s acceptance and concern. Sixty-two percent of the public now understands that global warming is caused mostly by human activities, an increase of 10 points since 2015.26 As climate change worsens and affects more people, we may see an increasing demand for more efficient homes as well.

In the meantime, I have refocused attention inward to the cities where there is greater potential for a clientele that highly values sustainability and is accustomed to smaller, denser housing. The post-war exodus from cities to the suburbs left abandoned houses that became
23 Scott, Edge, Laing
24 Busta
26 *Climate Change in the American Mind*, Yale Program on Climate Change Communication and the George Mason University Center for Climate Change Communication, 2018
27 Vacant Land in Cities: An Urban Resource; Brookings Institute, 2001
Unintended consequences of current net zero energy building practice

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ABSTRACT: Within the built environment, the current term “Net Zero Energy” is often used to describe the balance in the operating energy of the building. Other forms of energy use besides the operating energy—relating to the transport of building materials, manufacturing, construction, repair, and maintenance—are normally not counted. However, the original concept of “net energy,” as used in the field of ecological economics, has a very different meaning. (Hernandez et al, 2010) In ecological economics, net energy relates to the whole life cycle energy accounting of an object or system and includes all the stages mentioned above, instead of focusing on the operating/use phase alone. While the high efficient building such as net zero energy building is a global trend and will help us to achieve the 80% carbon emission reduction by 2030, however, the attention to energy performance need to be broaden up in order to avoid unintended consequences. In this paper, an overall analysis is given of three key inadvertent consequences of the present-day net-zero movement in the built environment: the life cycle environmental impact caused by neglecting embodied energy, societal impact due to several characterizations of net-zero energy building, and overall ecological degradation caused by a sole focus on energy counting.

KEYWORDS: Net Zero Energy, social impact, embodied energy, ecological degradation, life cycle environmental impact

INTRODUCTION

Within the built environment, the current term “net-zero energy” is often used to describe the balance in the operating energy of the building. Other forms of energy use besides the operating energy—relating to the transport of building materials, manufacturing, construction, repair, and maintenance—are not counted. However, the original concept of “net energy,” as used in the field of ecological economics, has a very different meaning. (Hernandez et al, 2010) In ecological economics, net energy relates to the whole life cycle energy accounting of an object or system and includes all the stages mentioned above, instead of focusing on the operating/use phase alone.

From the 1970s concept of net energy flow to the current definition of a net-zero energy building, how far have we moved from its ecological origin? Howard Odum outlined the two principles of energy flow—energy hierarchy and self-organization—in his 1971 book Environment, Power and Society. The energy hierarchy is the fifth energy law that Odum proposed: “All systems are organized hierarchically. . . . Energy flows of the universe are organized in energy transformation hierarchies. Position in the energy hierarchy can be measured by the amount of available energy transformed to produce it (Odum 1977). A building or built environment can be viewed as a living thermodynamic organism following principles in the same way any natural or organic organism would follow. To optimize such energy flow and hierarchical organization, we refer to nature as an example, as it is the best method for documenting such hierarchy. For instance, the pattern of a small center aggregating toward a larger center can be found in tree trunks, leaves, pinecone seeds, rivers, and even air bubbles. Biologists have also found that this specific pattern exists in the animal kingdom as well, such as in termite and ant nets (refer to figure 1).
Self-organization is where “the downstream products have less energy to feed back and amplify. In the competition among self-organizing processes, network designs that maximize empower will prevail.”1 Together, self-organization and hierarchy create a centralized hierarchical pattern in nature. Odum described the common systematic development and growth pattern found in the ecosystem: “Systems converge the transformation products to centers spatially, they concentrate these flows so that the feedback out from the centers is concentrated enough to have a strong effect by spreading its useful work over the contributing area.”2 A typical example would be the water and stream flow.

When we examine maps of historical towns and cities across different cultures, regardless of location or environmental conditions, the outputs of small neighborhood centers move towards larger district centers. These district centers then move towards even bigger city centers at the next level. Larger historical metropolitan cities might have multiple city centers, with each center having its associated convergence pattern (see figure 2). This represents not only a principle of geography but also the connection between spatial organization and energy hierarchies.

This ecological principle and systematic thinking of sustainable building has undergone several changes, starting in 2000. Attention has been undividedly given to technologies, advanced building materials, and end-energy usage. The isolated attention and heavy dependency on individual products or advanced building systems was indeed a method to defy the ecological origin and principles of net zero. Despite a higher interest in integrated design and construction and interactions between different building systems, energy flow and building performance have been confined within the individual building boundary and operational phase.

1.0 UNINTENDED CONSEQUENCE ONE: ENVIRONMENTAL IMPACT ASSOCIATED WITH EMBODIED ENERGY

1.1. Missing embodied energy (EE)
Most net-zero building focuses on new construction instead of renovating existing buildings. This might be due to the public’s perception that retrofitting existing buildings is difficult and uncommon as well a lack of awareness and knowledge about embodied energy. Embodied energy is defined as the total energy input consumed throughout a product’s life cycle. Initial embodied energy represents the energy used for the extraction of raw materials, transportation to the factory, processing and manufacturing, transportation to site, and construction. Once the material is installed, recurring embodied energy represents the energy used to maintain, replace, and recycle materials and components of a building throughout its life. Architecture and engineering professions continue to drive down operational energy levels of buildings
through initiatives like the AIA 2030 Commitment. This places greater importance on the energy embodied in the buildings’ materials, which represents a percentage of a building’s total energy footprint. Academic studies have illustrated that embodied energy accounts for most of a building’s energy footprint for approximately the first fifteen to twenty years of a building’s life cycle. The amount of embodied energy in a building depends on the material resources—the origin of construction materials, distance to transport raw materials to the manufacturer, and method for extracting the raw materials. Unfortunately, this area of research has been largely ignored in the current adopted net-zero energy building calculation. To date, no country has code requirements regarding embodied energy requirements for buildings. Several sustainable building rating systems include certain requirements for taking the environmental impact of building materials into consideration, such as LEED and the Living Building Challenge. However, in a study by Marszal et al., only two of twelve net-zero energy building definitions include embodied energy in the primary energy balance (Marszal et al, 2011). The concept of incorporating embodied impacts in the net-zero building design process is particularly important because the typical net-zero energy and net-zero emission concepts used in North America and Asia have only focused on the energy used during the operational stage. This omits implications that arise over the full life cycle (Lützkendorf et al, 2015), and the omission of the importance of embodied energy could create misleading results from net-zero energy calculations.

Figure 2. Map of Lucca city (google earth 2018)

Embracing the embodied energy in the current green building code and rating system is gaining importance as, in twenty years, the majority of buildings in developing countries will reach the end of their service life. In developing countries, like China, the average life span of a building, typically thirty years, is shorter than in developed countries. With such a short turnaround rate—half that of developed countries—understanding the full benefit of net-zero building will facilitate decision makers in making the correct decisions.
1.2. Is new always better?

All buildings will become obsolete at some point. In fact, obsolescence affects a building at any location any time during its life cycle, and building users must adapt the building to every changing condition. Ultimately, as Wilkinson says, all buildings will eventually become obsolete and will require modification to adapt to changes due to environmental, functional, locational, and economic conditions. Then, the question becomes: which is better—constructing new buildings or retrofitting the old? The answer lies in the understanding of embodied energy.

Embodied energy has three different phases, including initial and recurring embodied energy, which were described earlier. The third phase, demolition energy, includes all the energy used to deconstruct a building, transport and process the debris, and dispose of or recycle the used building and assemblies. When the decision is made to raze an existing building and build new, the entire embodied energy of the existing building will likely be lost. Accordingly, the benefits of retrofitting existing buildings have captured the attention of many academics, and a large number of studies have focused on the comparison of different options including adaptive reuse. However, only a handful of countries have taken serious actions toward promoting adaptive reuse and energy retrofitting of existing buildings. For instance, in the United Kingdom, more work is undertaken on adaption than on new building (Egbu 1997, Ball 2002). The high proportion and amount of annual expenditure on building adaption in the United Kingdom and several other developed countries demonstrate the importance of adaption to business and commerce. However, these countries only represent a small percentage.

Adaptive reuse and conservation are frequently discussed in terms of economic, cultural, and design values. Existing historical buildings not only have cultural and historical significance, but preservationists also believe that such buildings carry environmental impact reduction benefits. For instance, a report published by the Preservation Green Lab of the National Trust for Historic Preservation included several relevant findings. In particular, the authors concluded as follows: “Significantly, even if it is assumed that a new building will operate at 30 percent greater efficiency than an existing building, it can take between 10 and 80 years for a new, energy-efficient building to overcome the climate change impacts that were created during construction.” (National Trust for Historic Preservation 2016)

2.0 UNINTENDED CONSEQUENCE TWO: SOCIETAL IMPACT – MORE SUBURBAN SPRAWL AND A GREEN LIFESTYLE?

2.1. Low-density development

New single-family detached houses are an easy target for net-zero energy building. Currently, the most employed renewable energy technology is still the photovoltaic panel, and production of electricity heavily relies on the amount of solar radiation and total roof area that can receive and collect solar energy. Building with a large footprint but less levels certainly presents the best candidate; furthermore, this type of building leads to low density development. One place with low density development is a suburb. People are attracted to suburbia for its bigger lots, quieter neighborhoods, and the idea of being close to nature. However, merely being surrounded by green does not translate to sustainable and health living. Several studies have revealed that the carbon footprint of a suburban neighborhood is much higher than that of a dense urban block. Norman and his research team studied two cases in the city of Toronto, and results indicated that, compared to a high-density urban core development, a low-density suburban development has a higher intensity of energy and greenhouse gas emissions, by a factor of 2–2.4, on a per capita basis. Moreover, the research also recognized that, despite a comparatively low transit ridership for the low-density case, normalized transit energy use/GHG emissions are higher in a low-density context, which is likely due to the greater travel distances required and heavy reliance on diesel buses instead of streetcars and subways (Norman et al, 2006).
A suburban house has a larger footprint and less compact building envelope and consumes more energy on heating and cooling per capita. Additionally, most suburban dwellers use automobiles as their daily commute method. Overall, low density and a large building footprint together create a very wasteful development pattern. James Howard Kunstler called suburbia "the greatest misallocation of resources in the history of the world." (Kunstler 2006). In historical towns, following the law of thermal dynamic flow, the towns tend to have a hierarchical fractal-like pattern that helps create the most efficient energy flow without waste and all important public spaces act as subcenters that connect to one another. However, sprawling suburbia is based on a monolithic design principle, where low-density buildings stretch without a coherent or comprehensively derived pattern and are not connected to others. There are many societal impacts associated with suburban living, such as political fragmentation, a declining quality of community life, and lack of affordable housing. The widespread suburban sprawl has been viewed as an erosion of civic engagement and mutual trust; a loss called “social capital,” which has been studied extensively by professionals and research groups from different fields. Several researchers clearly attributed the decline of social capital in part to the suburban sprawl (Moe and Carter 1997, Calthorpe 1993). A number of forces could influence change on the unsustainable and soulless monotony of the modern suburbs, with energy related to financial costs at the top. More precisely, large households are associated with rising utility bills, and lengthy commutes not only result in increased fuel consumption and high carbon emissions but also increases individuals’ stress due to traffic jams.

3.0 UNINTENDED CONSEQUENCE THREE: ECOLOGICAL DEGRADATION

The third unintended consequence is closely related to the previous two unintended consequences. There are two misleading concepts of net-zero building that may have ecological and environmental impacts. The first is the sole focus on the operating energy. The net-zero approach is generally viewed as a design method of balancing resources drawn from the natural ecosystem, such as energy and water, and the overall consumption of resources within a particular boundary, over a specified time period. More precisely, net-zero building produces the same amount of energy onsite from a renewable source as that consumed by the building. The idea of incorporating embodied energy in the net-zero building design and calculation is particularly important since most current net-zero building only focuses on the operating energy that will be consumed onsite and its associated environmental impact. The environmental impact and energy consumption caused by the production of materials, building construction, maintenance, and end of life are not included as part of the zero balance, although several green building rating systems have begun to show interest. Globally, most building regulations and codes have focused on building energy consumption, with insufficient practical guidance for design professionals about the environmental impact caused by buildings, which can lead to miscalculations. It is possible for a net-zero energy building design solution to have a considerably high environmental impact due to the building materials and construction methods that have been selected (Lützkendorf, et al 2015). For example, Middle Eastern countries rely heavily on foreign companies to supply the curtain wall for most of their high-rise buildings. The energy-intensive manufacturing process occurs outside the property boundaries, thus the transportation/shipping energy is often neglected. A net-zero energy glass building in those extreme conditions may still be possible, simply because the client can have many solar panels installed on the building property, generating electricity to offset the energy consumed.

The second misleading concept is the fact that people regard renewable energy as “free,” as mentioned earlier. Even though solar energy itself is free, it requires the purchase of materials and energy to harvest its energy, with the most popular device being the solar panel. To produce solar panels, we must extract raw materials that are then processed into different types of solar cells using energy. The solar cell manufacturing process also includes several hazardous materials that contain the same types of chemical compounds used in the general semiconductor industry, such as hydrochloric acid, sulfuric acid, nitric acid, etc. These hazardous materials pose a danger to workers, and the chemicals will eventually be released.
back into the environment. As the thin-film solar cell becomes more popular due to its flexibility, awareness is needed of the potential environmental damage associated with the toxic materials in those cells.

4.0. POTENTIAL SOLUTION – ECO-DISTRICT

In order to shift generations’ rosy view of suburbia living being a lifestyle close to nature, an ecological perspective is needed to further examine suburban living. The concept of zero energy is not restricted to individual buildings (Polly et al. 2016) and has already been extended to campus, district, neighborhood and city levels. In dense urban areas, due to buildings having a high volume (height)-to-floorspace ratio, there is not adequate roof area for PV panels that can produce enough electricity for an entire building. The amount of renewable energy available within the building footprint is limited as well. Meeting the net-zero energy goal for an individual building becomes very challenging. Instead, approaching zero energy on a larger scale can provide the opportunity for district energy systems to exploit load diversity between buildings and access renewable energy sources in ways that may be impractical for individual buildings. These so-called eco-districts present the optimal scale to accelerate sustainability to achieve net-zero energy targets for buildings in urban settings with more constraints, and these cities will move from their current eco-districts to net energy districts over time.

CONCLUSIONS

Innovative design approach and advanced technology aim to serve humanity. There is no question that energy-efficient appliances, cars, and lighting fixtures help to conserve energy. Conversely, the high gas mileage of automobiles could indirectly encourage people to drive longer distances simply because of the cheap cost. Detached single-family houses that are one story, car-dependent, solar panel equipped, and scattered over a large area might have a higher chance of achieving the net-zero energy balance. But they require enormous quantities of gasoline for residents to commute between work and home as well as considerable embodied energy per house to construct, maintain, and repair, causing damage to large areas of land. Furthermore, even with energy-efficient appliances, mechanical systems, and high insulation, these scattered and detached houses lose heat and coolness to the surrounding air because they do not share walls, floors, or roofs with other structures. These unintended consequences described above are connected to the building industry’s tendency to treat buildings as individual and independent developments. The current approach to achieve net-zero energy heavily depends on advanced technology and highly controlled building systems, which creates huge financial and technological barriers for many less resourceful projects and building owners. Meanwhile, zoning and planning guidelines do not provide clear direction on how the performance of individual buildings should be assessed based on their impact on surrounding areas or as part of a large urban scale. The limited attempts to create net-zero communities and campuses have hindered bridging the gap between individual building performance and city-wide sustainability.

Understanding the natural environment and human society as one holistic system means viewing parts, processes, and connections as the foundation for all building design types. If we trace the origin of net-zero energy back to its ecological roots, we can consider net-zero building as a guiding design principle for all buildings and a professional ethic for all practitioners. Consequently, it must be perceived as a core consideration and not as an add-on item.

REFERENCES


ABSTRACT: Cities facing the dual environmental crisis of deteriorating water quality and threats of flood from increased rain are realizing the limits of centralized infrastructural capacity, projecting the need for temporary storage of large water volumes for both retention and detention. The notion that many sites should store a certain volume of water for periods from 24-72 hours for landscape-based treatment or delayed delivery to centralized systems—a buffering strategy—drives climate adaptation policies that connect building sites into the performance of urban ecosystems. Emerging urbanisms for decentralized storm water management usually follow standard parameters: e.g. retaining the first 1-inch (2.54cm) of rain during a storm, based on historic data and studies of water quality. As these standard parameters become concretized in the design of individual sites, rain events larger than 1-inch overflows into the centralized system, limiting capacity of the system to historical data and limiting the resilience of the system to future projections. As future rainfall projections intensify, sites will need to expand their buffering capacity. But while buildings still constitute the largest percentage of urban surfaces, their aesthetic, social and performative capacities for storage remains limited. When analyzed against urban scale storage needs, the standard measures of vegetated walls and roofs fall short. Explorations of the potential for buildings to temporary store larger volumes of water on site is fertile territory for new forms of urban architecture integrated to decentralized urban ecologies. This paper seeks to elucidate the idea of stormwater buffering at an architectural scale. A literature review provides various definitions and uses of the term buffering at a landscape scale, reveals the most relevant policy challenges that promote or limit strategies for buffering at various scales, and identifies the most common technical strategies and performance criteria to evaluate their capacity, environmental, experiential and aesthetic effects.

KEYWORDS: Decentralized, buffering, stormwater, storage, architecture

INTRODUCTION: THE WATER STORAGE PROBLEM

The recent discourse on the resilience of the built environment is heavily focused on the external threats of large water bodies: seas rising, rivers swelling, cities sinking, and delta cities disappearing to the loss of land caused by erosion from repeated storm surges—problems that require mega projects of reclamation, ecological restoration, infrastructure, and potentially the massive relocation of vulnerable populations. Those are real problems, and many researchers and designers are doing important work on modeling, predicting, mapping, speculating, prototyping, testing and designing for those situations. Many of the solutions operate at large regional landscape scales, occupying the time of landscape architects, civil engineers, and urban planners. But there is another set of climate change related problems and solutions operating at much smaller and localized scales: the increase in frequency and severity of rain events in urban environments and the excessive runoff generated on impervious surfaces that overwhelm urban systems from within. While these challenges are connected, e.g. storm drains backing up as a consequence of sea level rise, and will be made worse by them, rivers carrying urban runoff overflowing into cities downstream; many cities are facing the dual environmental crisis of deteriorating water quality and threats of flood from increased rain falling in their own space and running off their own surfaces.

Centralized infrastructure for stormwater—the pipes that carry water away from the source—has a maximum capacity for flow rate (volume of water per unit of time), and when that capacity
is exceeded, i.e. too large a volume in too short of time, it will back up closer to its source. The solutions are to either increase capacity of volume conveyance, or increase the time to get into the system. This can usually be solved with detention, or the temporary storage of water to give the system time to move the initial load and open up capacity again. Due to limited capacity of centralized infrastructure in many cities, there is an emerging need for temporary storage of unprecedented volumes of water to manage larger and more frequent storm events. Rotterdam, for example, has described a shortage of 600,000 cubic meters of storage, or the equivalent of 200-acres of additional lakes and canals to store the projected excess rain water that their centralized system will not be able to handle (Municipality of Rotterdam et al. n.d.). In Chicago, one of the largest infrastructural projects transformed large old quarries into temporary stormwater storage, delivered in massive tunnels underground (Metropolitan Water Reclamation District of Greater Chicago n.d.) to delay conveyance to the treatment facility while the main system is over capacity. Intercepting and storing runoff requires understanding site-specific dynamics at scales from a building lot to a block to an entire watershed. In its gravity-led journey water can evaporate from impervious surfaces, drain into tanks, saturate soil, evapotranspire from plants or infiltrate through pervious ground surfaces into lower aquifers; and in that path it removes, carries and deposits materials, nutrients and contaminants wherever it goes. There lies the other side of the problem: contamination of underground or surface water bodies, especially where stormwater combined with sewer overflows without treatment.

The solutions to storage usually need to address the issue of quantity (how much and where and for how long) and quality (if and how to clean it during that time). In both cases it is preferable to do so near the source. Increasing capacity of centralized infrastructure to convey and treat all stormwater uses large amounts of embodied and operational energy and may need to rely on chemical treatment, while building large-enough retention and filtration landscapes that handle all the water excess and treat it biologically requires land areas that are often not available. The most feasible and resilient method is to find a way to slow down water closer to the source so that it does not all come to the system at once, and to use that time for treating, biofiltering and even polishing water with decentralized but intensively engineered landscape-based systems. This approach of green over gray infrastructure can have the co-benefits of socio-ecological resilience: more legible and multi-functional environments that provide protection from heat island effect while increasing the aesthetic and ecological performance of public space. Many cities have implemented regulations requiring sites to keep some amount of runoff on site, the often cited first one-inch of rain. As cities continue to grow and densify, buildings will need to become part of the solution to storage and infiltration. Some designers and planners facing daunting projections for rain volume and/or water quality are acknowledging these limits and innovating, but the scholarship of this work is limited.

This paper critically examines the limits of landscape-based strategies for buffering stormwater at an urban scale, and explores the potentials and opportunities for a more ambitious program of research into the tectonic, spatial and urbanistic implications of architectural stormwater storage to extend the capacities of urban landscapes. This problem is increasingly relevant to the architecture profession and provides an opportunity for place-making, policy-making and advances in building technology.

1.0. LITERATURE REVIEW
This paper seeks to elucidate the idea of stormwater buffering at an architectural scale by examining technical paremeters, policies, and current design practices of stormwater buffering; and speculating a future agenda for the discipline. The literature review provides various definitions and uses of the term buffering at a landscape scale, reveals the most relevant policy challenges that promote or limit strategies for buffering at various scales, and identifies the most common technical strategies and performance criteria to evaluate their capacity, environmental, experiential and aesthetic effects. Examining multiple peer-reviewed articles and books of case studies had two objectives: identify how many of these projects are...
purely landscape-based versus how many are affiliated or integrated into buildings; and evaluate the potential contribution of buildings to stormwater buffering. The search for case studies started with peer reviewed articles from leading journals and reputable presses specifically focused on design with water in the last ten years. Various searches of multiple combinations of keyword including design, decentralized, stormwater, water, in the previous ten years yielded a number of publications that were narrowed down to those including designed projects. The search concluded when a few projects started to appear more than once. In several publications that look at this issue broadly, the case studies were only mentioned as examples without offering other specific criteria or analysis. To the extent possible this research tried to identify additional sources on these case studies to obtain, analyze and compare similar criteria for all projects. The search resulted in 79 case studies, of which 38 were exclusively landscape projects (48%), 17 were exclusively architectural projects (22%) and 24 were a hybrid of architecture and landscape on a surrounding site or urban proposal (30%). By cataloguing a broad range of building practices – this type of research identifies and organizes knowledge from practice; and generalizes challenges, opportunities and future directions needed in education, policy and design thinking. Finally, the paper discusses the implications for current and future architectural practice, including limitations and potential contributions to the socio-ecological resilience in the face of climate change, typical challenges for retrofit, and strategies not yet explored in the repetitive architectural fabric; and points towards ways that architectural education can engage more rigorously with this problem.

1.1 Buffering
The etymology of the word buffering stems from the word buff, which means “to react like a soft body when struck;” thus the verb buffering refers to lessening the shock, or serving as a protective barrier or a cushion against the shock of fluctuations (“Buffer” n.d.). Some researchers define buffer-based solutions to the urban stormwater runoff problem as increasing hydraulic capacity of underground drainage, while measures that reduce volume and intensity of runoff using blue-green infrastructure (buildings and landscapes acting as storage) are considered “surface-based” (Haghighatafshar et al. 2018). But this distinction is redundant with, for example, the distinction between green and gray or soft and hard infrastructure, which refers to both storage and treatment using biotopes (plants, bacteria, and living systems in general) as green or soft, and those using concrete pipes, tanks and chemical treatment as gray or hard. What both green and gray methods of storage have in common is buffering – that is, to protect the system from momentary shocks while allowing the system to work far below capacity otherwise. The term buffering was found more often in European literature to refer to the decentralized storage of stormwater, and was used in both cases of gray or green infrastructure, and in many hybrid examples. But the concept is well known and applied in the United States and other parts of the world, albeit with more of a focus on the traditional landscape-based strategies. These strategies are called Low Impact Development (LID), Best Management Practices (BMP), Sustainable Urban Drainage (SUD), Water Sensitive Urban Design (WSUD), Integrated Catchment Planning, and Ecological Stormwater Management (Stahre 2002; Backhaus and Fryd 2013), and variations of these names have been customized to some location-specific programs, such as the Natural Drainage Systems in Seattle (Tackett 2009). These are all designed to manage time, essentially increasing what is called the time of concentration to delay storm peaks of flow. These versions of stormwater management strategies are embedded in policies that promote forms of spatial planning and urban design that connect place-making that combine open space planning, climate resilience planning and infrastructure.

1.2. Policy and regulations: design parameters for emerging urbanisms
The notion of storing a certain volume of water for periods from 24-72 hours for landscape-based treatment or delayed delivery to centralized systems—a buffering strategy—drives climate adaptation policies enforced through construction permitting processes (LaRoss 2016; United States Environmental Protection Agency 2016a), integrating building sites into regional landscape performance. Emerging urbanisms for decentralized storm water management usually follow standard parameters: e.g. retaining the first 1-inch (2.54cm) of rain during a
storm. In regulations, the 1-inch (or equivalent) is usually referred to the “water quality volume” (WQV) – a specification in volume-based retention requirements (United States Environmental Protection Agency 2016b) which describes the depth of rainwater runoff over a certain area (D·A=V) that needs to be retained on site to effectively reduce runoff to pre-development levels. EPA regulations of Municipal Separate Storm Sewer Systems (MS4s) usually refer to a groundwater recharge volume (GRV) – or the volume that makes it into the ground through infiltration after all other losses. A report by the EPA on the regulations of different states identify what states use a specific depth of runoff in the requirement (50%) whether they require a volume of recharge or a volume of treatment, and what those quantities are (Fig.1). The 1-inch runoff depth requirement has a number of explanations. Reports by the EPA cite, for example, that the stay-on volume 60-years of data show that 90% of rain events in a specific place like West Virginia are under 1-inch. (United States Environmental Protection Agency 2015a) 1-inch has been found in some areas to be the depth of infiltration through plants at which most contaminants are removed, so that any remaining runoff going untreated into the stormwater sewer system is relatively clean. But that is not true everywhere and is likely dependent on soils, contaminant type and concentration, and the human use of groundwater. In some states, there are options for payments in lieu of on site retention, and this has paved the way for studies on the valuation of stormwater retention on site. One of these studies indicates that the GRV typically ranges between 0.5 and 2 inches, and are valued based on the cost of extraction of raw high quality drinking water from the aquifer (Tetra Tech and Tetra Tech 2016). Not all cities use groundwater for extraction, but some depend on keeping groundwater levels at certain levels to protect historic structures (Laboy 2017) or to prevent subsidence.

In the past decades, these policies inspired forms of urbanism that used sites around buildings to store, biofilter, and infiltrate stormwater in legible and experiential ways. The city of Malmö in Sweden is a well-known example of early forms of this urbanism developed in the late 1990’s (Fig.2a), and modeled on the U.S. EPA’s BMP’s for Low Impact Development. Residential buildings with green roofs are surrounded by open spaces with channels, bioswales, dry ponds and infiltration areas. Since, regulations in the UK and Sweden required community amenities as part of decentralized stormwater systems (Echols and Pennypacker 2015) combining ecological and social infrastructure. These urbanisms, even in dense European cities, rely on sufficient open space. In the United States, most jurisdictions have a threshold of 1 acre of disturbed or developed land to trigger these requirements, with the exception of nine states that use smaller thresholds between 0.1-0.2 acres (United States Environmental Protection Agency 2016a). In most municipalities in Germany, where decentralized stormwater systems are more widespread, regulations require building owners to pay for stormwater they discharge (Miller 2008), incentivizing implementation of innovative strategies through a “stick” approach, even in dense city centers.

There are two regulatory thresholds that limit the use of buildings as part of buffering strategies: the type/size of disturbance and the perceived practicability of implementation. The EPA requires controls and removal of pollutants to the Maximum Extent Practicable (MEP). MEP is ambiguously used, referencing Best Management Practices (BMPs) that should be applied in a “site-specific, flexible manner, taking into account cost considerations as well as water quality effects” (United States Environmental Protection Agency 1999). This regulation advocates for performance requirements rather than prescriptive design standards for small jurisdictions; but the agency’s lists of practices prioritize green infrastructure, which are mostly landscape-based, and only involve the building itself in green roofs, downspout disconnection and rainwater harvesting – tools described as not requiring infiltration (United States Environmental Protection Agency 2015b). Regulations in cities like Berlin, Seattle and Malmö try to build flexibility into the process of achieving decentralized stormwater goals (Lennon, Scott, and O’Neill 2014). For example Seattle uses a score-based systems that apply numerical factors (fractions of 1) to various strategies, which must add up to a specified number based on zoning designation (“Seattle Green Factor - SDCI | Seattle.Gov” n.d.). Some of these regulations incentivize the use of building surfaces (roof and walls) to reduce volume, while others place
unintentional disincentives to their use by keeping outdated performance criteria that these are less likely to meet. For example, while the Green Factor regulation relies mostly on landscape strategies (e.g. landscape-based bioretention facility is the only area that can achieve a 1.0 factor) these regulations apply substantial factors to two building-related strategies: green roofs and vegetated walls. In European countries, like France and the UK, source control policies, based on infiltration and regulated as a required volume are considered better than flow-rate policies because of pollution control; but policies that provide different paths can unintentionally incentivize the flow-rate path because the lack of specificity on volumes (or policies that imply zero-runoff) can be considered disproportionately by developers (Petrucci et al. 2013). The definition of specific volumes for storage/retention, while allowing flexibility of methods, may provide the necessary clarity combined with perceived practicability, to incentivize strategies that use buildings to temporarily store water while leveraging small areas of landscape for infiltration over longer periods of time. In Chicago, a city ordinance recognized green roofs as rainfall runoff control measure as a method to significantly reduce volume, where they are most effective; but previous requirements for runoff rate control remained, reducing the overall contribution of green roofs to compliance (Miller 2008). That is because green roofs reduce the frequency and severity of peak flows, especially in the smaller and more frequent storms, but it has less effect in meeting regulations based on historical detention approaches, which prioritized rate control for larger storms usually through larger ponds or detention tanks (United States Environmental Protection Agency 2009).

![Figure 1.](image_url) Figure 1. (a) Types of stormwater regulations in the United States include: volume of runoff reduction, and treatment of the runoff requirements. These stipulate the amount of volume based either on a depth of runoff (e.g. 1-inch of rain) or on parameters of storm size or flow (e.g. 10-year storm—a storm with a recurrence interval (probability) of 10 years, and/or the volume of rain that is in the 90th percentile). (b) Most standards that use depth of runoff are 1-inch, or close to 1-inch. Graph by author based on data published by the US EPA (United States Environmental Protection Agency 2016a).

The implementation of these regulations for stormwater storage or retention on site creates a network of site-specific infrastructures that provide a buffer to the centralized gray system during most common storms (around 1-inch). As these standard parameters become concretized in the design of individual sites, rain events larger than 1-inch overflow into the centralized system, limiting the capacity of the system to historical data and the resilience of the system to future projections. As future rainfall projections intensify, sites will need to expand their buffering capacity. A study modeled pre- and post-retrofit storm water in Augustenborg—an SUD project implemented in an area of Malmö between 1998-2002—and found the amount of infiltration to be about the same, speculating that the similarity was due to the infiltration that occurred pre-retrofit in broader unintentionally flooded areas (Haghighatafshar et al. 2018). The main benefit of the retrofits appeared to be a reduction in water in the pipe-bound system to less than half, with other volumes detained in blue-green systems (Haghighatafshar et al. 2018). This study found that green roofs in these projects contribute by reducing peak flows between 13% and 64% for the 10-year and 1/2-year storm respectively. In Malmö, centralized storm water systems were designed for the 10-year recurrence interval storm, which is about 26mm (1inch) in 1 hour; but now it is recommended
that a climate factor is applied to increase this number (Haghighatafshar et al. 2018). More intense rains, called cloudbursts, can deliver approximately this much rain in 20 minutes (Haghighatafshar et al. 2018). The type of urban planning in the area of Augustenborg has proven effective at controlling floods. When a 50-year flood affected Malmö in 2007, being cut off from the rest of Sweden, Augustenborg was not affected, not only protecting themselves retaining water that did not cause bottlenecks further down the centralized stormwater system ("Urban Storm Water Management in Augustenborg, Malmö — Climate-ADAPT" n.d.). While this project delayed and reduced peak and total volumes, one shortcoming of the Augustenborg project was that the open channels between existing residential buildings in the development had to be lined with geotextile fabric, reducing the potential for retention on site, in order to protect adjacent buildings. This limitation of managing storm water in close proximity to buildings represents a consistent barrier to on-site retention, which can only be addressed by better design of buildings.

**Figure 2 a-c.** Three scales of buffering urbanism: (a) Left: Stormwater strategies in Malmö, Sweden extend to the building edge. Photo: La Citta Vita. (b) Center: Temporary flooding of basketball court at the Waterplein Bentemplein in Rotterdam by De Urbanisten (2013). Photograph: Stadlanschaft. (c) Right: Qunli Stormwater Park, Heilongjiang Province, China. Photograph: Turenscape.

### 3.0. DISCUSSION: LIMITS AND LATENT POTENTIALS OF ARCHITECTURAL PRACTICES

Landscape architects have proposed centralized landscape-based systems for stormwater management in cities, for example in Qunli New Town in China (Fig. 2c), where a recently built stormwater wetland park will presumably manage the projected volume of stormwater for a future urban area ten times the size of the park, leading designers to speculate that if a city can "allocate 10% of the total area as green sponge area for stormwater management, it can virtually solve the problem that is commonly seen in contemporary cities" (Turenscape 2017). While these projects do allow an understanding of the potential territorial scale of these solutions, there are limits to these comparisons because these projects do not scale up or down the same way in all places, based on climate and geology among many other variables. What may be feasible in completely new cities designed from scratch like Qunli, is very challenging in existing cities where stormwater infrastructure is already in place and intertwined with buildings, landscapes and other infrastructure. Speculative landscape-scale proposals for post-disaster recovery in delta cities, like Sponge Urbanism in post-Katrina New Orleans, examine the capacity of adaptive networks of high density plantations with underground storage to absorb ecological and social fluctuations (Sowell and Wiedemann 2009). Others identify low points, where rebuilding is less likely, to suggest a new landscape-based program of economic and ecological productivity (Mossop 2014). Both leverage empty land as an alternative to current forms of retrofitted high-density urbanism, which still rely on rebuilding buried canals and pump stations along road medians (Sewerage & Water Board of New Orleans n.d.). The speculative projects explore what can be achieved with living-systems at a landscape scale, but neglect the existing social and human capital that still aspires to rebuild their neighborhoods one house at a time.
Hybrid proposals operate at intermediate scales. In delta cities like Rotterdam, the city’s climate initiative is based on the model of a water square, following new logics for urban design that transform below and above ground water storage into innovative design of public space in new developments (Bokern 2014). These squares are intended to combine green and gray infrastructure to maximize infiltration of stormwater, known as groundwater recharge (Laboy 2017), but also to transform conventional storage basins, which temporarily store water until the centralized system has capacity to deliver the excess runoff, into inundable public spaces with recreational programs (Fig.2b). A limitation of this model is the perception of cleanliness in the public space post inundation (Rotterdam Climate Initiative 2014); and that adjacent buildings only connect to this system by sending their roof runoff, but do not contribute to the storage capacity. The tunnel project in Chicago is an example of buffering at an urban scale, but the city is still pursuing pilot projects for street green infrastructure, which demonstrated significant capacity for reducing reliance on centralized systems and expanding decentralized networks (City of Chicago 2012). The project of the Benito Juarez School is an example of architecture that begins to engage with the green street at Cermac Road by amplifying its space and performance into the front landscape of the school, a very legible space where rainwater from roofs and plazas are biofiltered and infiltrated. However, beyond supplying roof runoff, the role of the building remains limited.

While many of these projects leverage the site of new buildings, buildings themselves rarely connect to or expand these ideas, driven by the long-standing defensive position that buildings take against water (to keep it out), and most matters of stormwater management and site relegated to separate client-owner contracts with the civil engineer and landscape architect. A critic of this is Herbert Dreiseitl, an artist and landscape architect who considers it rare or exceptional for architects to address other water themes, except liking sites on the water’s edge for experiential reasons, and suggests they are more likely to see water as “a hostile force that damages their buildings.” (Dreiseitl and Grau 2009, 44). David Leatherbarrow confirms that view: “Water is also the building’s greatest enemy, a foe that eventually victorious in every single case,” (Leatherbarrow 2014) while advocating for the acceptance of continual change and alteration of buildings over time, but limiting his references to LeCorbusier projects as formal and visual metaphors of maritime or nautical structures. Another writing referenced two examples: the city halls of Austin and Seattle, to illustrate how architecture reflects the politics of urban runoff: Austin’s City Hall uses materials that reflect the layers of its aquifer, while Seattle’s has an artificial waterway running through the building, a “deliberate and visible recognition of the importance of nature to the political culture of these cities” (Karvonen and Gottlieb 2011). Most examples where architecture acknowledges this aspect of the site are mostly limited to legibly and physically celebrating the path of stormwater to the landscape, whether through sculptural scuppers that project or vertical channels on the façade. A more promising view is provided by Marion Weiss who describes water as “volatile, fragile, violent, serene, elusive, ubiquitous, nourishing, devastating and fundamental to life;” and that architecture had to do more, to “somehow reveal the more powerful forces that were once at work on the site” (Weiss 2014), evident in examples Weiss cites, like the Museum of Earth, the McCann residence and the Brooklyn Botanical Gardens, where architecture adopts forms from the landscape to slow down water. These examples show that even in the best case architects limit the potential of buildings to being a metaphor, just a mere part of the path in the hydrological cycle, or a reflection of landscape forms, rather than becoming a performative instrument of the landscape.

Landscape-based approaches may “undermine compact city policies through a greater emphasis on multifunctional green space provision and less intensive urban development patterns” and require urban design that reconciles these competing goals (Lennon, Scott, and O’Neill 2014). Unfortunately, while buildings still constitute the largest percentage of urban surfaces, their aesthetic, social and performative capacities for storage remain limited. In existing cities where there is no additional open areas there is a potential to leverage architecture to become a vessel for stormwater storage in ways that also create socio-ecological resilience. This design and planning challenge has been dominated by the
disciplines of civil engineering and landscape architecture, as evident in the review of many projects that have masterfully combined aesthetic and environmental performance (Backhaus and Fryd 2013), but which are mostly limited to constructed basins, meadows, swales, wetlands, street gutters and channels, open water elements, dry infiltration areas, water playgrounds, water fountains, around or adjacent to building developments that either infiltrate or connect to natural water bodies. The literature review revealed that most case studies still follow a fairly traditional landscape approach to green infrastructure. The majority of architecture projects examined had limited agency in the landscape-based systems, sometimes relying on landscape courtyards, green roofs, green walls inside and outside of buildings (mostly limited to university buildings, retail and commercial office space) and sculptural conveyance of stormwater to adjacent landscapes. Temporal limitations need to be considered, as green roofs tend to be less effective in Winter, Spring and Fall, when evapotranspiration rates are much lower and there is less capacity for storage; and in back-to-back events; but they would better resemble the natural hydrological cycle if they were combined with other practices for groundwater recharge (Van Seters et al. 2009) in multi-tier strategies of storage. Furthermore, these are likely less effective in areas with extreme rains (monsoons or tropical storms) (Miller 2008), raising questions about how much these alone can contribute in a future where climate change causes more extreme rain events in more areas of the country. However, climate change is likely to cause both extremes of extreme rain and drought, and a good buffering strategy could consider not only the temporary storage of water for flood control and water quality, but also a more strategically timed release in times of drought to better manage the groundwater levels and risks of heat island effect. A handful of hybrids are emerging that begin to leverage architecture in a more integrated way: the Institute of Physics at Humboldt University in Berlin and the Prisma Nurnberg, both in Germany, stood out for managing all water on site, combining building and landscape strategies for storage and treatment within relatively limited footprints, and actively including rainwater as part of the thermal comfort and experience of the building.

Beyond these notable examples, most of architecture is generally in the “gray infrastructure” equivalent of stormwater management: relying on pipes and cisterns, rarely including biotreatment or integrating the process into the user experience. A literature review by urban ecosystem researchers in Australia proposed a green-to-gray horizontal continuum, represented in section, from the surface water body with low vegetation (green) to the building (gray) where the building (gray). The building is only represented as the surface of façade and roof, and both the building and the adjacent street were drawn as gray, with “man-made” vegetation applied to the surface. The open space is situated between the “natural” water body and the gray environment of street and building, with trees that are labeled as “naturally created” (Bartesaghi Koc, Osmond, and Peters 2017). But in most places in the world neither the water bodies nor landscapes are naturally created, having been modified, and in many cases requiring just as much construction and maintenance as the gray environments to achieve high performance. Man made or engineered vegetation on the building surface can be just as wild and unpredictable as the vegetation in other spaces deemed more natural, being part of a complex urban ecosystem. Starting from the premise that these are all constructed environments that combine living and non-living systems, a common goal is for the urban environment to perform like the pre-development landscape, or in some cases outperform it. But when analyzed against urban scale storage needs, the standard measures of common vegetated roofs fall short, meeting less than half of this minimum 1-inch (2.54cm) requirement (Happe 2005). The potential for buildings to temporary store larger volumes of water on sites continues to be fertile territory for new forms of urban architecture integrated to decentralized urban ecologies. As Charlie Miller said:

Ultra-urban environments can begin to emulate the performance of natural, undeveloped landscapes...buildings can become as efficient as forests in how they use the precious water resource. (Miller 2008).

Patrick Blanc, the botanist researcher that practices the design of green walls, observes that the height of many urban buildings, especially in cities like Paris, is comparable to the height of many trees in forests and their surface similarly shaded—suggesting that these surfaces can be manipulated and designed to grow certain species of plants— a design strategy that
has been subject to critique as simulacra that lends “some degree of eco-lustre irrespective of their actual functions” (Gandy 2010). This critique may be well deserved, especially when these systems use potable water and fill it with fertilizers that can worsen the quality of runoff; but the skepticism in the architecture field may be due to the fact that most research on the performance of these systems resides in other disciplines, and that the architecture discourse pays more attention to the formal and visual effects and much less to post-construction performance measurements.

4.0. CONCLUSION
This research points to the potential for storm water buffering at an architectural scale, suggesting that innovative architectural projects can be instruments of the landscape. Cataloguing strategies and projecting their environmental performance reveals potential future directions in design research that can examine their social and aesthetic performance, as well as other potential benefits for buildings thermal, seismic, and energy performance. As the legacy of 1-inch urbanism needs to expand to become a 2+inch urbanism, architecture will become the only next available space to innovate in stormwater buffering. A change to performance-based regulations rather than prescriptive volumes may be one solution to leverage high capacity sites and compensate for lower-capacity ones. Improved modeling based on downscaled sampling of climate projections could inform more sophisticated and site-specific design. All of this requires a field of research that can inform practice, and a professional field that understands the science and technique of stormwater buffering. Design education will need to engage interdisciplinary projects where the qualitative and quantitative aspects of this challenge are explored. This is a task that this author has undertaken, working with architecture, landscape architecture and environmental engineering students in real sites with real clients to demonstrate what may be possible; although pedagogical implications are subject of another article. Nonetheless, this research suggests that there is space for researchers and educators to advance the architecture discourse and practice towards more effectively and controllably buffering stormwater.

REFERENCES


Balancing performance and aesthetic: data-driven design for fixed shading devices

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ABSTRACT: This paper presents a new workflow to optimize a fixed shading device to reduce thermal loads so that performance and aesthetic can be balanced while exploring various shading forms and typologies during any stage of design. The south wall of a prototypical mid-rise office building zone per ASHRAE 189.1 criteria in Albuquerque, New Mexico is studied by extracting annual hourly heating and cooling data generated by Energy Plus. This new workflow is tested against other existing methods of shading device design in terms of performance and aesthetics. The workflow presented in this paper demonstrates the optimization of fixed shading devices for cooling and heating loads without limiting aesthetic options or the shading device typology at the beginning of the process. This workflow produces iterations that perform similarly in terms of energy savings so that a designer can select a shading device based on other criteria such as aesthetic concerns or constructability issues. The user can move between different shading typologies and add their own creative, artistic interpretations, while not being required to run many simulations after each design change. This paper demonstrates a process that is more in-line with the building design process. Foundational works in the field of other shading device design methods are included to provide a point of comparison between existing practice and the proposed workflow.

KEYWORDS: Shading Device, Aesthetics, Thermal Loads, Optimization, Design Process

INTRODUCTION
A survey of mostly European architects reported that 82% of respondents indicate solar energy aspects were important in their architecture practice, while at the same time 72% rated themselves as poor or very poor in using advanced tools. Most respondents preferred graphical design methods and tools with user-friendly design interfaces (Kanters, Horvat, Dubois, 2014).

Many designers aspire to holistic goals not dissimilar from the sentiment expressed by Peter Zumthor in *Thinking Architecture*, "Form and construction, appearance and function are no longer separate. They belong together and form a whole" (Zumthor, 2015). Designers, like Zumthor, are not looking to merely design shading devices that perform in terms of reducing thermal loads, but also in terms of aesthetics responding to the wants, needs, and feelings of people who come in contact with the design. John Ruskin highlights this concept in the dichotomy between building and architecture in *The Seven Lamps of Architecture*, "Building does not become architecture merely by the stability of what it erects" (Ruskin, 1857). For Ruskin, what defines architecture is pushing a structure beyond mere performance and into the realm of aesthetics and culture.

The shading device is not an insignificant part of a work of architecture. Victor and Aladlar Olgyay, having lived through the modern movement in architectural practice, highlight how changing building practices have created a greater need for adequate shading than perhaps ever before.

The single window, liberated by the structure, instead of remaining a fenestration becomes a window wall. Man is presented with a psychological sense of freedom, unrestricted views, and a variety of special relations. But this transformation has brought some new problems- or rather old problems in sharply enlarged magnitude of controlling the sun's radiation. (Olgyay and Olgyay, 1958).
The increased use of glazing in architecture has created an abundance of solar heat gain during more hours of the year. Marcel Breuer was certain that society would not give up its new conception of open architecture that the shading device would have to become the new Doric column, an element necessary to the performance of the building and with the potential to become an exterior architectural element (Breuer, 1956).

This paper critically examines existing shading device design methods in the context of this holistic mindset and develops a new workflow to facilitate solutions that balance performance and aesthetics. Performance is defined by this paper as the ability of a shading device to reduce thermal loads. Aesthetics is defined in this paper as the amount of freedom the design method grants the designer in creating the shading device geometry.

1.0 EXISTING METHODS

1.1. Climate design method
Victor and Aladar Olgyay (1958) pioneered the shading device design method that this paper calls the ‘Climate Design Method’. Their method focuses on combining climate data with shading design in a graphical manner. As currently implemented first running an energy simulation for the zone that contains the window that needs to be shaded, and from this simulation a balance point can be established, which is the outdoor air temperature where thermal loads are close to zero. This balance point can be used to evaluate all hours of the year for overheated periods and overlaid onto a sun path for the location of the zone. All sun hours where the outdoor air temperature is above the balance point represent times where additional heat gain would negatively impact the overall thermal load of the zone and therefore should be shaded. The designer can select from a range of shading typologies, each with a different shading mask. The goal is to match the best shading mask to the sun path with hours that need to be shaded overlaid. The shading mask guides a designer to select a shading typology and allows the designer to size that typology to respond to total thermal loads in a zone (Olgyay and Olgyay, 1958).

Others such as Elhinnawy and Abdou (2004) integrated Olgyay and Olgyay’s methods into digital tools to allow for the quick application of the graphical climate method to different projects. Since this point more modern tools such as Honeybee, a plugin for Grasshopper for Rhinoceros, (Sadeghipour Roudsari M., Pak M., 2013) allow designers to replicate the Climate Design Method much more easily.

One benefit of this method is; only one simulation needs to be run to gather the data to begin design. The simulation and graphical analysis on the front end of the process actual help guide the design towards a solution that will work in terms of performance while keeping the design itself more flexible to be interpreted in creative ways. However, a drawback is this method does generalize data to fit rectilinear solutions and does not easily support more complex designs.

1.2. Iteration and genetic optimization method
A more recent shading design design method begins with a predefined shading device form and finds an optimal design through iteration. Tools such as Sefaira, owned by Trimble, attempt to do this by iterating simple shading device typologies such as simple horizontal overhangs and vertical shading over ten or less ‘steps’ using only the depth parameter to create these steps/iterations. Each step is evaluated on a criteria that is output by the simulation software and selected by the user. The best performing design can be selected. The design firm Payette has done a study retroactively looking at the sizing of a louver system in one of their past projects. They created 36 iterations with the parameters, louver spacing, and depth of the louvers and created a weighted average score to combine the criteria including heating loads, cooling loads, and daylight levels to select the best performing option (Hinchcliffe, Korah, 2012).
A drawback is this method requires many iterations and simulations to be run for every design iteration. This method can be extremely difficult for someone in practice to navigate when time is limited. Genetic optimization attempts to bridge that gap by creating iterations for the designer and generating these iterations, not by running every permutation but by trying to learn with each generation of iterations to achieve the goals set in the beginning. Even with this measure, the structure of the method remains the same and often still requires a prohibitively high number of simulations. One study implemented genetic optimization to design a complex concrete shading screen, and succeeding in creating a unique architectural solution that also performed very well compared to more traditional shading forms. However, it utilized over 3000 simulations to achieve this design (Andrea, Andaloro, Deblassio, Ruttico, Mainini, 2017).

Another drawback is; changes in design become time consuming. For example, a switch to a new shading typology or the building form changes enough to impact the energy model seriously, the designer must restart the from the beginning. This makes this method extremely inflexible to changes that are all but guaranteed to occur within the normal design process. This method is capable of producing very complex and custom shading forms which could respond very well architecturally. However, if the designer has no past knowledge of shading device design, they could be led to optimizing a typology that would not function as well as another in the same situation, such as vertical shading on the south façade in the northern hemisphere as opposed to horizontal shading. This process does not help the designer make informed decisions about what form the design should take in the beginning of the process as the Climate Method does, but instead optimizes within a user-defined pool of options.

1.3. Cell method
This method evaluates a shade cell by cell and displays the results in a color gradient map on the shade itself. This instant graphic feedback allows a designer to understand which parts of their design contribute to reducing thermal loads, which parts increase thermal loads by blocking cells that would have had a net positive impact on the thermal loads of the zone, and which cells do not help or hinder the goal of reducing thermal loads. This feedback can be used to confirm a design is functioning or can be used to edit a design to make it perform better. SHADERADE is the basis of the tool found in Honeybee. SHADERADE takes the question of when a shade is effective and transforms it into a question of where is a shade effective by calculating the net thermal load for each cell in a volume near a specified window. This cloud of cells in mapped onto a shade that is created by the user, evaluating it for refinement (Sargent, Niemasz, Reinhart, 2011).

The initial design is not informed by project-specific data. Like the Iterate method, this method relies on the background knowledge of the designer to start with a form that makes sense for the situation and does not provide guidance before the design occurs. Unlike the Iterate method this workflow does provide quick feedback shortly after the design occurs allowing time for revision, however, this becomes more of a guess-and-check method for those without knowledge on the subject. Second, this method is constantly revising the designer’s inputs which means the computer has the last word on the design. It is less of a collaboration between equal parties and more of a conversation where only the designer or the computer can speak at one time, in contrast with the Climate Method where the graphic analysis in the form of the shading mask guides the designer to create a design that performs while promoting freedom to choose a path.

Additionally, the method has limitations that affect the possible design outcomes. The current application in Honeybee cannot support more than one window or shade surface at a time. This is due to how SHADERADE calculates each cell independent of each other, regardless of whether a neighboring cell has been shaded or not. This means any shading form or system that would be self-shading will not be accurately created under this method. Louver systems and screens, among the most common, are not supported which imposes severe restrictions of design for the user (Sargent, Niemasz, Reinhart, 2011).
2.0 PROPOSED VECTOR METHOD

This workflow begins with an unshaded energy model of the zone, step 1 in Figure 1. This model is used to create a shading mask to guide design exploration. The Vector Method takes inspiration from the Cell Method’s specificity and instead of evaluating every cell, evaluates every sun vector and matches the direct solar radiation passing through the window with the cooling load during the same hour. If there is no cooling load or direct radiation then an hour is culled from the list. A user-defined threshold is introduced to allow a designer to determine how sensitive a design needs to be towards cooling loads. If the threshold is set very low or not set at all, then most or all hours with cooling loads and direct radiation will be included in the shading mask, if the threshold is set higher only the hours with the highest cooling loads will be included. Often there exist hours with more extreme sun angles that do not contribute much to the increased cooling load in a zone and would create a larger mask without providing many benefits. Reducing the data to the highest set of cooling hours reduces the size of the mask and allows more direct sunlight to enter during times when the heating load is dominant. Determining which hours to shade occurs in step 2 in Figure 1.

Once each hour where shading is needed is identified, the position of the sun can be determined according to solar calculations through Honeybee using RADIANCE using the project’s location to determine for all daylight hours where the sun is relative to a single point on the ground. The Sun’s altitude and azimuth angles at each designated hour can become points \((X,Y)\) and a designated \(Z\) height above a prospective window. These \((X,Y,Z)\) points are the same as vectors originating at \((0,0,0)\), step 3 in Figure 1. By taking the profile of this set of vectors a flat shape a \(Z\) height that represents all solar vectors at all times that need to be shaded can be established, step 4 and 5. Extruding the profile of the window or area to be shaded along each vector and joining each extrusion results in a three-dimensional shading volume that can be interacted with in modeling space, as any other architectural element. The mask shown in step 6 takes into account the geometry of the window, orientation, and data filtered from the initial energy model to inform the size, shape, and character of the resultant shading volume.

Once the three-dimensional shading volume is created, the user creates a solution that cuts the whole window off from the sun vectors represented in the volume. This could take the form of anything from a simple plane intersecting the mask above the top of the window, as shown in step 7, or smaller tessellated shapes covering the window, each sized to shade their own portion of the window during the desired time frame. Because this shade mask is in model space that can be integrated within the context of the whole project, it is easier to understand the aesthetic impact each decision makes while ensuring that each iteration performs to a similar degree.

Any update in the energy model or geometry of the shaded area feeds back directly into the generation of the shading mask to provide instant feedback to the user. Allowing the software to control more complex operations such as the generation of the mask and displaying the consequences in real time allows the designer to focus on design and not be concerned as much with the time and knowledge involved with creating and interpreting a two-dimensional shading mask. Real-time feedback was critical in helping users to understand what the implications were for various actions in creating a design through a parametric script (Maleki, Woodbury, Neustaedter, 2014). The creation of a three-dimensional shading volume is a parametric exercise, driven by hourly energy data, which needs to be understood conceptually by users. Therefore, a real-time link between design decisions on the building level and the outcome in terms of the shading mask is essential to ensure a success shading device design method in practice.
Because the Vector Method requires only one simulation to be run and the process does not have to be repeated from the beginning to create design iterations, this method is flexible for many stages of design. A simple energy model could be created during schematic design to test different shading options on different building orientations and forms to get an idea to communicate to the client about what the skin of a building could look like and what kind of energy savings they might expect. A final more complex energy model could be created towards the end of design, when the building form is decided upon, and a finalized shading device system can be designed and altered per construction and budget restrictions. The Vector Method supports quick typology selection, as the Climate Method does, form finding and quick typology sizing, like the Cell Method, without the high number of simulations like the Iterate Method.

3.0 COMPARATIVE CASE STUDY

3.1. Performance study
To determine how the Vector Method performs in pragmatic terms, in its ability to design a shade that reduces overall thermal load, it is tested against each of the other existing design methods. This is accomplished by using Honeybee as an interface to EnergyPlus to run a baseline simulation and then, using the existing and new methods described above, create simple horizontal overhangs to reduce thermal loads as much as possible. The baseline consists of a single zone 3.05m x 6.10m x 3.05m (10’ x 20’ x 10’) with one south facing window 5.18m x 2.13m (17’ x 7’). The baseline uses the default closed office schedule and ASHRAE 189.1 envelope assemblies. The study is run for three separate locations, in different ASHRAE climate zones to ensure the Vector Method performs as well or better in multiple situations. The Climate Method is carried out by using the ‘Honeybee_Balance_Temperature_Calculator’
in conjunction with the Ladybug sun path and shading mask components to determine graphically which parts of the sky need to be shaded and to match a rectangular form to shade this area. The Iterate Method mimics the Sefaira workflow to simulate this method realistically being used in practice. The shade is assumed to be the width of the window and incrementally increased from a .30m (1') overhang to a 3.05m (10') overhang. Each result is analyzed through the same settings in Honeybee as the other methods, and the best performing option of the group of ten is selected. The Cell Method uses the ‘Energy_Shade_Benefit_Evaluator’ in Honeybee, which was based directly on the SHADERADE process, provides the cell-by-cell analysis as well as visualizing this data on the surface of the shade using Ladybug. The simple overhang starts as an oversized rectangle and is trimmed based upon the results of the shade evaluator component to create the Cell Method solution. The Vector Method is carried out utilizing a mix of Honeybee, Ladybug, and native Grasshopper components to create a script that creates the three-dimensional shading volume as described earlier. The shading mask is used to trim a horizontal surface at the top of the window. The resulting shape is the Vector Method solution. The design solutions for each method for the three locations are shown in Figure 2 below.

![Figure 2. Comparative Method Study Designs.](image)

<table>
<thead>
<tr>
<th>Table 1. Comparative Method Study</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Method</td>
<td>Albuquerque, NM</td>
</tr>
<tr>
<td>Baseline (Annual kwh)</td>
<td>2,611.3</td>
</tr>
<tr>
<td>Climate (Annual kwh)</td>
<td>2,084.3</td>
</tr>
<tr>
<td>% Improvement</td>
<td>20.18%</td>
</tr>
<tr>
<td>Iterate (Annual kwh)</td>
<td>2,073.6</td>
</tr>
<tr>
<td>% Improvement</td>
<td>20.59%</td>
</tr>
<tr>
<td>Cell (Annual kwh)</td>
<td>2,084.9</td>
</tr>
<tr>
<td>% Improvement</td>
<td>20.16%</td>
</tr>
<tr>
<td>Vector (Annual kwh)</td>
<td>2,060.3</td>
</tr>
<tr>
<td>% Improvement</td>
<td>21.10%</td>
</tr>
</tbody>
</table>

Table 1 shows the performance results of each design in Figure 2 compared to an unshaded baseline. Annual thermal loads are presented (kwh) and the percent improvement over the baseline. The Vector Method performed the best in two of the three cases against existing methods and followed closely behind the Climate Method in the third case. Overall, each method was able to achieve a design that performed in a similar manner for the three test locations, however, the form that each design took was unique. The Climate Method was restricted to rectangular forms with wide side overhangs, the Iterate Method was confined to predefined rules in the beginning of the process, and the Cell and Vector Methods created more unique geometries. Even though the typology of simple overhangs was utilized the form each solution takes is unique due to the effect of each method on the end product. This indicates that there are multiple design solutions that function to a high degree and multiple paths to achieve these
designs. This shifts the focus back to how much time is required to generate a solution and how much effort is required to create design iterations based on aesthetic criteria.

The Climate, Cell, and Vector methods all rely on setting a threshold, whether it is a quantifiable number or interpreting a graphics display, to design a solution. For this reason, user error could easily be to blame for one method overtaking the other, and it would not be right to say that the Vector Method is the 'best performing' method. However, this study does show that the Vector Method has the potential to work as well or better than existing methods in designing shades that reduce thermal loads.

### 3.2. Design iteration study

To study the aesthetic potential of the Vector Method, the Albuquerque baseline model is used, and twelve different design options are created and evaluated using only the Vector Method, as shown in Figure 3. It is impossible to create an aesthetic that could be agreed upon by all to be objectively better than another. In that light, demonstrating that the Vector Method can quickly produce unique design iterations leaves the potential for each designer to decide for themselves what is aesthetically pleasing for their project. Overhangs, hoods, louvers, and screens are iterated and simulated.

#### Table 2. Vector Method Iteration Study

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Thermal Load (Annual kWh)</th>
<th>% Improvement Over Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2,611.3</td>
<td>-</td>
</tr>
<tr>
<td>Overhang 1</td>
<td>2,060.3</td>
<td>21.10%</td>
</tr>
<tr>
<td>Overhang 2</td>
<td>2,029.9</td>
<td>22.26%</td>
</tr>
<tr>
<td>Overhang 3</td>
<td>2,092.7</td>
<td>19.86%</td>
</tr>
<tr>
<td>Hood 1</td>
<td>2,087.6</td>
<td>20.06%</td>
</tr>
<tr>
<td>Hood 2</td>
<td>2,070.7</td>
<td>20.70%</td>
</tr>
<tr>
<td>Hood 3</td>
<td>2,114.8</td>
<td>19.01%</td>
</tr>
<tr>
<td>Louvers 1</td>
<td>2,061.5</td>
<td>21.06%</td>
</tr>
<tr>
<td>Louvers 2</td>
<td>2,074.6</td>
<td>20.55%</td>
</tr>
<tr>
<td>Louvers 3</td>
<td>2,047.0</td>
<td>21.61%</td>
</tr>
<tr>
<td>Screen 1</td>
<td>2,128.8</td>
<td>18.48%</td>
</tr>
<tr>
<td>Screen 2</td>
<td>2,100.0</td>
<td>19.58%</td>
</tr>
<tr>
<td>Screen 3</td>
<td>2,107.8</td>
<td>19.28%</td>
</tr>
</tbody>
</table>

Table 2 includes the annual simulation results for all of the iterations generated by the Vector Method shown in Figure 3. Annual thermal loads are given (kWh) and the percent improvement over the baseline is provided.

All iterations from Table 2 show between an 18.48% and 22.26% reduction in thermal loads. Variation in iterations is likely due to how the Vector Method is only addressing direct sunlight and is attempting to create a binary list of shade hours. Each hour is either assessed to be 100% shaded or not, which means different typologies and forms might create different hours with partial shade. Despite these shortcomings, shades were able to be altered at the designer's discretion without significant sacrifices in performance. The Climate Method can move freely between most typologies, but cannot account for irregular forms such as screens and complex geometry such as non-rectilinear forms. The Iterate Method requires too many simulations to adequately explore this many typologies and variables to be feasible in practice. The Cell Method can help to evaluate many options (aside from self-shading typologies) but can only evaluate what the designer creates, meaning each iteration is not guaranteed to perform similarly if changes between iterations are drastic enough.
4.0 VECTOR METHOD DESIGN APPLICATIONS

In the Practice of Architecture, baseline models can only prove so much before decisions must be made branching out to multiple variables involving physical context, building program, personal taste, and more. Figure 4 show a potential design solution for an office building located in the parking lot just north of Civic Plaza in Albuquerque, New Mexico. The south side of the office ‘block’ utilizes a triangulated screen generated by a Grasshopper script using the Vector Method, similar to screen 1 from the study above. The screen creates an interesting dynamic for users inside the space and creates a textured effect for people passing by the project. The ground level is comprised of commercial programs and uses the Vector Method to generalize how far the building should extend above to shade the ground level programs. This creates a sheltered walking space for pedestrians as well as allowing the building to perform better. This is only one example of the Vector Method being applied to one theoretical project, however, this example highlights the potential for this method to account for user experience and the creation of space that many find central to the practice of architecture. One can see how the different iterations in section 3.2 could lead to many fruitful design iterations that could change the character of the project completely.

CONCLUSION

The Vector Method improves upon existing shading device design methods by offering freedom to explore aesthetic options through design while holding the designer accountable to performance criteria. This adherence to performance and freedom to explore aesthetics holds the designer closer to the ideals of what makes an object into an ‘architectural element’. The creation of a three-dimensional shading mask from hourly energy data mimics the intent of the original two-dimensional shading mask used in the Climate Method by Olgyay and Olgyay, allowing designers to switch between and size shading typologies freely while also informing the designer about which typologies will work best in their unique case. The three-dimensional mask improves over the two-dimensional version by existing in modelling space in the context of the building being designed, relating to an interface and workflow that designers are more familiar with. The parametric connectivity between the building geometry and properties to the generation and display of the shading mask mimics other successful parametric design systems including the Cell Method. As seen in the studies above, the Vector Method is capable of producing solutions that perform on par with existing design methods as well as producing a wide range of design options that perform to a similar level. The Vector Method ensures performance to a high standard while leaving the end solution ambiguous for the designer to define.
REFERENCES
Student learning through monitoring and simulating buildings’ energy use and comfort

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ABSTRACT: This paper shares the methods, selected projects, and reflections on the effectiveness of extracurricular student learning through monitoring and simulating buildings’ energy use and occupant thermal comfort. The following applied research features occur sporadically in architecture schools and it is notable to see a research laboratory consistently maintain them over many years. The atypical method uses a research lab to simultaneously combine: extracurricular in-depth, hands-on environmental systems education; community engagement on “real world” buildings; paid student research positions in multiple disciplines; gradual acquisition of an environmental systems tool kit; and sustained consistent funding from research grants. While the previous qualities exist in architectural education, studies show they are the exception and not the norm (Carraher et al., 2017). The University of Hawaii at Manoa School of Architecture Environmental Research and Design Lab consistently goes beyond the typical professional architecture curriculum to deepen students’ knowledge in and affinity for designing and operating energy efficient, comfortable buildings. The pedagogical approach and hypothesis proposes that student researchers who work in these extracurricular research positions gain a deeper understanding of building physics and are enriched by interdisciplinary student interactions, which will positively benefit their future studies and careers in a way that is not possible through curricular work only. Finally, the evidence of the student learning and positive influence on students’ future careers are benchmarked against Bloom’s Taxonomy, a framework for categorizing educational objectives (Bloom, 1956).

KEYWORDS: student learning, pedagogy, architecture research laboratory, energy efficiency, thermal comfort

INTRODUCTION

Fossil-fuel energy use in the operation of buildings accounts for nearly 30% of global greenhouse gas emissions (Architecture, 2030, 2018). The American Institute of Architects (AIA) updated the AIA Code of Ethics and Professional Conduct in 2018 to “require architects to consider environmental impacts, and… recommend addressing specific environmental priorities like energy… conservation” (Melton, 2018). As educators, we have a responsibility to help students understand how their design decisions affect energy consumption and occupant well being in buildings.

Per the conference prompt, this paper contemplates how we, as instructors and architectural designers, can teach students to make decisions that result in a sustainable future seven generations away, without resorting to checklists. One alternative to prescriptive checklists or minimal code requirements is to provide students in professional architecture degree programs the opportunity to learn about energy efficiency and thermal comfort through hands-on monitoring of existing buildings and practice with computer simulation programs.

The uncommon pedagogical quality of the University of Hawaii School of Architecture (UH SoA) Environmental Research and Design Lab (Lab) is that it simultaneously meets the following multiple objectives through one delivery method: extracurricular student research positions in building science.
ENVIRONMENTAL STEWARDSHIP

- Provide extracurricular learning opportunities rather than squeezing more building science content into an already packed architecture curriculum.
- Provide paid building science positions, acknowledging that most of the student body must work to support themselves through school.
- Develop students’ ability to use equipment to monitor existing building energy use and thermal comfort.
- Build up a tool kit for use in curricular and extracurricular activities.
- Enable students to use computer simulations to compare to existing building measurements.
- Understand and reference energy and thermal comfort standards to benchmark monitored and simulated energy data.
- Communicate benchmarked data for the benefit of building occupants and developers.
- Motivate students to reduce greenhouse gas emissions by using building science content delivery methods other than lecture.
- Attract student researchers from fields outside of architecture (e.g., computer science, mechanical engineering, urban planning).
- Learn skills and problem-solving approaches from students in other disciplines.
- Conduct community engagement that meets needs of underserved populations (e.g., Department of Hawaiian Homelands).

The pedagogical approach and hypothesis proposes that the student researchers who are hired in these extracurricular research positions gain a deeper understanding of building physics and are enriched by interdisciplinary student interactions, which will positively benefit their future studies and careers in a way that is not possible through curricular work only. The effectiveness of the student learning is benchmarked against Bloom’s Taxonomy, a framework for categorizing educational objectives (Bloom, 1956).

First, we describe student learning on a variety of equipment and computer simulation, benchmarking, and communication techniques. Second, we reflect upon the extracurricular student research successes, challenges, and opportunities for improvement. Finally, we consider the long-term student impact through the Lab’s alumni job placement and feedback.

The processes and lessons learned should be useful to researchers and professors at other schools of architecture. This paper provides replicable examples of enhanced education that enables students to go beyond checklists by monitoring and simulating buildings’ energy use and occupant comfort. The paper describes the structure of the laboratory staff, criteria for project selection, student activities and learning, and assessment of student learning.

2.0 MOTIVATION

This section discusses the motivation for extracurricular opportunities for students to enhance knowledge in environmental systems, including lack of time in the architecture curriculum; need for student employment; and the dual benefit of community engagement projects for under-represented communities and students. Several forces shape the ongoing demand for the Lab to hire students for extracurricular work on “real-life” projects to build environmental systems knowledge. Given that 86% of A/E firms report difficulty finding employees equipped with the knowledge and skills needed to achieve the AIA’s 2030 Challenge (Kwok et.al., 2014), one would think that extensive use of hands on tools and simulation programs would be a NAAB requirement for professional degree programs. At the UH SoA, the NAAB student performance criteria “Environmental Systems” is addressed in a 3-credit required course with only a brief introduction to hands on tools or building performance simulation. In depth coverage of hands on tools and simulation is likely a challenge at other schools, as architecture curricula are already “packed” (Kwok et al., 2015) and oversubscribed with important content (Nicol et. al., 2000 and Smith, 2017).
A 2017 national survey of over sixty building technology educators provides insight into other schools’ practices. Integration of building technology courses with studio courses is possible but a survey shows that this is atypical (Carraher et al., 2017). Other solutions such as elective courses may address hands on tools and simulation but are inconsistently offered based on an instructors’ discretion. The most frequent delivery method for building technology is lecture (Carraher et al., 2017), which would not provide the desired weeks or months of hands on experience with tools and simulation programs. Thus, extracurricular opportunities for hands on tools and simulation are pursued.

Anecdotes from architecture educators at other schools show that students sometimes volunteer unpaid extracurricular time to work with existing buildings or real clients. At UH SoA, most students do not pursue unpaid extracurricular projects because they need to work to support themselves financially, which is a trend reflected in the following study. A National Public Radio story reported “non-traditional” students are the new normal, comprising 74% of today’s college undergraduate students (Nadworny, 2018). Non-traditional students’ qualities include, but are not limited to: financially independent from their parents; having a child or other dependent; and being a single caregiver (Radford, 2015). The need for student employment has shaped the Lab’s pursuit of grants.

Another major factor shaping the Lab’s student dedication and selection of project work is the desire for community engagement and to meet the UH’s commitment to be a Hawaiian Place of Learning (UH, 2019). Community engagement projects are “collaboration between institutions of higher education and their larger communities … for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity” (Carnegie, 2005). The Lab’s work with the Department of Hawaiian Homelands (DHHL) serves the local Native Hawaiian community. In addition, studies on engaged research show it can have significant positive impacts on faculty and student recruitment from underrepresented populations (ACSA, 2019), which has been the experience in the Lab.

Given lack of sufficient time in the curriculum, the desire for hands on (non-lecture based) learning, need for paid work, and community engagement opportunities, the Lab’s solution is to pursue grants to hire student researchers to improve energy conservation and thermal comfort in buildings.

3. METHODS

3.1 Lab organization

Researchers may be interested in the replicability of the Lab’s model of hiring and project selection. For nearly two decades the Lab employed over ninety students, self-supported by funding secured from sources outside the School of Architecture. The Lab is within the UH SoA is directed by one faculty member and employs one full-time staff member, multiple graduate research assistants, hourly student employees, occasional post-docs, and occasional consulting professional engineers from outside the University. The Sea Grant College Program provides funding for about one-third of one full time position.

Students from architecture, mechanical engineering, electrical engineering, computer science, and urban planning learn to work together, which will benefit their future careers. Students work 10-20 hours per week during the school year, and 20-40 hours per week during the summer. The summer work is especially effective for students to feel ownership over a project and gain a deeper understanding of it. Students typically work at the Lab for 1-3 years and work on 1-4 projects during that time.

The Lab’s staff typically select projects with one or more of the following criteria: have a real-world beneficiary who could not otherwise afford consultation on building energy and comfort; significantly reduce greenhouse gas emissions; have a significant role for students to learn about building science; and inform future net zero energy buildings in sub-tropical climates.
Real-world beneficiaries include the Department of Hawaiian Homelands, which assists the under-served population of Native Hawaiians; public K-12 schools; and the University of Hawaii, which is a public institution of higher education.

3.2 Selected lab projects
This section briefly describes two applied research projects in which students gained hands-on experience using tools and computer simulation for energy efficiency and thermal comfort improvement in existing buildings, and influenced future building design.

In a three-year military housing study, the Lab’s staff guided a team of interdisciplinary student researchers to: identify and quantify the end-uses of energy consumed by the existing homes; determine the factors that contribute to high consumption; provide recommendations to the building management company as well as residents; and provide data to consultants for building simulation studies to determine the best retrofit options. The building management company manages over 6,700 military houses in 37 neighborhoods. Any energy saving measures adopted could add up to a significant reduction in annual energy use, cost, and greenhouse gas emissions. The project involved three stages: (1) initial energy auditing to disaggregate energy use and identify key issues; (2) blower door testing, duct testing, and monitoring energy and temperature conditions pre- and post-retrofit of the HVAC systems in three houses; (3) identifying the points of failure in the solar water-heating systems. The student roles, equipment training, and energy reductions are described in the section below.

In a separate two-year project, the Lab’s team worked with the [housing agency for an underserved population] and two developers. The team studied nine homes in a [neighborhood] in [location]. Computational building simulation (via BEopt software) was used alongside monitored data onsite (e.g., electricity usage at breaker level, temperature, and humidity levels of nine homes) to identify and quantify potential future design strategies and technologies to reduce energy and improve thermal comfort in existing homes and influence the design of hundreds of future homes.

3.3 Lab tools and equipment
Through work on the above (and other) research projects, the Lab’s staff and outside professionals trained students to use tools to study existing buildings’ energy use and occupant comfort. This section describes why students’ hands-on tool use is valuable; how students learned to use physical and computational tools on the two projects above; how the Lab accumulated a tool kit over time; how students understood the significance of their work by comparing gathered data to energy and comfort standards; and how students learned to communicate their analyses to various audiences.

A paper on a tool kit for passive house education suggests tools that enhance learning outcomes and provide validation of design decisions for architecture faculty and students (Kwok, 2015). Of the six tools listed, Lab faculty and students acquired and used four of the tools on existing building work including: blower door; carbon dioxide meter; infrared camera; and data loggers. We plan to incorporate the suggested infrared temperature sensors into our suite of tools. For over two decades and dozens of projects, the Lab has built up a kit of physical tools that students use on projects including: energy submetering equipment (eGauges and current transducers); weather stations; airflow sensors (anemometers); globe thermometers; pressure differential sensors; water flow gauges; and illuminance meters.

3.3.1. Tools to measure existing military housing envelope performance and hvac energy use
This section describes how student researchers learned the significance of their hands-on equipment use by comparing gathered data to energy and comfort standards.

On the existing military housing project the interdisciplinary team conducted blower door tests to measure air tightness and compared it to the performance standards in the construction
documents’ specifications (see Fig. 2). In addition to learning to use the blower door themselves, the students also witnessed a blower door test by a Home Energy Rating System (HERS) rater. The students also used an infrared camera to identify locations in the façade with inadequate insulation and found that at the edge of the attic insulation had been pushed back to install cables but never replaced (See Fig. 1).

College of Engineering students monitored electricity, managed energy use data, and compared it to regional energy use data to identify unexpectedly high consumption. The Information and Computer Sciences team members imported vast quantities of fine-grained historical metering data into a database for further analysis with their open source software. The existing building data collected informed a separate consultant’s inputs to a computational whole-building energy simulation, which was then used to compare various energy efficiency improvement options for retrofitting the structures.

3.3.2 equipment for energy and comfort monitoring at department of Hawaiian homelands

This section describes how student researchers set up data gathering equipment and learned the significance of their hands-on equipment use by comparing gathered data to energy and comfort standards. Students also used the data to inform their computational models for the improvement of the current and future DHHL residents. The Lab’s student researchers were trained in building monitoring, data analysis, and computer building performance simulations. Their research data and recommendations were shared with participating homeowners, DHHL, and housing builders.

An electrician taught electrical engineering students and architecture students to submeter electricity using eGauges and current transducers (see Figure 3). Submetering the breaker panel measured whole house use: AC compressor; AC air handler; clothes dryer; water heater; kitchen refrigerator; and photovoltaic system. “Other” loads were calculated by subtraction from the whole house use and included lighting and plug loads (any devices plugged into an outlet, e.g., extra refrigerators, TVs, other electronics, countertop oven, etc.). Data was recorded at one-minute intervals.

The Electrical Engineering students set up the eGauges to be remotely accessed via the Internet. The Information and Computer Science (ICS) students created a Python data pipeline to remotely access the eGauges and download the data and store it in a PostgreSQL database at the University campus. The ICS students also automated organizing the data with identifying information for later retrieval and graphing by architecture students. The ICS and Architecture students plotted the energy end uses in “R”, MS Excel, and/or Tableau.

The architecture students compared the houses’ energy use to other comparable houses using energy use intensities from a research paper studying a nearby housing development and from the State Energy Office. In addition to learning tools, by examining the disaggregated energy
use students learned to identify large differences in air conditioning and plug load energy use based on user behavior. This informed the energy efficiency measures they would later test with whole building energy modeling (described in the forthcoming computation section of this paper).

Architecture students deployed HOBO data loggers to record the temperature and humidity in the nine existing houses by selecting their locations and launching them (see Fig. 3). The information was collected, managed, and graphed, similar to above. Temperature and humidity were measured in four rooms inside each house and one outdoor location out of direct sunlight. In order to create one file of observed outdoor temperature and humidity, staff and students discarded the high and low readings and averaged the readings from multiple sensors. HOBO data loggers collected temperature and humidity in 15-minute resolution and staff and students manually downloaded data during site visits over the period of about a year. In addition, nine weather stations were installed throughout the neighborhood.

The students compared the data collected from the data loggers above to the ASHRAE 55 Standards for Thermal Comfort for conditioned spaces and the Adapted Comfort Standards for naturally ventilated spaces. The students graphed the monitored temperatures for each house according to the predicted mean vote value for conditioned houses and adaptive comfort chart for the natural ventilated house. The ICS students used the adaptive comfort code on GitHub for University of California, Berkeley’s Center for the Built Environment to process and quantify the percentage of monitored hours considered comfortable (Hoyt et. al., 2017). The ICS students accommodated requests for specific graph colors for comfortable and uncomfortable hours, and quantified the percentage of time for each. The staff and students used ASHRAE 55 graphs correlating air speed and temperature perception to further inform the potential for improved thermal comfort using ceiling fans.

### 3.4. Simulation: whole building energy modeling

Computation building performance simulation includes multiple types of analysis, including whole building energy modeling. While architecture students in a first professional degree program may learn energy modeling at an “awareness” level in required coursework, they probably would not achieve the “ability” level of comprehension without having an elective course or extracurricular activity. The Lab provides students an extracurricular research employment in which they learn to compare the existing physical building monitored data to energy models, CFD model, and established standards, such as the energy code and thermal comfort standards. The simulation iterations encourage students to be curious and develop their intuition about energy use and comfort in buildings.

Based on monitored data and with guidance from staff, students formulate hypotheses about strategies to reduce energy use or improve occupant comfort. For example, the section above describes a project with multiple houses’ energy submetering and temperature and humidity monitoring. Under the guidance of an architect and engineer, students from Architecture and Mechanical Engineering created whole building energy models to: 1) compare to actual monitored energy use, temperature, and humidity data gathered from the existing houses; 2) create an energy model for comparison to represent a house that meets the new State of Hawaii energy code; 3) identify and quantify potential future design strategies and technologies to reduce energy and fossil fuel use and improve thermal comfort; 4) develop a speculative future net-zero site energy design; 5) communicate potential energy efficiency opportunities to developers, builders, and residents for consideration for inclusion in future thousands of homes planned for development. Testing potential future design strategies developed students’ intuition most because of the structured process of changing one variable and understanding the resulting impact on energy use. Students referenced the Building America Simulation Protocol (NREL, 2014). The following anecdotes about the process demonstrate how students developed their intuition about energy use by changing models inputs and seeing the difference in energy use. We also describe how staff and students addressed challenges along the way.
For the first step, staff trained students to use BEopt, a software tool developed by the National Renewable Energy Laboratory (NREL) that uses the EnergyPlus simulation engine (DOE). Students created the energy models using the houses’ construction documents and compared the monthly and annual energy use to the monitored monthly energy use. When some houses’ simulated and monitored data were dissimilar, the students examined differences and concluded that the actual number of occupants and plug loads were higher, based on visual observation during site visits. Students were able to adjust the hot water use and plug loads in the energy models so that the simulated and monitored monthly energy use was similar. Students also followed guidance from ASHRAE 14 in calibrating the energy model. This gave the team confidence that the simulations reasonably represented the actual condition and were useful for testing design improvements.

In the naturally ventilated house, the students used the simulated indoor temperature and the weather file temperature to create the ASHRAE 55 adaptive comfort graph (the graphing method is described in the section above). We compared the percentage of time considered comfortable in the simulated and monitored data sets and found them to be quite different. After trying to determine what caused the difference, we discovered the window opening control thresholds in the simulation program needed to be adjusted to better represent the actual window-opening schedule. After this adjustment, the observed comfort and simulated comfort were reasonably similar.

4.0. RESULTS

4.1. Current student learning successes through extracurricular research
In this section of the paper, we reflect upon the ways in which the Lab successfully serves student needs in terms of lessons that are applicable to other architecture researchers.
1. The Lab enhances building science learning through hands-on study of existing buildings while performing research with tangible community benefit. For reasons previously mentioned in this paper, creating time for students through paid research positions is necessary to get students “in the door”. Studies and student feedback shows performing research with real-life beneficiaries motivates students, particularly the engineering students who often have theoretical assignments.
2. The Lab is a growing resource to the School of Architecture. By purchasing equipment with various projects’ funding over time, we have built a tool kit, which is a resource for faculty, students, and even other departments. Students are able to work with equipment to which they would not otherwise have access.
3. Students learn soft skills through communicating with students in other disciplines and learn management skills by organizing in-house teams and work flows.
4. The Lab meets students’ employment needs by providing paid work in their area of study, with flexible hours during busy periods in the school year.

4.2. Current challenges to student learning through extracurricular research
In this section of the paper, we reflect upon challenges and potential mitigations to better enhance student learning in the extracurricular academic research environment.
1. The heavy course load in a professional degree program limits architecture students’ time for work. Potential solutions include conducting work in the Lab as a course for credit, such as an undergraduate capstone project.
2. The required architecture coursework has limited physics and computation courses so students must enhance their knowledge of those subjects on the job. Our approach is for staff to offer informal refreshers and formal training sessions (1 hour) on subjects when we see that there is a gap in student knowledge.
3. The project-based funding provides a valuable, positive service, but has some challenges. First, the topic of the project determines the types of equipment and computer simulation to which the current students are exposed. There is limited knowledge transfer between
“generations” of students. One way to address this is through “tool training days” where student researchers practice using the Lab’s tools.

4. Student researchers’ employment is limited to a few semesters, which makes continuity on project work a challenge. To address this, all digital files are stored on a shared server. The staff students at the Lab address continuity of knowledge and file locations through explanatory videos for the internal lab audience. The ICS students also post versions of code and their explanations on a web-based version-control and collaboration platform for software developers called GitHub (Github, 2018). These records make it easier for staff and students to recall, recreate, and build upon past work.

4.3. Pedagogical assessment using bloom’s taxonomy

In this section, we examine evidence of student learning or positive influence on students’ future careers by benchmarking student experiences using the Bloom’s Taxonomy educational objectives framework (Bloom, 1956). Bloom’s Taxonomy describes a hierarchy of educational goals, progressing from knowledge-based goals, to skills-based goals, and affective goals. In this section, we describe how selected student researchers in the Lab progressed, meeting all three educational goals.

First, the cognitive, knowledge-based goals include knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956). One example is a student who evaluated the monitored temperature and humidity and selected, compared, and graphed the ASHRAE 55 thermal comfort criteria for either conditioned or naturally ventilated buildings. A second example of this is an ICS student researcher with a software engineering background who developed the thermal comfort survey (in a project not described in this paper). The student applied his knowledge of programming to create a thermal comfort survey and analyze its responses, which was outside of his academic discipline and required comprehension and synthesis of multi-disciplinary knowledge.

Second, the affective, emotion-based goals include receiving, responding, valuing, organizing, and characterizing (Bloom, 1956). Because the student researchers often meet the people who benefit from the [Lab’s] projects, the students are often motivated and emotionally invested in the work. Students report that it is rewarding and fulfilling to see how the results of their work impact the building occupants and building developers. When conducting skills-based learning, such as existing building data collection or computer simulation, students showed eagerness and initiative in self-organizing to complete the work based on discrete skills they wanted to learn. Students also showed that they can organize the energy and comfort analyses and ideas, relate them to their own experiences, then hypothesize and test potential improvements.

Third, the psychomotor, action-based goal describes the ability to physically manipulate a tool or instrument, such as a hand or hammer, and usually focuses on a change in development in behavior or skills (Bloom, 1956). When considering equipment such as the computational whole building energy model, one student achieved a level of “mechanism”, the intermediate stage in a complex skill where the process of running parametric models and graphing results is habitual and can be repeated with some confidence and proficiency. When considering equipment such as the HOBO data loggers, the ICS students achieved a higher level of learning. Their data collection, organization, and retrieval skills are well developed and they modified the process to fit different buildings, types, or amount of data.

Quotes from students show evidence of learning using knowledge-based, emotion-based, and action-based goals. All of the following quotes demonstrate a growth in attitudes to valuing energy-efficient, comfortable design. The first two students demonstrate action-based, psychomotor skill development using equipment to study existing buildings.

“Working at the Lab really rounded out my experience at UH by adding great hands on experience to my mainly theoretical classroom studies. Besides training on the tools and techniques used in energy management it also allowed me to touch on subjects I never
got in my area of study such as computer simulation and modeling, database analysis and management, and behavioral psychology related to energy use and comfort. This took my experience level far beyond what I was expected to know when I began working after graduation.” – Former lab graduate student researcher from Urban Planning

“While studying at SoA, I was lucky to be part of the Lab team, and obtain so much knowledge and skills through taking part in blower door tests, full scale experiment of measuring air movement, energy modeling and wind tunnel testing. This knowledge and skills helped me to fulfill my thesis and is an invaluable resource for me in teaching sustainable architecture design in my home country.” – Former lab graduate student researcher from Architecture

In describing the lab training and career, another former student demonstrates comprehension and analysis using the building performance simulation software. The former student also demonstrates an emotional reaction with an affinity for the process of diverse student backgrounds and disciplines.

“The Lab has offered the most significant exploration and experience in BIM technology and advanced sustainable design. Indeed the Lab [had] great cultural and disciplinary diversity, showing leadership initiative in a built environment, with instructors and students working collaboratively.” – Former lab graduate student researcher from Architecture

CONCLUSIONS

This paper shares examples of interdisciplinary students’ extracurricular applied research in building science through funded applied research in an academic lab. This is one method for students to develop the desire and skills to create tomorrow’s net zero energy buildings. The lab’s senior researchers guide architecture, engineering, computer science, and planning student researchers through existing building energy and thermal comfort monitoring as well as computer whole building energy simulation. Student researchers learn to use hands-on tools such as a blower door, carbon dioxide meter, infrared camera, and data loggers. Over time, the Lab built up a kit of physical tools that students used on projects including: energy submetering equipment (eGauges and current transducers); weather stations; airflow sensors (anemometers); globe thermometers; pressure differential sensors; water flow gauges; and illuminance meters. The student researchers also learn to collect, organize, and visually communicate the energy and comfort data they gather, and compare it to existing standards such as [energy code], ASHRAE 55, and ASHRAE 14. The student researchers develop their intuition when creating whole building energy models of the buildings they monitored. Students develop energy models through the stages of calibration, energy code compliance, individual parametric energy efficiency measure runs, combined proposed design, and on-site energy generation to create a net-zero energy building. The paper also reflects upon the Lab’s structure and pedagogy highlighting successes and giving suggestions for improvement. Finally, the evidence of the student learning and positive influence on students’ future careers are benchmarked against Bloom’s Taxonomy, a framework for categorizing educational objectives (Bloom, 1956). Students demonstrate various depths of learning in three categories. Students address knowledge-based goals by quantifying building energy by end uses and comparing it to regional averages, or by graphing monitored thermal comfort monitored data and comparing it to ASHRAE 55 PMV or Adaptive Comfort standards. Emotion-based goals are addressed through students’ initiative in pursuing careers in building. Action-based goals are considered through students’ skills, such as using the data loggers. Overall, the paper describes a working example of a funded, extracurricular applied research lab’s ability to deepen students’ knowledge in and affinity for designing and operating energy efficient, comfortable buildings.

ACKNOWLEDGEMENTS

The director emeritus, Stephen Meder, associate researcher, Jim Maskrey, sustainability specialist, Eileen Peppard, consulting engineer, Manfred Zapka, and dozens of student researchers’ persistent enthusiasm and curiosity are to credit and thank for the work described in this paper. Thank you.
REFERENCES


NREL. Building America Simulation Protocol. 2014.


A framework for the co-benefits and trade-offs of resilience & sustainability certification programs

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ABSTRACT: Although concepts of resiliency and sustainability have long been tenets within the culture of design, their modern classification, measurement, and codification in the late 20th and early 21st century are fiercely debated. The need to reduce greenhouse gas (GHG) emissions and mitigate the impacts of global climate change influence current debates around the ways in which to operationalize sustainability and resilience within the built environment. This debate contributes to the confounding relationship between the consensus of ‘sustainability’ (i.e. carbon reduction) and the myriad domains of ‘resilience’ for designers, which include ecosystems, cities, communities, and individual buildings. The clarity of this debate is further attenuated in the variety of outcomes it seeks, the timescales in which it operates, and the necessary tradeoffs inherent in the process. While sustainability is concerned with resource use and the “carrying capacity of the earth” (Moffatt 2014), increases in manmade and natural disasters have focused attention on how design professionals evaluate both building’s impact on the environment (sustainability) and the environment’s impact on building (resilience). This paper proposes a framework for describing the synergies and discords that occur between several ‘resilience’ and ‘sustainability’ building certification programs (BCP). The evolution of various concepts of resilience are briefly explored and used to later inform this framework. Several BCPs are cited within this framework. A matrix showing the relationships between multiple green building rating systems and resilience rating systems is used to incorporate the interpretations of resilience cited in this paper. This comparison includes the rating system origin, application, and range of implementation as it considers resilience scholarship. The table aims to identify the problems, objectives, and co-benefits of various green building rating criteria and resilience criteria. Comparing several rating systems, the gaps and overlapping objectives in each system are identified as they relate to ‘sustainability’ or ‘resiliency’ outcomes.

KEYWORDS: Resilience, Sustainability, Adaptation, Vulnerability, Building Certification Programs

INTRODUCTION
Existing metrics for sustainability and emergent metrics for resiliency in architecture must seek a convergence considering carbon reduction goals now being set by governments (e.g. USA, EU) and municipalities (e.g. New York, Chicago) and because of the increasing impacts of rapid global climate change (hurricanes, droughts, and heatwaves). These considerations force an examination of how sustainability and resilience are operationalized and practiced by design and engineering professionals. However, the relatively narrow focus and long view of sustainable building practices are divergent to the immediacy of risk and the shorter temporal dimensions of resiliency. A broader framework for converging sustainability and resilience paradigms is necessary to improve design inquiry around risk, resilience, and sustainability.

A few key questions are in focus: How do existing voluntary sustainability and resilience certification programs - referred to here as building certification programs (BCPs) - address issues of risk, resiliency, and resiliency’s closely related concept adaptation?; do current BCPs address emerging issues around resilience?; do building code cycles (every three-years), their
voluntary adoption by states, and voluntary BCP’s provide the right amount of flexibility to reduce GHG emissions and decrease risk?; and, do efforts to increase energy-efficiency and design optimization provide a cogent foundation for resilient buildings given variability in climate and weather? The comparisons made in this paper suggest that practical synergies exist between voluntary sustainability and resiliency metrics as they are defined in the various BCPs. However, the benefit to which more specificity is given on performance criteria (under normal operating conditions and under various disturbances) is subject to further investigation. The aim of this paper is to advance the modes of inquiry into sustainability, resilience, and adaptation by organizing various programs under a common framework.

1.0. SUSTAINABILITY’S RELATION TO RESILIENCE

Scholarship on resilience and adaptation has expanded in the last half-century. The modern concept of resilience, that examines a system’s behavior under stress, is largely credited to ecologist C. S. Holling. This definition of resilience, beginning in the 1970s, marks a change in thinking regarding disaster response, capacity building, and coping strategies (Holling 1973). Holling’s systems theory and the non-equilibrium understanding of ecology and environment evolved alongside emerging notions of sustainability and energy efficiency in the 1970s. Today, Holling’s work still provides the initial frameworks for resilience and a foundation upon which to view resilience and disaster risk reduction within the built environment. Based on this scholarship and later iterations, we begin with the notion of “[a stable system’s tendency] to return to a position of equilibrium when disturbed” and how quickly it can return to a predefined “stable state” (Ludwig et al. 1996) provides the foundational idea of resilience. Another more detailed interpretation of resilience, as defined by the United Nations International Strategy for Disaster Reduction (UNSDR 2009, p. 24), is:

[the] ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and function.

With mutable definitions of resilience as a result of shifting from ecological to social contexts, the concept of resilience has “blurred boundaries of meanings” rather than provided a straightforward definition (Davidson et al. 2016). Whatever the specific definition or application to date, the concept of resilience has been most useful as a “boundary object” which has helped communicate it across disciplines. A “boundary object” is “malleable” in nature, allowing it to be adopted by diverse disciplines and stakeholders (Brand and Jax 2007). Although increasingly more common in the lexicon of design professionals, the need to operationalize resilience in a meaningful way within the built environment requires an understanding of its conceptual basis as a “boundary object” as well as a more precise application and agreement on discipline-specific language and metrics pertinent to buildings and infrastructure (Davidson et al. 2016). The subset “engineering resilience”, which recognizes a return to a single stable-state after a disturbance (Holling 1996), focuses on ‘return-time-recovery’ to a single operating state as the most critical attribute (Gunderson 2000, Hu 2018). The National Academy of Science (NAS) expands on this concept of resilience through a timeline that describes a system’s capacity to “plan for, absorb, recover, and adapt” to disturbances over time. A system engineered for resilience resists (i.e. absorbs disturbances), recovers (i.e. rebounds within a desirable timeframe), adapts (learns, anticipates, operates flexibly, and continually changes), and hopefully transforms (to restore and/or improve upon a system’s critical functions) (Folke et al. 2010). Critical functionality under various conditions is critical to this timeline (Angeler et al. 2016). And one must consider multiple outcomes, including diminished performance in the longer term (Ayyub et al. 2014).

It is important then to think about “sustainability” and “resilience” as complementary concepts. Both concepts, as they relate to the built environment, propose outcomes for long-term viability. The distinction is that, while sustainability might consider how a building draws on resources and impacts the environment, resilience addresses how a building responds to environmental impacts exerted upon it. The impetus of resilience as a paradigm for today’s design professionals is the introduction of risk-assessment as a fundamental principle of sustainable design. A building, or any other asset, cannot by definition be sustainable if it does...
not incorporate risk mitigation, economic stability, community, and their interdependent relationships to the city as a vital network in short- and long-term timeframes (Tobin 1999, Asprone et al. 2014, Rose 2014). Therefore, when pursuing sustainability, all relatable direct and indirect factors from present and future must be considered.

2.0. SUSTAINABILITY, RESILIENCE, AND ADAPTATION

Modes of urban development in the United States have significantly changed in the past several decades. In terms of [sustainable] environmental planning, before the 1980s frameworks associated with “suitability” were based on matching characteristics of location, land use and type of design (Hill 2016). Since then, the focus of urban development has evolved toward “sustainable development” and later “ecological urbanism” and “landscape urbanism” which attempt to incorporate temporal patterns of resource use and availability in addition to the design of spatial patterns and functional production of development (Mostafavi 2010, Waldheim 2006). Most recently, the concepts of “resilience” and “adaptation” are being incorporated into the literature (Chelleri et al. 2015, Hill 2015). According to Kristina Hill, the shift from sustainability to resilience is the result of isolated [shock] events like storms and flooding rather than incremental [creeping] trends such as higher sea levels and warmer winters attributable to climate change (Hill 2015). Hill posits that the evolution from sustainability to resilience to adaptation represents a paradigm shift in today’s urban planning efforts which are beginning to consider the unprecedented environmental and social changes contemporary cities are experiencing. In this regard, instead of existing as a desirable end-state, resilience is positioned as a “boundary object” that connects the longer temporal scales of both sustainability and adaptation.

Taken in isolation, “sustainability” as it relates directly to resilience has been problematic for architects and designers because of ‘sustainability’s narrow (positivistic) value system and timescale, and despite ever-evolving metrics, as a single value system sustainability still remains dependent on often erroneously defined boundary conditions (Reese 2009, Moffatt 2014). While environmental drivers exist as the main focus of ‘sustainable’ design, social, economic, and institutional metrics are bourgeoning principles of green building rating systems (Doan et al. 2017) However, it is the increased complexity and dynamism of ‘resilience’ that contributes to the difficulty of evaluating it in such a reductive manner. The context of place, the context of problem, and the absence of absolute-good are the driving issues behind this. Unlike the generally positive attributes of green building rating systems like LEED®, BREEAM, and others, ‘resilience’ requires a more nuanced approach due to the inherent trade-offs by definition. A building can be resilient against one perturbation, but not necessarily resilient to another, and increased resilience to one disturbance might result in decreased resilience to another. For example, locating sensitive materials or operations at the basement level of a building to increase resilience against criminal or terrorist attack makes these materials or operations more vulnerable to environmental shocks like flooding (Reference manual to mitigate potential terrorist attacks against buildings 2011). Additionally, tactical decisions at the site and building scale may inhibit more appropriate order of magnitude decisions at the urban or regional scale (Meerow et al. 2016). This, again, speaks to the importance of trade-offs when assessing risk, the difficulty of establishing “no-regret” adaptation policies, and the critical importance of a systems-based approach when attempting to operationalize resilience within the built environment (Preston et al. 2013). Asking - resilience for whom, for what, for when, for where, and why? - is critical (Meerow et al. 2016). With resilience defined as a desirable state, one must ask ‘who defines the state of resilience?’ Asking ‘resilience for when?’ must determine a focus on short-term shocks (e.g. severe weather or storm events) or long-term “creeping” stressors (e.g. drought) and requires an examination of timescales and the desired return to time and to equilibrium (Miller et al. 2010).

This contextualization is precisely what describes the importance of conceptualizing resilience as a modifier to sustainability and a function of adaptation. For the building industry, hazards, risks, and vulnerabilities vary from place to place, and design priority must focus on both imminent hazards and for general adaptive capacity (Meerow et al. 2016). Expanding on
Meerow’s definition of urban resilience, optimizing for specific resilience outcomes with the co-benefits of general sustainability goals can build the ‘adaptive capacity’ of a building, organization, or individual (Keenan 2015). This is perhaps the most salient balance of resilience and sustainability moving forward.

Figure 1 attempts to diagram and better understand these dynamics. The interventions (and outcomes) of sustainability, resilience, and adaptation operate on different timescales. Sustainability metrics largely aim to reduce greenhouse gas emissions by increasing energy efficiency, reducing resource consumption to address the root cause of climate change, which is located the farthest point upstream on the diagram. Resiliency metrics largely respond to the impacts of climate change in the form of adaptation to shocks and stresses attributable to a warming climate. However, investing in buildings and infrastructure to adapt them to existing or future hazards bears more difficult questions: Are these responses to known disturbances only? How does one evaluate making known investments on unknown return on investments given the uncertainty and range of climate change projections (IPCC) and the unclear probability of risk?

Figure 1. Diagram of sustainability, resilience, and adaptation to address GHG and Climate Change (Authors 2019)

3.0. OPERATIONALIZING SUSTAINABILITY, RESILIENCE, AND ADAPTATION

There have been many efforts to develop sustainability assessments (BCPs) as tools to assist decision-makers about actions they need or need not take on the path towards their sustainability goals and a healthier environment. The objective is to ensure that the contribution of the plans and activities by project stakeholders to sustainable development are optimal. Most sustainability assessments are developed based on the three-pillar definition of sustainability where environmental, social, and economic factors are equally important for the decision-makers (Pope et al. 2004). In 1995, an “institutional” dimension was introduced by the Commission on Sustainable Development as the fourth pillar for sustainability. It has been gaining attention in recent years to consider aspects such as political dimensions, non-discriminatory education, gender equality, etc. within sustainability assessments (Doan et al. 2017).

In the realm of disaster risk reduction and community development, there have been attempts to organize resilience in a pillar structure similar to sustainability, including more “resilience indicators” (Cutter et al. 2008). For example, Cutter explores the indicators of community resilience and examines ecological, social, economic, and institutional aspects among the first four. In this structured approach, factors such as wetlands and acreage loss and erosion rates are considered as ecological variables; demographics, social network, and cohesion of
community values are named as social variables; factors like employment, wealth, and value of property are considered economic variables; and factors such as participation, hazard mitigation plans, and emergency response plans are introduced as institutional variables. The research then introduces infrastructure and community competence as the other indicators. However, more recent data shows nearly all single categories of resilience have little bearing statistically on rate and degree of recovery. Indicators in themselves are not so clear because they are more accurate indicators of vulnerability and not of resilience (Burton 2015, Sharifi 2016).

The concepts of vulnerability and adaptation have been subjects of much research (Gallopin 2006). However, interpretations of vulnerability remain understudied in architecture; approaches addressing vulnerability have largely developed within social and natural science fields. Adapting cities for future change is an increasing issue for designers and policy makers (Rose 2014); adaptation at the urban scale through land use and zoning policy is paramount for coastal and riverine communities (e.g. managed retreat policies), and the adaptations may be most reasonable scale to address specific issues concerning coastal and riverine flooding. Adaptation defined as:

adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates, harms, or exploits beneficial opportunities (Gallopin 2006).

Adaptation involves decision-making processes and actions that need to be undertaken in order to prepare and maintain the capacity for significant future changes, without interruption of a system’s functions, identity, or feedback of the system (Nelson et al. 2007). The need for large scale adaptation without interruption is indeed a challenge for practitioners and policy makers. Tools that use sustainability, resilience, and adaptation measures and metrics that adequately address contextual vulnerabilities at a useful magnitude must be made available to design professionals. Indeed, the market is already beginning to require that designers “exercise professional judgment in the context of resilience for climate-related risks [within the context of] an evolving professional standard of care” (GSA 2017 pp. 33). However, the states do not always adopt the most recent code cycles.

4.0. SYNERGIES AND DISCORDS OF VOLUNTARY BUILDING CERTIFICATION PROGRAMS

For design professionals, the operationalization of sustainability and resilience through certification programs is constantly evolving, and it is critical that scholars and practitioners work to develop frameworks that fully encompass sustainability, resilience, adaptation, and vulnerability metrics. Among the discourse of architects and designers today, there still exists two parallel modes of applied research. The more mature of the two is clearly within the voluntary green building assessment systems which primarily focus on energy efficiency and greenhouse gas mitigation (e.g. LEED, BREEAM, ENERGY STAR, Passive House). Emergent resilience metrics are now coming to the industry that are hazard-specific and contextual, and they incorporate methods of risk assessment (e.g. LEED Pilot Credits, RELi, Fortified, Envision). In order to begin to think about these metrics simultaneously in the design and planning phases of buildings and infrastructure, one must be able to evaluate the co-benefits and tradeoffs within them.

The modern concept of resilience is nascent in the professional practice of architecture and design and involves a wide range of meanings and interpretations. However, tools and methodologies are emerging (Linkov et al. 2018). These tools vary from simple checklists to quantifiable metrics and network modeling methods. Resilience assessment tools are developed by a large variety of agencies and entities including public and private sectors and are targeted for cities, industry administrators and operators, and even those inexperienced in resilience but willing to explore this emerging field. In recent years, there have been encouragements for US federal agencies to implement and mandate resilience in the form of regulations and policies (Linkov et al. 2018).
In the private sector, the RELi Resilience Action List Credit Catalog (2017) defines resilience as the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption.

In the RELi framework, resilience is defined at different levels of individuals, households, communities, and regions. Based on this definition, resilience involves not only maintaining livable conditions during disasters but also includes adaptation to a wide range of impacts related to global warming and climate change. In the same catalog, resilient design is defined as the “intentional design of buildings, landscapes, communities, and regions in order to respond to natural and manmade disasters and disturbances” which is expandable to long-term changes because of climate change. This follows closely the definitions and concepts of resilience cited earlier in this paper.

The U.S. Green Building Council (USGBC), largely known for its work on the LEED green building certification program, has begun to adapt its credit system toward operationalizing resilience. In November 2015, the USGBC approved new credits in resilient design as part of an effort to increase awareness about natural and man-made disasters. The objective is to encourage project teams to understand vulnerabilities and the most important risks to projects to address them in design. There are three LEED pilot credits (LEED Pilot Credits on Resilient Design 2019; Pearson 2019): IPpc98, Assessment and Planning for Resilience is the first credit. The objective of this credit is to encourage project stakeholders to plan for potential effects of disastrous events in building design in addition to addressing the impacts of long-term changes like climate change on building performance. The credit requires a hazard assessment prerequisite and one of the two options of “Climate-related Risk Management Planning” and “Emergency Preparedness Planning” (LEED Credit Library 2019). The second credit is IPpc99, Design for Enhanced Resilience: The objective of this credit is to encourage the design of buildings that can survive expected natural disasters and weather events with minimal damage. Mitigation strategy processes must be introduced in this credit for the hazard related risk identified in the first IPpc98 credit. The credit provides options for each hazard separately (LEED Credit Library 2019). IPpc100, Passive Survivability and Back-up Power During Disruptions, is the third pilot credit. The objective of this credit is to ensure passive survivability and building functionality during emergencies. The credit offers two options and multiple paths in each option. The first option ensures passive survivability and safe thermal conditions in the event of extended power outages, while the second option demonstrates the ability to provide enough backup power for critical loads in case of an extended power outage (LEED Credit Library 2019). Passive survivability refers to “the ability of a building to maintain critical life-support conditions for its occupants if services such as power, heating fuel, or water are lost for an extended period” (Wilson 2005).

5.0. COMMON FRAMING CERTIFICATION PROGRAMS

To reduce the noise surrounding the various interpretations and applications of resilience and adaptation, it is critical that designers first begin to make judgments through an evaluation of the criteria laid out in the academic scholarship and broader policy. Considering various evolving sustainability and emerging resilience certification programs, it is critical that designers unpack the material into its constituent parts and decide how the parts relate to one another as well as to the overall structure and intent of each program. Taking these two approaches, designers may then be able to form a novel or at least coherent product that addresses the positivist tenets of sustainability while incorporating tradeoffs inherent in resilience frameworks. Taking the scholarship of Bruneau et al. (2003), Miller et al. (2010) and Woods (2015) as a starting point, Table 1 begins to lay out a framework in which to examine sustainability and resilience certification programs together. The table incorporates Woods’ (2015) four basic concepts of resilience: 1) “resilience as rebound”, 2) “resilience as robustness”, 3) “resilience as graceful extensibility”, and 4) “resilience as sustained adaptability”. The concept "rebound" is characterized by a return to a previous set of “capabilities or resources” (Woods 2015), and importantly these resources must be able to be
deployed in the event of a shock or stress. This concept includes important aspects of organizational and operational planning. It is the most commonly interpreted concept of resilience according to Woods. “Robustness” can be thought of as the ability to absorb disturbances; this concept expands the range of disturbances a system can deal with and it is perhaps the most operationalized within engineering resilience applications. “Graceful Extensibility” increases the adaptive capacity of a system and allows it to degrade gracefully if the disturbance exceeds the system’s capacity to rebound. The sub-optimal, but acceptable performance of a system under stress (as it pertains to this concept of resilience) is understudied in design. “Sustained Adaptable”, the most comprehensive notion of Woods’ characterization of resilience, incorporates adaptive capacity as a clear criterion at the scale of a single system and its inclusion in a larger network of dependencies.

Table 1. Matrix weighting of resilience and sustainability voluntary certification programs (Authors 2019)

<table>
<thead>
<tr>
<th>External Impacts</th>
<th>LEED v4.1</th>
<th>RELI (RS)</th>
<th>Envision (RS)</th>
<th>Fires (Cert)</th>
<th>LEED (RS)</th>
<th>BREEAM (RS)</th>
<th>ENERGY STAR (Cert)</th>
<th>PHAS (Cert)</th>
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<tbody>
<tr>
<td>Natural</td>
<td>Earthquakes</td>
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<td>Fires</td>
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<td>Tsunamis &amp; Floods</td>
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<td>Storms &amp; Hurricanes</td>
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<td>Other disasters such as landslides, etc.</td>
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<td>Environmental</td>
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<td>Extreme Weather</td>
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<td>(GHG emissions)</td>
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<td>(extreme heat/storm)</td>
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<td>(energy/water scarcity)</td>
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<td>Health</td>
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<td>(neighborhood cohesion, crime, weather, etc.)</td>
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<td>(public health and safety)</td>
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<td>Economic</td>
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<td>(economic competitiveness)</td>
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<tr>
<td>Stages of Resilience**</td>
<td>Rebound</td>
<td></td>
<td></td>
<td>Robustness</td>
<td></td>
<td>Graceful Extensibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sustained Adaptability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Stages of resilience as defined by the NAS
*** Concepts of resilience as defined by Woods (2015)
**** Disturbances as defined by Miller et al. (2010)

6.0. DISCUSSION & CONCLUSION
Although broader concepts of resilience and sustainability have been linked together by ecologists and ecological economists, their relationships and how their interdependencies can help inform the design of cities must be further developed (Rose 2014). While adaptation of resilience and sustainable strategies is more complex in urban scale compared to building scale due to larger number of variables, working at a reasonable order of magnitude, land use
planning and zoning codes are critical tools for increasing sustainability and resilience in the future. In the meantime, tools available to work on the building, site, and neighborhood scale are necessary to manage the current realities of the built environment. And synergies do exist between sustainability and resilience at these scales. For example, strategies such as increased insulation and a “tight” building envelope that increase energy efficiency and passive survivability, is an area where sustainable design and resilient design outcomes align (Samuelson et al. 2015, Baniassadi et al. 2018). Increased insulation contributes to a building that can maintain comfortable temperatures and thus passive survivability if a storm event disables power to a building for some length of time. A more efficient building envelope and mechanical systems also extend the usefulness of backup power systems (e.g. well-anchored photovoltaic system and batteries to supplement conventional electricity grid-supply). Furthermore, by driving down the cost of energy for the building occupant, it’s possible to build capacity (e.g. fiscal resources). However, the translation of these synergies into design metrics must recognize the limitations of GHG mitigation and disaster risk reduction within the confines of the building industry. Architects and designers will only balance these limitations by promoting sustainability, resilience, and adaptive capacity in a more literate and informed manner by engaging in cross-disciplinary work at all stages of design. Bourgeoning examples of this is early design evaluation of buildings under increasing timescales and design conditions. For example, because of the interdependent nature of building systems, uncertainty in design, construction and occupancy timescales of buildings, more work is being done on understanding the performance of such systems (e.g. HVAC and building enclosure design) under stress and under extreme conditions (Eleftheriadis & Hamdy 2017, Waddicor et al. 2016, Wang & Hong 2013). Taking the author’s above framework as a guide, more granularity in investigating the elasticity of buildings and their systems is a much-needed step in the design process.

There is a clear tension between careful analysis of design decisions and reliance on reductive tools like checklists or metrics. However, tables like the one proposed by the authors help frame and evaluate the application of real-world technologies and behaviors for increasing resilience within the built environment. Indeed, RELi as an integrative approach seeks early synergies for planning sustainability and resilience goals. For example, RELi was cited as a critical tool for buildings such as Christus Spohn Hospital in Corpus Christi, TX. RELi’s integration with LEED prerequisites and credits and other guidelines help identify its position as an evolution in sustainability centered certification programs, building on and refining the long history of sustainable design outlined in this paper (Perkins + Will 2017). Given the above complexities, the authors conclude that understanding how the synergies and discords of sustainability and resilience are codified and operationalized within a comprehensive framework coupled with performance evaluation in early design are critical steps in effectively operationalizing sustainability and resilience.

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REFERENCES


ENVIRONMENTAL STEWARDSHIP

https://www.gsa.gov/cdnstatic/2017_Facilities_Standards_%28P100%29%C2%A0.pdf


The design of a wellness center for orphans in Idlib, Syria

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¹Thomas Jefferson University, Philadelphia, PA

ABSTRACT: Syria has reached its seventh year of war, with its future decimated and its citizens searching for hope. For those who stayed, their lives, lifestyles, customs, and historic legacy are uncertain. This research focused on providing orphans located in Idlib, Syria with a holistic mixed-use facility that provides for well being, education, health care, and spiritual needs, while using the culture’s vernacular architectural history. The research used the Integral Framework as a rigorous methodology to guide analysis of the problems and identify solutions. The framework provided a systematic means to research experience and well being, performance, systems and culture at multiple scales to help ensure the process was not just broad, but also deep, meaningful and holistic. The site has the capacity to house 500 children, with services that include a Montessori-style school for ages 3-12, a medical and dental clinic, an urban farm, soccer field, and bakery. Holistic wellbeing is enhanced by water and food security, energy supply, economic growth, ecological experiences, and resilient architecture. The project is an important symbolic representation of hope for Syria’s future generation and reconstruction. This project’s location in Idlib was primarily chosen for bridging the coastal and central regions, becoming a refuge for many displaced Syrians escaping the regime. By assessing the past and current problems, the wellness center will provide a model for environmental stewardship and restorative design.

KEYWORDS: Syria, Biophilia, Sustainability, Sustainable Design, Integral Framework

INTRODUCTION

March 2011 marked the beginning of the Syrian Civil War, when courageous Syrian teenagers from Dara’a wrote on a wall, “the people want to overthrow the regime.” The teenagers had become inspired by the Arab Spring uprising that led Tunisia, Egypt, and Libya to revolt against their own regimes (CNN, 2016). As a result, authorities imprisoned and tortured the students, and refused to return them to their families. Since then, peaceful protests emerged in Dara’a, leading other Syrian cities to follow. Today, the Assad forces and its allies have attacked civilians, violating all human rights. The war has led 5 million Syrians to evacuate to neighboring countries, Europe, and the U.S.; 6.3 million have been internally displaced (Kenneth, 2019). Many cities in Syria are drastically affected by the civil war through destroyed infrastructure, declining populations, and wavering economic conditions and resources. Thus the aim of the project was to create a resilient biophilic wellness center that acts as an agricultural, economic, and architectural model for rebuilding Syria.

This model, to address such comprehensive issues, must be designed holistically to refrain from recreating the problems of the past and resolve the problems that have arisen since. A holistic approach will help to create a project that serves the community, increases cost-efficiency, increase service-accessibility, decrease stigmatization and suffering, and most importantly, to serve the children. Therefore, a typical design process would not be adequate in creating a long-term solution for the people of Syria. A project supported by holistic research can fully acquire viable results bridging theory and practice. To accomplish this, a design approach was used that includes the Integral Framework (DeKay, 2011; Wilber, 2000). The Integral Framework uses a four-quadrant system, which is similar to viewing a topic through four different lenses: experience, culture, performance, and systems, as illustrated in Figure 1.
Additionally, within each quadrant, the past and present problems are explored through multiple scales from global to local. This approach attempts to ensure that most (if not all) aspects of the topic are addressed without any social, economic, experiential, or ecological problems being excluded.

1.0 PROBLEM

2.1 Experience

The experience quadrant explores physical and psychological well being as a result of the personal experience of the built environment conditions that developed as a result of multiple phenomena. Before the war, Syrians suffered from a lack of rainfall, population influx, crumbling infrastructure, and the mismanagement of natural resources. These dire conditions brought rural communities to a state of poverty resulting in a massive migration to cities. Figure 2 shows that water and adaptive capacity was most vulnerable (Werrell, Femia, Sternber, 2015).

As a result of the war, Syrian children have suffered psychological and physical stress from witnessing the death of a family member, the destruction of their homes, fleeing their neighborhoods, and living in dire conditions. These children have lost everything, and their future has become unstable. Studies have shown that traumatic experiences from the war
provoked a spectrum of psychological problems including: fear, difficulty sleeping, sadness, grief and depression, isolation from family and friends, aggression or temper tantrums, nervousness, hyperactivity and tension, speech problems, and somatic symptoms (UNHCR, 2013). Many children have attempted suicide to escape the horrors they have endured, and others have turned to self-harm and taking drugs (Taylor, 2017). Syrian children are seen as the hope for the future, but at the same time their well-being has been diminished. The horrors they endured will have a long-term affect on their development and psychological well-being.

Mental health services inside Syria have become all but impossible to provide due to the scarcity of mental health specialists. The adults’ well being is highly affected, which in turn makes it difficult for children to have proper support. As adults face mental health disorders, there is a stigma associated with seeking help, limiting those who are actually treated. The International Medical Corporation suggests making mental healthcare part of the general healthcare to help combat the stigma of visiting a psychiatrist (Karaplan, 2016).

2.2 Culture
The culture quadrant explores the built environment’s repercussion on Syria’s rural and urban communities. Farmers in rural communities build their homes using modern building techniques that unfortunately cost more, creating an unnecessary strain on families. Rural housing projects were funded through government loans with interest rates that would take 15-25 years to pay back, and was equal to half the farmer’s income (Jiroudy, 2012). “The government is paying an inflated price for an imported item and low-income dwellers are trapped in a high-debt poor housing long term situation” (Jiroudy, 2012, pg. 1).

As these issues were occurring in the rural outskirts of cities, urban centers had their own architectural problems. Marwa Al-Sabouni, an architect located in war-torn Homs, explained how the built environment had also laid the beginning stages for war. She postulated the “brutal unfinished concrete blocks, aesthetic devastation and divisive communities that zoned communities by class, creed, or affluence,” had brought state fragility to Syria (Doroteo, 2016, pg. 2). The government created a master plan (see Figure 3) to rebuild Homs, which has the same problems as before.

![Figure 3. Government Master Plan of Homs. Source: (Doroteo, 2016)](image)

Those problems included an industrial modernized architecture influenced by western invasions which is unsuitable and detracts from Syria’s heritage and culture (Doroteo, 2016). It included skyscrapers, and Le Corbusier’s building principles of modernization devoid of any historical influence (Doroteo, 2016). Rebuilding in this way repeated the cycle of disconnecting the community. Planners wanted to modernize cities and widen streets, but people wanted to restore their neighborhoods and preserve the character of the narrow streets (Aleppo Project, 2015).
2.3 Performance
The performance quadrant provides quantitative results for water and food supply, energy consumption, attack on healthcare facilities and schools, carbon emissions, agriculture, and the number of orphans. While the country was experiencing one of the longest droughts from 2007 to 2012, the Assad regime had been subsidizing water-intensive crops requiring flood irrigation techniques. This resulted in the waste of 60% of water consumed (Werrell, Femia, Sternberg, 2015). The lack of water supply resulted in crop failure of 75% and livestock loss of 85% (Werrell, Femia, Sternberg, 2015). Regarding energy, oil and natural gas were the prominent resources before the war, but during the war Syria’s oil supply was disrupted, dropping to nearly zero, leaving residents without a source of energy. This decreased the associated GHG emissions, but this not a sustainable nor desirable means to reduce emissions. Healthcare facilities and schools have been the main targets of attack with 336 medical facilities destroyed, and 1 in 4 schools damaged or destroyed (BBC, 2016 and Nolan, 2016). With the number of attacks rising, the war has resulted in 600,000 Syrian orphans, exceeding the humanitarian and service efforts. (Daily Sabah, 2016). These quantifiable results aid with setting the energy, water, and food production results for the project.

2.4 Systems
The systems quadrant investigated the water supply, agriculture, and economy in Idlib, Syria, to identify the problems on a local scale for the project. Idlib relies on water springs and groundwater wells for its potable water, which is distributed via pumping stations (Alshamli, 2016). After the conflict, air raids damaged most of the pumping sites, incurring expenses and difficulties in attaining water (Alshamli, 2016). Before the conflict, the production of goods and agriculture brought 7 billion Syrian pounds to the city. The two major crops of Idlib are olive trees and figs, which are manufactured traditionally into olive oil and dried figs (Syrianet, 2015). Today there has been a major fluctuation in prices depending on resource availability.

3.0 SOLUTION
The problems discussed in each of the quadrants above were addressed systematically. The experience and well being of the children were addressed by the types of spaces and services provided, which are set within a biophilic campus. Performance issues were addressed through the exploration of water conservation, natural ventilation, and daylighting. The systems of the site were addressed through the harvesting of rainwater, solar power, and the development of agriculture on site. Finally, culture was instilled in the site by employing vernacular architecture techniques, forms, and aesthetics. The master plan shows how the design created cohesion between the landscape and buildings as seen in Figure 4. The project creates a layout of all the services, with additional emphasis and simulations of energy performance and water conservation on the school building only.

3.1 Biophilia
Biophilia, a hypothesis proposed by Edward O. Wilson, explains humans’ innate affiliation and connection with nature, which is a trend growing in popularity. Studies supporting the theory are multiplying, thus building an ever-increasing case to apply biophilic design in projects. In the case of Syrian orphans, biophilia would transform the lives of orphans physically, psychologically, and emotionally from the chaos of war they endured.

3.2 Wind Towers
Natural ventilation was investigated as a technique to improve performance (see Figure 5). A vernacular technique for thermal comfort, the wind tower was simulated using IES (see Table 1). The results were iteratively tested, until proper sizing was reached to provide natural cooling. It was also evident that natural cooling may be limited during the hottest times of the year due to Idlib’s climate, and backup systems would be required.
The design of a wellness center for orphans in Idlib, Syria

**Figure 4.** Site plan. Source: (Author, 2017)

**Figure 5.** Performance, apply resilient principles suitable for the region to build a self-sufficient wellness center. Source: (Author, 2017)

**Table 1.** Two-story wind tower – trial simulations

<table>
<thead>
<tr>
<th>Trial Final</th>
<th>Size</th>
<th>Simulation</th>
<th>Scale</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final</td>
<td>Two wind tower, one for each classroom wind tower</td>
<td>Size 0.9m x 2.1m Opening: 1.5mx2.1m</td>
<td>0.3 m/s</td>
<td>Air flow reaches both classrooms</td>
</tr>
</tbody>
</table>

Air flow reaches both classrooms
3.3 Daylighting
Daylighting allows for a building to save on energy and improve children’s performance and experience. To allow the proper amount of daylighting, the window to wall ratio was calculated and simulations were run using Radiance. The results show that a window with a light shelf and clerestory windows allow for proper daylighting (Figures 6 and 7).

![Figure 6. Clerestory for winter/summer. Source: (Author, IES, 2017)](image)

![Figure 7. Clerestory for fall/spring. Source: (Author, IES, 2017)](image)

3.4 Vernacular Design
The decision to place the site in Idlib was based upon several factors: to bridge the gap between urban and rural contexts; provide shelter and well-being for the orphans; synchronize traditional solutions with modern technologies; and incorporate personal childhood memories of Syrian summerhouses. Vernacular design informs the climatic solutions for the buildings, while modern technology enhances the energy and water efficiency systems. The building was designed according to the resources available in the area in an effort to provide “appropriate technology”. Idlib’s streets are filled with pointed arches, stonewalls, intricate motifs, domes, and awnings. Syrian architecture needs to be revived and its techniques honored for its application to achieve holistic sustainability.
Figure 8. Celebrate the history and culture of Syria. Source: (Author, 2017)

3.5 Water
Rainwater harvesting could only occur during the rainfall season, which is between November and March. The rainfall from these months would be retained on site to provide water during the dry season. Table 2 shows the amount of rainwater that could be retained on site (175316.42 liters), which meets the demand (518859.73 liters). The amount of water leftover is approximately 37854.12 liters, which could be used for irrigation. Overall, the annual percent savings from using municipal water is 74%.

Table 2. Rainwater harvesting

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall cm/month</th>
<th>Total rain on site (liter)</th>
<th>Total rain collected (liter)</th>
<th>Rain for dry season</th>
<th>Supply for dry months</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>6.5</td>
<td>356144.71</td>
<td>33353.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>4.74</td>
<td>260152.57</td>
<td>24363.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>3.25</td>
<td>178072.35</td>
<td>16676.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>1.12</td>
<td>61212.37</td>
<td>16676.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>1.37</td>
<td>75124.26</td>
<td>7035.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>0.33</td>
<td>18085.48</td>
<td>1693.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>0.02</td>
<td>1112.94</td>
<td>104.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>0.27</td>
<td>14746.60</td>
<td>1381.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>0.11</td>
<td>5843.01</td>
<td>547.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0.97</td>
<td>52865.24</td>
<td>4950.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>15.49</td>
<td>848626.10</td>
<td>79476.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Rainfall</td>
<td>3.09</td>
<td>15895.20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Indoor Water Needed/Month 33943.79

Total Rainwater Collected in 2016 175316.42 147631.06
Figure 9. Create a collaborative and fast revitalization process in Idlib to ensure a safe haven for children. Source: (Author, 2017)

3.6 Solar Energy
After energy conservation and natural ventilation strategies have been met, solar energy was selected to meet the remaining energy loads, and solar calculations were completed for the school. The school rooftop area alone is not enough to hold the required number of photovoltaic panels; so additional roofs on campus were also used. The total available roof area was 528.71 m², allowing for 330 panels to be installed. The solar panels produce 127,119.65 KWH of energy, which provides more energy than the building needs. The building’s energy consumption was determined on Sefaira. After the daylighting, natural ventilation, u-values and r-values were added to the settings the building required 96,936 KWH of energy. Based on the results the school building surpasses net zero energy consumption.

CONCLUSION
The Integral Framework is an approach to design which attempts to include multiple aspects simultaneously and move closer to holistic solutions by exploring issues through four different lenses: experience, culture, performance, and systems. Well being was achieved by improving the experience of the city, connecting with the architectural heritage and creating a peaceful biophilic space for healing. Performance was improved by adding resilience via an off-grid decentralized pv system, energy efficient buildings using passive daylighting and cooling techniques. Systems were addressed through water harvesting methods, and cultural issues are addressed via vernacular design and providing badly needed physical and psychological services. Often, overlaps between quadrants were unearthed, leading to solutions with the potential to become truly holistic, such as one element simultaneously serving all four diverse quadrants, and to bridge the quantitative and qualitative, such as the school building. The building of the orphanage is a catalyst for a bright and sustainable future in Syria. Its strategies provide a prototype for construction of the city. The center becomes a place where the orphans heal, learn, and grow. The elderly will become optimistic about Syria’s future plan. Wars eventually subside and people will be ready to work.

ACKNOWLEDGEMENTS
The contribution of the previous ARCC conference organizers and committees is hereby gratefully acknowledged. I would like to thank ARCC committee for the opportunity to showcase this research analysis on the Syrian Conflict at Toronto’s 2019 conference. I would like to thank my family for their love and support. I would also like to thank Professor Robert Fryer for his continued support, encouragement, and profound knowledge.
The design of a wellness center for orphans in Idlib, Syria

REFERENCES


Environmental performance evaluation of enclosure systems alternatives in office buildings in the U.S.

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ABSTRACT: Low impact materials have become key player towards achieving environmental sustainability in the built environment. Such materials also contribute to carbon neutral buildings, responding to AIA 2030 challenge and many other initiatives by governmental and professional institutions. Building enclosure incorporates many construction materials that contribute to overall embodied energy and environmental impact. It also affects building operational energy as a barrier between indoor and outdoor environment. The study method employs a quantitative Life Cycle Assessment (LCA) approach in calculating environmental impacts of enclosure systems. The paper models an office building over a service life of 60 years and its implications on the environment from cradle to grave. It also quantifies and compares the total impacts of the assembly systems of this building throughout this life span. The case building is located in the Midwest in zone 5, where steel construction is the common method of construction for commercial type in the region. The building is a 1-story high that incorporates few sustainable materials. The study calculates the environmental footprint of the building per unit area (impact to air, water, and land). To achieve its goal, the study provides an assessment to which building component (structure, walls, floors, roofs) contribute the most to the total building impacts where the worst burden, among its assembly systems, is identified. The outcome tests other materials alternatives to use in the roofing system to minimize its impact. The paper employs a “what if” scenario analysis to evaluate replacing high-impact materials with alternatives that have less impacts and briefly calculate the reduction in the total impacts against the original construction materials.

KEYWORDS: Environmental Impacts, Life Cycle Assessment, Sensitivity Analysis.

INTRODUCTION

The contribution of buildings to the overall environmental impacts of human activities has been significant and well-documented (EPA 2009, EIA 2015). According to the US Energy Information Administration (EIA 2015), 19% of the world’s primary energy is consumed in the U.S. Buildings also contribute 40% to carbon dioxide emissions in the U.S. (EIA 2012) and near 66% of non-industrial solid waste generation (EPA 2009). The building sector in the U.S. constitutes approximately 44% of the total material use as well as roughly 1/3 of the total CO2 emission identified as one of the main factors of greenhouse gas emissions (U.S.DOE 2002). Life Cycle Assessment LCA represents a quantitative tool for calculating the environmental impacts of buildings at all stages in their life cycle from cradle to grave. Throughout the life cycle of a building, various natural resources are consumed, including energy resources, water, land, and several pollutants are released back to the global/regional environment. These environmental burdens result in global warming, acidification, air pollution, etc., which impose damage on human health, natural resources, and biodiversity. There is no doubt that reducing the environmental burden of the construction industry is crucial to a sustainable world.

Many studies use LCA in assessing the environmental impacts of buildings. For example. Klunder (2001) gave a description of environmental issues of dwellings, noting that assessments should focus primarily on components that involve large quantities of materials (e.g., foundation, floors, and walls), but there are also dangerous materials that should be avoided regardless of quantity (e.g., lead). Junnila and Horvath (2003) took the same path to
quantify the most significant impacts of a high-end office in Europe. However, this study narrows down to the systems and materials that release most emissions for the studied case in order to test better retrofitting or fit out alternatives as building adapts to its future. Ragheb (2011) concluded that that the walls system has the highest percentage of emissions among other components, mainly in global warming, acidification, smog, and respiratory effect impacts in a comparative study of 3 office buildings. Tingley et al (2015) have used LCA at the level of construction materials to compare three different insulation materials when applied in a typical dwelling.

Building assembly systems (structural, envelope, floors, and roofs) on the commercial side are rarely studied on individual or as combined systems in LCA studies. Thus, such information and data indicating the significant impacts by building systems would be of great use in design and management of the building life cycle maintenance. The literature also supports that the design process, especially for office buildings, is never a finished process and the retrofit and building adaptation support this fact. Thus, LCA is a beneficial tool in this ongoing adaptive process as the findings support these flexible retrofit of systems, and/or materials, with way less impacts alternatives.

1.0. RESEARCH METHOD AND ASSUMPTIONS

A life cycle assessment (LCA) framework is selected to analyze the environmental impacts of a new office building in the Midwest. Sixty years of use was assumed to be the basic life cycle. LCA is the most appropriate framework for the identification, quantification, and evaluation of the inputs, outputs, and the potential environmental impacts of a product, process, or service throughout its life cycle, from cradle to grave i.e., from raw material acquisition through production and use to disposal [as defined in ISO 14040, 1997]. The LCA had three main phases; inventory analysis for quantifying emissions and wastes, impact assessment for evaluating the potential environmental impacts of the inventory of emissions and wastes, and interpretation for defining the most significant impacts.

LCA is defined as a holistic and systematic process to calculate the environmental burdens associated with a product or process. The process identifies and quantifies energy and material usage and environmental releases of the studied system and evaluates the corresponding impacts on the environment. Identification and quantification of material and energy flows (inputs and outputs) of the case study office building were obtained from the construction drawings and specifications and modeled using series of software listed below.

The quality of the data used in the life-cycle inventory was evaluated with the help of a six-dimensional estimation framework recommended by (Heijungs, et al. 2002). The quality target for the LCA was set to be at the level of “good,” which means reliability of a most recent documented data from actual drawings, specs sheets. In life-cycle impact assessment LCIA, the magnitude and significance of the energy and material flows (inputs and outputs) were evaluated. The impact categories included were those identified by EPA (2006) as ‘Commonly Used Life Cycle Impact Categories’. Among the 10 listed categories, the impact categories in this paper include:

- Primary Energy (Fossil Fuel Consumption) FFC,
- Resources Use RU,
- Global Warming Potential GWP (Climate Change),
- Acidification Potential AP,
- Eutrophication Potential EP,
- Human Health Respiratory Effect Potential HHREP,
- Photochemical Ozone Creation Potential POCP, or Summer Smog,
- Ozone Depletion Potential ODP.

The chosen impact categories are also on the short list of environmental themes that most environmental experts agree to be of high importance in all regions of the world and for all corporate functions (Schmidt and Sullivan, 2002). Furthermore, the used impact categories
are consistent with the air and water emissions that the World Bank (1998) has recommended to be targeted in environmental assessments of industrial enterprises. The classification, or assigning of inventory data to impact categories, and the characterization, or modeling of inventory data within the impact categories (ISO 1997), were performed using the ATHENA 4.2 Impact Estimator (2014) which is used to model the building. The program filters the LCI results through a set of characterization measures based on the mid-point impact assessment methodology developed by the U.S. Environmental Protection Agency (U.S. EPA); the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2. In the life-cycle interpretation section, the results are also examined from the building assembly systems (foundations, structures, walls, floors, and roof) so that the environmental impact of each system’s life cycle can be quantified.

1.1. Case study building description
The case study is a new office building located in zone 5 (per ASHRAE’s classification) in the Midwest of the U.S. Its construction ended in 2014. The targeted use of the building is mainly offices. The building has 21,500 sq ft (1997 m²) of gross floor area, and a volume of 354,750 cu ft (9985 m³). The building consists of 1 main floor 16.5 ft (5 m) high with no basement. The structural frame is Hollow Structural Steel HSS columns and open web steel joist for roof support. Floors are light reinforced concrete of one slab-on-grade floor. The exterior walls are brick veneer with steel studs backing. Interior walls are galvanized steel studs with gypsum board facing to receive paint or wall paper. Foundations are cast-in-place concrete. The annual energy consumption (operational energy) is modeled/calculated using eQuest 3.65 (2016). The estimated natural gas consumption, mainly for water heating, of the building is 35.44 Mbtu (1648 Btu/sq ft/year) and this is equivalent to 0.483 kWh/sq ft/year. The estimated electricity consumption is 184,650 kWh/year (8.58 kWh/sq ft/year, or approx. 29,300 Btu/sq ft/year of energy intensity), which is slightly below U.S. average consumption for a small office bldg.

In the study, the life cycle of the building was divided into 5 main phases; building materials manufacturing, construction processes, operation phase, maintenance, and demolition. Transportation of materials was included in each life-cycle phase through the software. The building materials phase included all of the transportation to the wholesaler warehouse. The construction phase included all of the transportation to the warehouse to the site.

1.2. Materials manufacturing
The following building element categories were included in the study: foundation, structural frame (beams & columns), floors, external walls (envelope), roofs, and some internal elements e.g., doors, partition walls, and suspended ceilings. The amount of each material used in the building was derived from the bill of quantities generated by the software. However, building modeling was mainly based on input from architectural and engineering drawings, and the architect’s specifications. Around 30 different building materials were identified and modeled.

1.3. Construction phase
The construction phase of the building included all materials and energy used in on-site activities. Data were modeled for the use of electricity, construction equipment, and transportation of building materials to the site (average 100 mi).

1.4. Operation phase
The use of the building was divided into mainly heating service (by natural gas) and electrical consumption. For the purpose of energy simulation, the building was estimated to be used 55 hr/week for 60 years. Energy calculations were performed using eQuest 3.65, a DOE 2 energy simulation program for electricity use and HVAC heating and cooling loads. All building parameters (dimensions, orientation, walls, windows, etc) were modeled.
1.5. Maintenance and retrofit phase
The maintenance phase included all of the life-cycle elements needed during the 60 years of maintenance; use of building materials, construction activities, and waste management of discarded building materials. An estimated 75% of building materials was assumed to go to landfill, and 25% was assumed recovered for other purposes such as recycling.

1.6. Demolition phase
The demolition phase included demolition activities on-site, transportation of discarded building materials (75% of the total) to a landfill (100 mi), and shipping of recovered building materials to recycling site (100 mi, on average). The entire building was assumed to be demolished.

2.0. INTERPRETATION OF RESULTS
To interpret the results for the purposes of design management, an analysis of the result from the building assembly systems perspective is important. Hence, the life-cycle phases are divided into life-cycle elements, the elements belonging to different building assembly systems are grouped together, and the life-cycle impacts of each building system; foundations, walls, structure (columns and beams), roofs, floors, are calculated. Fig. 1 shows that the environmental impacts of the office life cycle are divided into 5 building components systems. Three significant systems accounts for the highest environmental impacts of this building. These are roof, structure (columns/beams), and the wall systems respectively.

The results for all impacts have to be normalized per sq meter of building area for fair comparison. However, when comparing the life cycle impacts of assembly systems, it was surprising to find that the roof system has huge impact compared to building structures and walls which come second and third respectively. This happen in most impact categories (FFC, GWP, AP, EP, POCP, HHREP). In this study (Fig.1), the result was primarily due to increasing the roof insulation thickness to increase energy efficiency. The rigid insulation used (polyisocynurate), albeit high in R-value per inch (R 7.2), it has high embodied energy and has huge emissions during its manufacturing process. Insulation also covers wide area of the roof and walls systems forming the building enclosure. The other material, causes this huge roof impact, is steel (with its massive embodied and transportation energy) in building structure. These results made energy consumption (embodied + transportation energy) the most dominant impact category in the whole assembly (Fig.1). Resources use is the highest in foundations and floors systems due to the massive concrete weight and wide area both systems cover. GWP is more in roof and walls (due to insulation emissions) than structure. AP is the highest impact in walls assembly due to some materials such as gypsum boards, fiberglass insulation, and vapor barriers which release Sulphur dioxide (SO2) and Nitrogen oxides (NOx) during manufacturing that contribute to acid rain formation when released to the environment.

3.0 RETROFIT SCENARIO ANALYSIS
Sensitivity analysis is typically used to check either the significance of changing key parameters contributing to the overall LCA or key assumptions governing the methodology of the LCA itself. The what if scenario is used for sensitivity analysis according to Pesonen et al. (2000). Sensitivity scenarios are used to compare the replacement of materials that have high impacts within the building with more environmentally friendly alternatives, and then quantify these changes in the environmental impacts again at the end of the 60 years. From the previous results, the study found that materials such as roof insulation and membrane have huge area, quantities, and potential high impact in many categories. Therefore, roof materials are replaced with more environmentally friendly alternatives, then the total impacts are assessed again with the new alternatives to test how much reduction to the results was achieved. The other systems (foundations, structure, floors) are not changed in this analysis because they are fixed systems (cannot be changed) once building is erected. The roof is chosen because it represents the highest impacts share by building systems, besides structure...
(Fig. 1). This is consistent with ISO 14043 (1998) to “assess the sensitivity of data elements that influence the results most greatly”.

![Graph showing environmental impacts by building assembly systems.](image)

**Fig. 1.** Environmental Impacts by Building Assembly Systems

**Table 1.** Retrofit Scenario Analysis

<table>
<thead>
<tr>
<th></th>
<th>Roof Insulation</th>
<th>Roof Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing</strong></td>
<td>4.5” rigid poly-isocyanurate insulation w/ R-30</td>
<td>Mechanically fastened 60 mil black EPDM</td>
</tr>
<tr>
<td><strong>Retrofit</strong></td>
<td>6.5” rigid expanded polystyrene insulation w/ R-30</td>
<td>Mechanically fastened 60 mil white TPO</td>
</tr>
</tbody>
</table>

### 3.1. Retrofits assumptions scenarios

A list of changing variables included in the analysis is shown in (Table 1). The main assumptions for retrofitting was to try other alternatives for the roofing system since it showed the highest impact among assembly systems (Fig.1). Expanded polystyrene proved to be more environmentally friendly and gives comparable R-value over similar polyisocynurate insulation but with less environmental impact due to its recycling nature. Since polyisocynurate is more durable than expanded polystyrene, it is important to mention that although durability plays a factor in roof design, it was normalized here for the sake of testing and comparing the impact of these 2 alternatives. Roof replacement is suggested to take place 2 times during 60 years of life (every 30 years). This seems quite reasonable assumption since the life expectancy of an ordinary roof insulation is around 30 years. Suggested changes are to replace the 4.5” thick polyisocyanurate insulation and 60 mil black EPDM membrane with 6.5” thick expanded polystyrene insulation (to give the same R-value) and 60 mil white TPO membrane (Fig. 2). The materials that were chosen represent the most significant materials of the roof system due to quantity (coverage area) and their possible high emissions during manufacturing. Other materials such as steel decking, fasteners, roof board were similar in both comparative assemblies.
3.2. Retrofit sensitivity results

Figure 3 shows results of all impact categories by building assembly systems. The two scenarios are the existing calculations scenario and the retrofit scenario. Results show that sensitivity scenario with alternative materials has reduced values in all impact categories due to the change of insulation and membrane (Table 1). These reductions range between 6% and 19% in the 8 different impact categories this study has investigated. The retrofit sensitivity also highlights the importance of roof insulation and membrane as sensitive materials that have huge quantities within a building. They significantly reduce the whole impacts if chosen carefully by architects.

**Fig. 3. Environmental Impacts Reduction Due to Retrofitting**

**CONCLUSION**

The purpose of the study is to quantify and compare the environmental impact caused by an office building's assembly systems. The study also determined the life-cycle phases that contribute the most to the whole building impact. The study examined the building assembly components that most contribute to its life cycle impact. The study found that roof and wall
systems to have significant environmental impacts due to the use of insulation and membrane materials. Using more environmentally friendly materials (expanded polystyrene insulation + TPO membrane) in roof assembly rendered a reduction of 6% -19% in different impact categories throughout the entire life cycle. Using the TPO membrane reduced the annual energy consumption of the building by 10% over 60 years which in turn reduced the total impact. Suggestions have shown the importance of LCA as tool to choose better alternatives during the maintenance (retrofit) phase of an office building. Some limitation on impacts include office furniture, computers, construction of infrastructure are not assessed due to the limitation of the modeling software. These were excluded to focus on modeling the building assembly systems not the interior furniture.

LCA results demonstrated that the case study building has overall lower energy consumption rate for an office building in the U.S. This is mainly due to tighter enclosure. One shortcoming though was the use of polyisocyanurate insulation and EPDM rubber membrane without considering the high environmental impact of using such alternatives. This resulted in that the roof system had the highest impact in most categories. The LCA method helped to narrow down to this high-impact system and material choices used (e.g. insulation, membrane). Hence, even an energy efficient building may have a reverse huge impact due to selection of high-impact building materials within its assembly systems. It seems to have an overall annual energy savings but has significant high impact of materials that achieve this saving.

One of the limitations of the study relates to the single-case study method used, because wider generalization based on a single case is not possible. However, the results of the study can be interpreted together with the results from previous studies. The findings of this study support previous arguments that operation energy is a major environmental issue in the life-cycle of an office building, and that some building materials e.g. insulation, membrane also have significant impact. This is typical for an office building in the U.S. For other countries, it is more difficult to generalize based on the results of this study. There are many regional conditions used in the calculations that could affect considerably the results outside the U.S. Building design, intensity of materials, construction methods, and intensity of energy use in the operation phase are all different. Most importantly, there are differences in electricity generation and energy use (grid mix) especially if a higher proportion of coal is burned in the power plant like the case in the United States. Europe and Canada have a higher percentage of electricity from hydro power (almost no emissions) and non-fossil fuels which will affect the final emissions especially the release of CO₂, SO₂, and NOₓ to air. The study is also unique in modeling the building with the U.S. electricity grid which depends on coal as a resource at 39% (DOE, EIA 2015).

REFERENCES
eQuest 3.65 (2016), USDOE interface, the QUick Energy Simulation Tool (eQuest) [software tool]. Available from: http://www.doe2.com/equest/


Energy savings by form design in schools

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ABSTRACT: This study is a part of a comprehensive study that aims to investigate the impact of school building form on energy consumption. The methodology included two parts: in part one the study conducted a survey that covered all schools under Abu Dhabi Department of Education and Knowledge (ADEK) authority; in addition to performing a design model analysis that helped identify the possible form design variables that can impact the building performance with their value ranges. Part two the study performed an hour-by-hour computer simulation to test the impact of different building form variables on energy consumption. The simulation was carried out in two phases, Phase I covered the investigation of the existing design models obtained from ADEK without any manipulation of the form variables. While Phase II covered a broader range of cases under more controlled conditions. The investigation was based on Abu Dhabi climatic conditions with respect to ADEK school requirements and Estidama green building guidelines. The simulation results revealed the effect of each design variable of the school building form on energy consumption and CO₂ emissions. The most important outcome of the study is the establishment of two concepts to evaluate the behavior of building form in influencing energy performance; i.e., form verticality and horizontality.

KEYWORDS: Energy consumption, school, building form

INTRODUCTION

United Arab Emirates (UAE) is located in the Middle East between 21.5° and 26.5°N and 51° and 56.25° with a total area of 77,700 square kilometers. The climate in the UAE can be classified as hot in summer, and warm to moderate in winter, the temperature can reach up to 50°C in July and August, which are considered as the hottest months of the year (Abdullah Al Mandoos, 2005). Due to the harsh climatic conditions of the UAE, building design with regards to improving thermal performance and reducing heat gains should be given a special consideration.

According to the Environmental Protection Agency (EPA), Americans spend 90% of their time in the indoor space. Regarding schools, statistics indicate that 84 million Americans, of which 73.7 million are children, spend almost their entire day at schools. Moreover, one out of five of these schools expressed dissatisfaction about indoor air quality (EPA, 2009). The inappropriate building designs cause an extensive reliance on mechanical and electrical systems, which leads to increase in cooling and heating loads and hence increase in energy consumption. In UK, schools are classified as the third most consuming energy buildings, while in USA schools consume 10.8% of the total electrical energy consumed by buildings (Pérez-Lombard, Ortiz, and Pout, 2008). Governmental and commercial buildings in Abu Dhabi are responsible of 9.3% and 48.2% of the consumed energy, respectively (Clarke, 2016). Between 2012 and 2015, the energy consumption of buildings in the Abu Dhabi increased by 33%.

Abu Dhabi Department of Education and Knowledge (ADEK) has launched the New School Model (NSM) in 2010; which is based on the Learning Community (LC) concept. The LCs known also as pods, families, academies, houses, and schools-within-a-school is a well-known concept that has been used for decades (Kellough and Jarolimek, 2008). Generally, the LC concept is based on dividing the school into subdivisions (learning communities) where each subdivision includes one or multiple grade levels. This is designed to provide intimate environments for both, students and teachers. Yet, each LC is designed with a certain degree of openness that reflects the level of integration intended for targeted students’ grade level and
associated tasks (see Fig. 1). To facilitate the design process of schools and helps architects and engineers producing designs that satisfy ADEK’s requirements, ADEK produced a design handbook and five architectural design models. One of the five models was created for the KG schools. There is also a plan to produce a new model (model 6) for very large schools; that has not released yet. The information in these resources include several sustainability features required by the green code of Abu Dhabi such as; the reliance on passive design strategies and the implementation of efficient electrical and mechanical systems. (ADEK, 2013). These models share the same finger-plan design but they differ in terms of their students’ capacity and the educational cycles they accommodate. This paper belongs to a comprehensive research project that aims to optimize energy efficiency of the UAE schools through improvement of the architectural form design. It investigates the ADEK’s design models.

The aim of the study is to investigate how energy consumption in school buildings responds to different designs of building forms. The current paper conducted a survey of school buildings and a design model analysis that helped to identify specific variables of the building form needed for optimizing the school buildings’ energy performance; then it conducted hour-by-hour energy simulations divided in two different phases, Phase I aims to analyze and compare between the design models without controlling any variables. Phase II on the other hand examined produced models under controlled conditions.

![Learning Community Relationship diagram (ADEK, 2013)](image)

**Figure 1.** Learning Community Relationship diagram (ADEK, 2013)

### 1.0. LITERATURE REVIEW

Several previous studies tackled the relation between the building form and energy consumption (AlAnzi et al., 2009; Catalina, Virgone, and Iordache, 2011; Depecker, Menezo, Virgone, and Lepers, 2001; Koranteng and Abaitey, 2010; Ourghi, Al-Anzi, and Krarti, 2007). Al-Sallal (2016) has defined several considerations to help reduce the heat gain in buildings, these are the optimization of the building forms regarding its compactness and self-shading. Compacted forms which have less exposed areas to the climatic conditions are recommended in regions with hot dry climate as they prevent heat gains. Spread-out forms, on the other hand, are recommended in regions with hot humid climate. Moreover, building forms should be designed in a way that can maintain the passage of the cool breezes. Strategies to reduce energy consumption can be categorized into three main categories as follows (Al-Sallal, 2016; Kharecha, Kutscher, Hansen, and Mazria, 2010): (1) Strategies related to the planning and design, (2) Strategies related to the building envelope, equipment and material, (3) Strategies related to the added technologies. The building form, which is the focus of this study, is related to the first category. Several studies identified the most consuming energy systems in schools; generally, it was found that heating (for cold climates) and cooling (for hot climates) systems...
consume more than 40% of the total energy consumed (DOE, 2013; Kim, Lee, and Hong, 2012). There is three (3) factors related to the building form can have an impact on the energy consumption according to Al Anzi et al (2009). These are: the relative compactness (RC), the window to wall ratio (WWR), and the solar heat gain coefficient (SHGC). Due to the unlimited number of forms, the RC was used in many previous studies as an indicator of the building form. It was found in previous studies that the RC have a direct impact on energy consumption, the increase of the form RC leads to less exposed areas to the harsh climatic conditions, and hence, less energy is needed for heating or cooling (Pessenlehner and Mahdavi, 2003; Depecker et al., 2001). However, this method according to Pessenlehner and Mahdavi (2003), this method is not completely accurate for three (3) reasons; it does not count the self-shading, the transparent components, and the form direction. Yet these factors can have a significant impact on energy consumption.

2.0. METHODOLOGY

2.1. Survey of schools and design models analysis
In 2016, when this research started, there were around 411 schools in Abu Dhabi and Al-Ain regions including the old and new of the public and private schools. Public schools are designed based on design models generated by ADEK. ADEK advised to give priority for the new generation of public schools. Thus, public schools were considered in this study; in addition their typologies are more commonly used. There is a plenty of them; which can cause significant impact on the total energy consumption of schools. Moreover, old schools were no longer authorized by ADEK, Hence, the scope of this research is limited to the new generation of the public schools. The school design that had only KG level (Model 5) was not considered; as this type was considered as a special case; which can be investigated in a future study. The study started by surveying these schools in two mentioned regions. The aim of this survey was to investigate the total number of the new schools following each design model. The survey was carried out using several tools/resources: an online database application called School Finder, Google Maps, and School Contacts Excel sheet. The School Finder and School Contacts are databases available in ADEK website. The School Finder helped provide full information about all schools in Abu Dhabi Emirate, including their GPS coordinates. These coordinates were used in Google maps to view the site layout of each school. The School Contacts helped obtain other information such as school's types (public or private), gender, grades, and contacts. The survey tracked down a total number of 48 schools categorized by the four Design Models (see Fig. 2): 10 schools followed Model-1, 16 schools followed Model-2, 9 schools followed Model-3, and 13 schools followed Model-4.

The tracked down schools were analyzed to identify the design variables of the school form that have potential effect on energy consumption. The four models have finger-plan configuration (see Fig.3); with each finger includes a number of LCs distributed in 2-3 floors. The analysis also helped define the value range for each design variable (see Table 1).

2.2. Simulation
The computer simulation was performed using ENERWIN-e9 software. ENERWIN-e9 was based on an earlier version named EnerCalc. Both programs depend on hour-by-hour calculations and have been used extensively in previous researches (Degelman,1999; Zhun et al. 2011; ). ENERWIN-e9 has a great flexibility with regards to entering the design input data since it has a graphical method to enter the physical geometry of the forms and define the thermal zones in addition to allowing the change of input values manually. It is capable of simulating school buildings based on safe input data suggested by the program and allows the user select from three different standards (90.1-2010, 90.1-2007, or the Standard 189.1-2011 for Green Buildings); which considers the building type. The results generated by ENERWIN-e9 can serve the purpose of this research because it provides the utility energy/costs and a summary of the greenhouse emissions. It also provides thermal comfort analysis and peak HVAC loads. It provides weather data for over 4700 cities including the one for Abu Dhabi.
Figure 2: ADEK Design Models (ADEK, 2013)

Figure 3: Representation showing the design variables of the finger-plan configuration of the school form.

<table>
<thead>
<tr>
<th>Design Models</th>
<th>N° of Floors</th>
<th>Finger L×W (m); AR</th>
<th>Courtyard W (m)</th>
<th>W</th>
<th>WWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model-1</td>
<td>2</td>
<td>31×22.5; AR=1:1.38</td>
<td>0</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Model-2</td>
<td>2</td>
<td>33×22; AR=1:1.5</td>
<td>8</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Model-3</td>
<td>2</td>
<td>30×25; AR=1:1.2</td>
<td>12</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Model-4</td>
<td>3</td>
<td>38×27; AR=1:1.4</td>
<td>14</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

2.2.1. Phase I
In Phase I, the aim was to investigate the four Design Models as they are practiced in real life (values for the investigated variables are kept as defined in Table 1) on energy consumption. In these models only the architectural configurations of the form differ from one model to another, while other variables such as the construction materials, equipment, occupancy schedules, are the same between the models. The design data of each model were derived from their drawings and entered into the simulation software ENERWIN-e9. These data included the following:

Data that are unique to each case:
The physical geometry of the building form such as the form outline, dimensions, and number of floors. This also included identifying the thermal zones.
The dimensions of the building components including the walls, roof, windows, and space height.
Total built-up area.
Common data between the cases:
Building orientation (E-W orientation was used in all models).
The construction materials of the wall, roof, slabs’ assemblies including the U values for each assembly. This also included the type of window glazing and shading.
The electrical lighting system’ power loads, type (Fluorescent), and cost. The target lux level was chosen as 500 lux in classrooms.
The HVAC / AC type: VAV with parallel FCU (Central chilled water C.T.).
Energy efficiency measures as prescribed by ASHRAE 90.1, 2010 version was considered.
Occupancy schedules.

The aim of running the simulations was to detect any change in the energy consumption and environmental issues (CO₂ emissions) as a result of changing the variables of the building form.

2.2.2 Phase II
The previous phase tested the school design models of ADEK, as they are implemented in practice. This produced limitations in the obtained results due to the limited scope of the defined design variables. To overcome this limitation, Phase II was added. Phase II investigated the variables of the building form in a more controlled process (one variable was changed per a time). The cases in Phase II differed in variables that have effect on configuring the building form (i.e., finger dimensions/AR, courtyard width, number of floors, and WWR); while other variables were fixed (Table 2). Phase II included 16 cases (see Fig. 4), planned based on a multiplication of the following:
2 alternatives for the LC fingers’ configuration (LC-1= 20*37.5 with AR= 1:1.875 and LC-2= 27.38*27.38 with AR= 1:1).
2 alternatives for the C width configuration (C-10m and C-30m).
2 alternatives for the number of floors (2 floors or 3 floors).
2 alternatives for the WWRs (20% or 40%).

Figure 4. Phase II cases.

3.0. RESULTS AND DISCUSSION
The results of the energy simulation for the four models, expressed in in MJ per square meter per year, are shown in Figure 5. Model-1, proved to consume more energy than the other models. Model-4, Model-3, and Model-2 achieved 37%, 4%, and 3% energy savings respectively, compared to Model-1. The major difference in the design of form between the four models was the building height and WWR; Model-4 has three floors with 20% WWR and larger courtyard spacing while the other Models have 2 floors with either 30% or 40% WWR and smaller courtyard spacing. The other design variables between the tested cases are either the same (such as the orientation, the building envelop construction materials) or very similar (such as the courtyard size and the LC size). When comparing the energy consumption of Model-1, Model-2, and Model-3, one can find that they have similar results although they differ
in their WWR values (Model-1 has 40% WWR while Model-2 and Model-3 have 30% WWR). Since Model-4 achieved the best energy savings, this indicates that increasing the form height (in terms of number of floors) has a major effect in reducing energy consumption. That is because taller buildings result in more compact forms. Actually, Model-4 could have achieved even better savings if it had smaller courtyard spacing. The CO₂ emissions results showed a consistent pattern with the energy consumption results (see Fig. 6).

Table 2. Constant variables among the cases with their values, Phase II.

<table>
<thead>
<tr>
<th>Constant Variables</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Area</td>
<td>12,630 m²</td>
</tr>
<tr>
<td>Form Axis Direction</td>
<td>North-South</td>
</tr>
<tr>
<td>Glass U-Factor</td>
<td>6.814 Watt/m²°C</td>
</tr>
<tr>
<td>Wall U-Factor</td>
<td>0.505 Watt/m²°C</td>
</tr>
<tr>
<td>Roof U-Factor</td>
<td>0.358 Watt/m²°C</td>
</tr>
<tr>
<td>Occupancy densities</td>
<td>Based on ASHRAE 90.1 2010 standards</td>
</tr>
<tr>
<td>Electrical lighting power densities</td>
<td>10.7 W/m² Based on ASHRAE 90.1 2010 standards</td>
</tr>
<tr>
<td>Ventilation rates:</td>
<td>CS1.829 L/s/m² Based on ASHRAE 62.1 standards</td>
</tr>
<tr>
<td>Ceiling height:</td>
<td>3.75m</td>
</tr>
<tr>
<td>HVAC system</td>
<td>VAV w/ parallel FCU (Cent. Chilled Water C.T.)</td>
</tr>
<tr>
<td>Electrical lighting system</td>
<td>Fluorescent tubular 100 Lum/watt</td>
</tr>
<tr>
<td>Exterior Exposure</td>
<td>Grass</td>
</tr>
<tr>
<td>Target lux in classrooms</td>
<td>500 Lux</td>
</tr>
</tbody>
</table>

Figure 5. Energy consumption results, Phase I.
The results of energy simulation in Phase II demonstrated a similar pattern with regards to the impact of building height (number of floors) on energy consumption. A reduction that is equal to 30% of the total consumed energy was attributed to the cases with 3 floors compared to the corresponding cases with 2 floors. Regarding the finger configuration, it can be seen from the results in Figure 7 that in the cases with 2 floors LC1 (the most linear form with AR = 1:1.875) consumes more energy compared to LC2 (the squared form with AR = 1:1), the increase can reach up to 8% of the total consumed energy. However, this pattern was not consistent in the cases with 3 floors. The impact of the WWR is also remarkable, a reduction of 5% of the total consumed energy achieved when WWR decreased from 40% to 20%. Regarding the courtyard configuration, it can be seen that no significant impact was achieved between the cases that differ in their courtyard width values. The CO₂ emission results showed a consistent pattern with the energy consumption results (see Fig. 8).
The savings achieved by the more compact building form confirms the findings of previous research (Pessenlehner and Mahdavi, 2003; Depecker et al., 2001; AlAnzi et al., 2009). To understand this phenomenon better, two form design variables were established. These are the verticality and horizontality of the form. The two terms can be expressed as:

Form Verticality = Vertical Surface Area / Vertical+ Horizontal Surface Area
Form Horizontality = Horizontal Surface Area / Vertical+ Horizontal Surface Area

These two variables were calculated for the tested cases in Phase I and Phase II and presented in Figures 9-12. One can observe that when increasing the verticality of the form, which corresponds to reducing the horizontality of the form, energy consumption decreases. This can be justified by the amount of solar gain transferred through the building surfaces. Both Abu Dhabi and Al-Ain are located very near to the tropic of cancer where the summer solar radiation is perpendicular on the roof surfaces. Hence, forms with high ratio of horizontality (or less ratio of verticality) are more exposed to this effect, and therefore, higher cooling loads are required.
CONCLUSIONS
The design model analysis helped address a number of design variables that represent the building form based on the finger-plan configuration and have influence on energy performance in school buildings. These variables are: the size and AR of the fingers that include the learning communities, the width of the courtyard, the number of floors (height), the form axis direction (orientation) and finally the WWR. The design models analysis helped also define the value ranges of the investigated variables. The most important finding based on the
conducted energy simulation of the cases from Phases I and II was the effect of the form verticality on energy savings (30% energy savings when the number of floors increased from 2 to 3, keeping the same total floor area). The WWR had also potential for improvement of energy savings; yet it was not as significant as the form verticality (5% energy savings when WWR was decreased from 40% to 20%). This paper depended on testing 20 cases only. To have a comprehensive investigation of the effect of school form, especially with the significant design variable established here (i.e., the form’s verticality as opposed to its horizontality), future research is needed. The paper covered only limited number of configurations of the finger-plan design considering the most dominant building orientation (E-W form-axis direction) as dictated by the direction of most streets in Abu Dhabi and Al-Ain cities. Future research should cover larger number of configurations of the finger-plan design typology. It should also include other design configurations such as the courtyard, the rectangular/square, the circular, and other configurations. Other design variables that can be covered in future research are the effect of landscape/greenery, green roofs, shading devices, advanced glass technologies, and potential of passive cooling systems.

REFERENCES
ADEK. (2013), Educational Facilities Design Manual (Rep.). Abu Dhabi


A case study for sensitivity-based building energy optimization

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¹Texas A&M University, College Station, TX

ABSTRACT: Building design optimization process is associated with uncertainties due to climate change, unpredictable occupant behavior, and physical degradation of building material over time. The inherent uncertainties in the design process reduce the reliability and robustness of the optimal design solution(s) and affect design decision-making results. This research studies the capabilities of parametric design tools in adopting probabilistic methods to handle uncertainties in building performance optimization. Variance-based methods, e.g., Monte Carlo sensitivity analyses are implemented to identify the most critical parameters in design optimization problems and improve the efficiency of design optimization. The optimal solutions achieved with variance-based methods are satisfying the design objectives more efficiently, also remain robust to changes and uncertainties.

KEYWORDS: Building design optimization; Variance-based methods; Parametric design; Sensitivity analysis; Monte Carlo;

INTRODUCTION
The building design process includes making important decisions about different issues such as building orientation, form, layout, Window-to-Wall Ratio (WWR), and material properties (Lim et al., 2015). Building design decision-making is essentially solving multi-criteria optimization problems (Rahmani Asl et al., 2015). Building performance simulation tools can be useful in the design optimization process to evaluate design options. Refs. (Attia, 2011; Attia et al., 2012) compare several building performance simulation tools and introduce the potentials and challenges of each one in solving design problems.

Parametric modeling and simulation platforms, e.g., Grasshopper facilitate the optimization process in architectural design (Touloupaki & Theodosiou, 2017). Multiple optimization methods using heuristic algorithms such as Genetic Algorithm (GA) and Simulated Annealing (SA), along with model-based optimization algorithms such as Gutmann and MSRSM (Wortmann, 2017), are developed in Grasshopper to solve architectural design problems. On the other hand, a typical building design optimization process using these tools is time-intensive, ignores the uncertainties, and lacks a systematic framework to incorporate expert knowledge. The absence of efficiency and the lack of a systematic approach for considering uncertainties and integrating expert knowledge necessitates the development of a new approach to building design optimization.

This paper aims to investigate the integration of probabilistic strategies with simulation-based optimization process to handle the uncertainties and improve the reliability and efficiency of architectural design decision-making. This paper examines the capabilities of visual programming interfaces, available in parametric tools, e.g., Grasshopper to handle uncertainties in building performance analysis and apply variance-based techniques to enhance the efficiency of building design optimization process. The Genetic Algorithm (GA) that is the most popular optimization algorithm in architectural optimization and variance-based methods such as Monte Carlo sensitivity analysis with random sampling are deployed to develop a probability-based optimization framework for parametric design decision-making. A test case of building thermal energy consumption analysis is presented to demonstrate the application of the proposed framework.
1.0 BACKGROUND

1.1. Uncertainties in building design optimization
The optimization process under uncertainty is one of the main challenges in performance-based building design (Evins, 2013; Kheiri, 2018; Nguyen et al., 2014; Shi et al., 2016). Solving this type of optimization problems with deterministic approaches leads to overestimation of design requirements and thus, inefficient design optimal solutions (Grille et al., 2017). Non-deterministic methods including variance-based methods are capable of improving the efficiency of building design decision-making (Hopfe et al., 2013).

Two main types of uncertainty sources in building performance optimization are known as epistemic and aleatoric uncertainties (Hopfe, 2009). The epistemic uncertainties, e.g., the thermal properties of building material exist due to measurement errors or model simplifications. Aleatoric uncertainties are unknown parameters that depend on other factors such as weather conditions and occupant behavior, and thus are irreducible (Grille et al., 2017).

Variance-based methods are the most commonly used approaches to handle uncertainties in building performance analysis (Tian et al., 2018). The variance-based methods such as Monte Carlo use random variables and input probability density functions to address the stochastic status of the problem. The applications of these methods in building performance analysis have been broadly studied (Bordbari et al., 2018; Ding et al., 2015; Hopfe, 2009; Hopfe et al., 2012; Lee et al., 2013; MacDonald, 2002; Rezaee et al., 2018; Shahsavari et al., 2018; Struck, 2012; Tian et al., 2018).

Various tools including MATLAB, Simlab, and jEPlus have been widely used in uncertainty and sensitivity analysis for building performance analysis (Tian et al., 2018). The integration of these probabilistic methods with parametric tools such as Grasshopper has not been fully covered, yet. This research intends to apply variance-based methods such as Monte Carlo sensitivity analysis in the design optimization process. The integration of variance-based methods with simulation-based optimization process enables designers to eliminate those input variables with a small effect from the optimization setting, and thus leads to a more efficient optimization process (Evins et al., 2012).

1.2. Sensitivity analysis in building design optimization
As (Saltelli et al., 2010) state, variance-based methods, e.g., Monte Carlo approaches, have shown more effectiveness and reliability when working with stochastic variables. Thus, this paper performs a sensitivity analysis based on the Monte Carlo approach. The following is a brief mathematical description of the Monte Carlo method for dealing with input uncertainties and sensitivity analysis.

Let a mathematical modeling $Y = f(X)$ define correlations between a vector of one-dimensional (1D) input variables $X = (X_1, X_2, ..., X_n)$ and an output $(Y)$, where $(f)$ is a deterministic integrable function which translates from a k-D space into a 1-D one, i.e., $\mathbb{R}^k \rightarrow \mathbb{R}$. The model produces a single scalar output $Y$ when all input variables are deterministic scalars. However, if some inputs are uncertain or undecided, the output $(Y)$ will also associate with some uncertainties. An input variable $X_i$ is defined by a mean value $\mu_i$, a variance $\sigma_i$, and a probability distribution, such as normal, uniform, etc. In the Monte Carlo methods, $N$ sets of samples from possible values of each input variable are generated. These input values are fed into the simulation model to generate the probability distribution of the output $(Y)$. Processing the output range $(Y)$ delivers a mean value and a frequency distribution for the output. A sensitivity analysis further investigates into the contribution of each input variable on the total variations of the model output.

This paper details predictions for sensitivity index $S_{TI}$, the total effect coefficient. The calculation of the sensitivity index $S_{TI}$ requires sampling sequences and estimators to act upon
a single set of simulations and compute the sensitivity indices for all input variables (Saltelli et al., 2010). In this research, the Monte Carlo uncertainty analysis, random sampling technique, and the Jansen indices have proved applicable. Equation (1) indicates $S_{Ti}$ calculation (Saltelli et al., 2010):

$$S_{Ti} = \frac{1}{2N} \sum_{j=1}^{N} \left( f(A)_{j} - f(A_{B}^{(i)})_{j} \right)^{2} \frac{\text{Var}(Y)}{\text{Var}(Y')},$$

Note that A and B are two independent matrices of N samples (and thus N values) of k input variables, that are generated with normal distribution using the mean and standard deviation of each input variable. $f(A)_{j}$ denotes an output based on input values from the $j^{th}$ row of matrix A. $f(A_{B}^{(i)})_{j}$ denotes an output based on input values from the $j^{th}$ row of the matrix $A_{B}^{(i)}$, which represents a matrix with all columns from matrix A except column i, which comes from matrix B. $\text{Var}(Y')$ is the output variance, having all input variables form matrix A.

2.0. A PROBABILISTIC FRAMEWORK FOR PARAMETRIC DESIGN OPTIMIZATION

2.1. Variance-based methods in parametric building design

Building design decision-making includes multi-objective optimization problems, dealing with financial, physical, functional, aesthetical, and performance-related concerns. This process requires a systematic workflow to meet the design requirements efficiently. This research focuses on performance-based building design including building energy consumption analysis. Figure 1 illustrates a general workflow of building design decision-making followed in this research.

This research builds upon the optimization framework introduced in (Nguyen et al., 2014) to investigate the application of variance-based techniques in parametric building design decision-making. Nguyen et al., (2014) subdivide a generic simulation-based optimization process into three phases: 1- preprocessing, 2- optimization, and 3- post-processing. Modeling the building to be optimized, defining the optimization problem, selecting the input variables, objective functions and constraints, are the major tasks in the preprocessing phase. Integrating the variance-based methods with design optimization is an optional task in the preprocessing phase. In this research, the variance-based methods are deployed for sensitivity analysis to identify the key input parameters. The next phase is the optimization, and the important role of a designer in this phase is fixing the potential errors and keeping the optimization process running. The post-processing phase includes analyzing the optimization results and presenting the data by charts and graphs, e.g., scatter plots.

The Genetic Algorithm (GA) is applied for optimization in this research. The GA process imitates the natural genetic evolution and requires preparation, consisting of input chromosome generations, setting the objective function, and defining the constraints (Lim et al., 2018). The optimization begins with the first generation of design inputs, and the performance of different combinations of design inputs is compared. The fittest combinations remain in the next generation, and the weakest combinations are removed. The remaining chromosomes create new combinations through the cross over and mutation. The GA selects the fittest combinations, and this process goes on until there is no better solution found (Nguyen et al., 2014).
Sensitivity analysis with the variance-based techniques guides the search for the optimal solution and improves the efficiency of the optimization process in two ways. First, designers can use the sensitivity analysis results to find input parameters with the highest impact on the output and adjust the optimization input parameters, accordingly. Second, the probability distribution of the values of input parameters, that are generated based on the expert knowledge or previous research, can be used as a source of input selection in the mutation and cross-over processes of the GA optimization. These two applications of sensitivity analysis in design optimization will lead to more reliable optimization results since the optimization is based on expert knowledge and probabilities.

This research deploys Rhino and Grasshopper to illustrate the benefits of sensitivity analysis in building design optimization. Ladybug and Honeybee, the two plugins available in Grasshopper are used to upload the weather data, prepare building model, and run the energy analysis with EnergyPlus (Toutou et al., 2018). The model preparation with these energy modeling plugins in Grasshopper includes creating thermal zones from masses and surfaces, followed by solving space adjacencies, setting the WWR for each façade, material selection, and adjusting occupants, lighting, and equipment schedules (Figure 2).

After preparing the building model, energy analysis simulation is executed using the Honeybee energy analysis component in Grasshopper. The user defines the timeframe for energy analysis, and the weather data is imported from the EnergyPlus website. CPython component in Grasshopper is used to import statistical tools such as Numpy and Scipy into Grasshopper. The CPython also enables the designers to present statistical results in Grasshopper by charts and graphs (Abdel Rahman, 2018). To conduct optimization, Galapagos is applied for a single-objective design problem such as thermal energy consumption analysis. Figure 3 illustrates the proposed optimization framework with probabilistic techniques, that includes the addition of sensitivity analysis to guide designers in input selection for optimization.

The proposed optimization process with parametric tools, e.g., Rhino and Grasshopper begins with creating the building model. The initial input variables are selected based on the needs and requirements of the design project. The input parameters along with design constraints and design objective functions define the optimization setting. A normal distribution of all input variables is generated with $N$ number of values (defined by the user), using the mean and...
standard deviation (MacDonald, 2002). The lists of input variables are connected to the simulation engine, e.g., Energy Plus and the outputs of each simulation run are recorded for later comparisons.

The simulation model is executed repeatedly using the samples of input parameters. To automate the random value selection for each input and run EnergyPlus for \( N \) times, a number slider, that is remotely controlled ("Grasshopper3D", 2017), is connected to the list of input variables and selects a random index of each list automatically and feeds the associated input value to the simulation. The simulation runs through all the input values, and the results are used in further calculations to identify the sensitivity index of each input parameter. In this proposed method, the sensitivity indices associated with each input parameter is calculated through sensitivity analysis techniques, and the input variables with higher impact on the output will remain in the optimization process. Figure 4 shows the implementation of variance-based methods for sensitivity analysis in Grasshopper, using list management and CPython programming.

### 2.2. Test case results

A hypothetical five-zone building is modeled in Rhino/Grasshopper to demonstrate the application of the proposed probabilistic optimization framework. The Typical Meteorological year for College Station, Texas is imported from the EnergyPlus website ("EnergyPlus", 2018). The weather data and HVAC specifications are kept constant, while building material thermal properties including wall thermal conductivity, density, and specific heat capacity, along with WWR, and occupant behavior in the opening and closing windows, are varying. Figure 5 shows the 3-D model of this test case in Rhino/Grasshopper.
Two random lists of values (list A with 100 samples and list B with 100 samples) for each input variable are generated. The mean and standard deviation values for the thermal properties of exterior walls are listed in Table 1.

The mean values of WWR for north, south, east, and west facades are 0.45, 0.45, 0.3, and 0.3, respectively. The WWR values are varied by 10% of their mean values. The occupant behavior in the opening and closing windows is defined based on the Outdoor Air Temperature (OAT) and is connected to the infiltration schedule. This variable is studied through the possibility of opening windows when the outdoor air temperature (OAT) reaches a certain point. For example, if OAT is larger than 20°C (with 0.2°C variation), the user will probably open the windows. This probability status is recorded through the year as zeros and ones (for opening and closing windows). This list of zeros and ones is saved as an Excel file, and the Excel file is linked to the infiltration schedule, which is used in the EnergyPlus analysis.

All the input variables are fed into the simulation to get the output, which is building annual heating/cooling energy consumption. Sensitivity indices for input variables are calculated and presented to guide the user in selecting the most important input parameters to participate in design optimization. Figure 6 compares the sensitivity indices of the input variables in this study.
### Table 3: The mean and standard deviation values for the thermal properties of exterior walls (MacDonald, 2002)

<table>
<thead>
<tr>
<th></th>
<th>Density $\rho$ (kg/m$^3$)</th>
<th>Heat Capacity $c_p$ (J/kgK)</th>
<th>Thermal Conductivity $\lambda$ (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu$</td>
<td>$\sigma$</td>
<td>$\mu$</td>
</tr>
<tr>
<td>Exterior Walls Thermal Properties</td>
<td>1900</td>
<td>28.5</td>
<td>1000</td>
</tr>
</tbody>
</table>

The input variables with higher sensitivity indexes have a higher impact on the output. In this test case, the output is building annual heating/cooling energy consumption. The sensitivity analysis result shows that occupant behavior in the opening and closing windows is the most important parameter, compared to exterior wall thermal properties and WWR. Exterior wall thermal conductivity, density, and heat capacity are the next most impactful variables in this model. The WWR (sum of the sensitivity indices of WWR for four facades in this model) shows a small contribution to the output. The reason for this small sensitivity index of WWR is that the sensitivity index of a specific variable in a certain model is highly dependent on the sensitivity indices of other variables. It means that if a variable shows a significantly high index compared to the other variables, it will affect the values of sensitivity indices of the other variables (Saltelli et al., 2010). In this example, the occupant behavior shows much more significance than WWR, and it affects the sensitivity indices of WWR.

Considering the sensitivity analysis results, the list of input parameters for the optimization process is limited to the thermal properties of exterior walls. The effects of WWR on building energy consumption in this case study is negligible (Figure 6) and can be ignored in the optimization process. Also, the occupant behavior is excluded from this list, since it is an aleatoric uncertain variable which is dependent on many other factors. Figure 7 illustrates the input setting for this design optimization, also the optimization output.
DISCUSSION AND CONCLUSION

This research investigates the integration of sensitivity analysis into design optimization to improve the efficiency of parametric building design optimization. Since the sensitivity study helps to reduce the number of input variables, the optimization search space is reduced, which leads to less computing time than a conventional optimization process.

The occupant behavior is one of the most important uncertain design variables and understanding different patterns of occupant behavior and reflecting the effects of this parameter in building performance simulation requires further research. Also, further development of the proposed optimization framework may focus on using probability distributions of important input variables to search for the optimal solution. Choosing the input values for an optimization process out of a normal distribution allows searching for the optimal solutions considering their probability of occurrence. This method may improve the reliability of optimization results since the probability of occurrence of each design option is considered.

The conditional probability and Bayesian network are also promising fields of research related to probabilistic optimization. The Bayesian inference updates the prior belief, which is a starting point for the optimization, to a posterior outcome based on additional data and information. This method allows the integration of expert knowledge with design optimization and may improve the simulation-based optimization in architectural design decision-making.

REFERENCES


object-expired-during-a.
Mind the perception and emotional response to design: emerging methodology

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ABSTRACT: Design involves constant decision-making. The decision process is influenced by sets of conditions or parameters; some controllable, such as the context, and some unpredictable and uncertain, such as stakeholders’ preference. Design decisions related to user’s perceptions and emotional response to sustainable features (daylight and green space) and aesthetic value (look and feel) are generally hard to evaluate and quantify. Typically, user response is solicited following construction, in post-occupancy evaluation studies. However, decisions with long-term impacts are often irreversible after implementation; therefore, decision-makers must seriously evaluate the design proposals (alternatives) before arriving at a decision. This paper presents an experiment conducted combining an immersive virtual environment and electroencephalogram (EEG) as a promising tool to evaluate design options during the early design stage of a project. More precisely, the objective is to (a) develop a data-driven approach for design evaluation and (b) understand the correlation between the end users’ preference and emotional state. To our knowledge, this is the first time that the combination of virtual reality technology and brainwave response monitoring has been proposed to study the design validation method in architecture.

KEYWORDS: design decision, EEG, virtual reality

INTRODUCTION

What would it mean if data management were at the core of our discipline? Data gives insights into users’ responses to environments. The more data, the richer the insights, promoting a better fit of environment to people. How can the design process be informed by data on human response to space and place? Stakeholder preference of one alternative over another plays an important role in design process, especially in dealing with multi-objective design problems in which designers juggle competing objectives. Current tools for design evaluation are surveys, scorecards, and verbal comments. The goal of this research project is to develop, test, and validate a data-driven approach for design decision-making. Such a framework would facilitate participation and action by multiple decision-makers and stakeholders, offering insights into the architectural design process. This paper presents an experiment combining an immersive virtual environment (VR) and electroencephalogram (EEG) as a promising tool to evaluate alternative options during the early design stage of a project. More precisely, the objective is to (a) develop a data-driven approach for design evaluation and (b) understand the correlation between end users’ preference and emotional state. To our knowledge, this is the first time that the combination of immersive virtual reality technology and brainwave response monitoring has been proposed to study the design validation method in architecture.

1.0. METHODOLOGY: SAMPLE, EXPERIMENT AND SETUP

1.1. Theoretic base

This research method is based on the event-related potential (ERP) neuroscience approach and cognition architecture (CA) theory. ERP studies brain activity in response to visual stimuli (Picton et al. 2000). More specifically, it compares the neural signal (brainwave) during different conditions to determine whether and how the brain responds to different stimuli. CA was proposed by Herbert Simon, a pioneer in artificial intelligence, in 1960. CA has since then
been explained, expanded, and further developed by researchers, mainly from the psychology and computer science domains. It has also been applied to research on design thinking. Leading researcher William Mitchell (1990) explained the basic trial-and-error structure of design process and stated that different types of computational devices may be used to generate proposals, test them, and apply control strategies. CA theory can be translated into a method of scoring and providing principles to demonstrate how specific physical/virtual environments can influence our mental state (Hollander and Foster 2016). Our hypothesis is that a design proposal based on the participants’ preference could result in better evaluation scores and stimulate a more positive mental/emotional state. To this extent, the emotional state could be used as supplementary evidence to evaluate design proposals. In order to validate our hypothesis, we designed a case study in which participants experienced two alternative design solutions and we captured their responses to determine whether participants might experience a higher positive emotional state, such as interest and engagement, and less negative emotion (stress) as a result of being immersed in their preferred environment (the environment was constructed in VR). It is useful to illustrate the methodology framework in a diagram (refer to figure 1). The goal was to discover whether mental state corresponds with ERP and CA theory.

Figure 1. Research methodology

1.2. Case design and tools
This research combines a neuroscientific technology (EEG) with an emerging design technology (VR) to compare emotional stage levels (interpreted from the EEG raw signal) of participants in a well-controlled, three-dimensional virtual environment. A virtual reality set (Samsung Odyssey) and EEG equipment (Emotiv EPOC Insight) were used to collect design evaluation data from six males and two females (aged 18–60). All test participants at University of Maryland were either architecture school faculty members, architects, or architecture students. The design task was to create a layout best-suited to the preference and needs of an architecture department. The test layout occupied a single floor of an L-shaped building on a university campus. The space included lecture rooms, conference rooms, offices for professors and staff, computer labs, and other spaces (e.g., restrooms, stairs, and elevators). The design alternatives were proposed independently by two architectural designers. Test participants acted as clients who would be end-users of the building. Before the experiment began, the clients and designers agreed that six attributes (flexibility, economics, comfort, safety, sustainability, and aesthetics) were important to consider when designing the floor plan layout, although no specific interpretations for the various attributes were given at that point. Although we only chose six attributes, we acknowledge that other attributes would be considered in real practice, such as the initial cost, long-term profit, and ease of maintenance.
and repair. The above attributes were used to test the hypothesis, and the same framework can be applied to other design attributes.

Two design options were proposed: OPT A and OPT B. OPT A was designed without knowledge of the primary weighting factors (comfortability, flexibility, and safety) whereas OPT B was designed with all the information. We built two virtual models reflecting the two design options (refer to figure 2) and asked test participants to experience the two design options in an immersive virtual environment (VR). We then used an EEG device to record their brainwaves and emotional response to those two different environments. Afterwards, each participant completed the survey, scoring the quality of design—on a scale of 1 to 7—on comfortability, safety, flexibility, aesthetic value, sustainability, and potential cost. Finally, they provided a preference score for both design options.

![Figure 2. Two design options (Autodesk Revit model)](image)

1.3. Virtual reality (VR) model setup and EEG measurement

In general, there are three types of VR technologies: (1) direct VR into 3D modeling software, (2) VR with a game engine, and (3) a 360-degree panorama picture (Burdea 1994). In this research project, direct VR integration technology was applied due to the speed and quality of the work. Firstly, a 3D model was created with Autodesk Revit based on the initial design. Then, a plug-in tool called ENSCAPE was used to translate 3D Revit to a virtual environment. This is the only program that can be directly integrated into multiple 3D modeling software, which creates high requirements for the hardware (computer); however, it allows for instantaneous design changes in a virtual environment. Two models were set up and transferred to VR (see figure 3). In this research, the Emotiv INSIGHT EEG headset was chosen based on its relatively low cost and the accompanying software, which can aggregate raw data. The headset was fitted on the underside of the VR headset. We immersed them into two different design options, with each design option taking approximately 15-20 minutes to experience. The device consisted of five sensors positioned on the wearer’s scalp according to the international 10–20 system: the antero-front (AF3, AF4), parietal (Pz) and temporal sites (T7, T8). Brainwaves were measured through those five channels in terms of amplitude (10–100 microvolts) and frequency (1-80Hz) at 128 samples per second per channel (Aspinall et al. 2015, Emotiv website). The four main brainwaves/bands measured and recorded were beta, alpha, theta, and gamma. After the raw EEG data was collected from each participant, the signals were analyzed with the software Emotiv Pro (developed by Emotiv) and categorized into one of five emotional states: engagement, focus, interest, stress, or relaxation.
After immersion in the two VRs, an eight-item questionnaire measuring the six design attributes of the building was given to each participant. Each attribute was rated on a seven-point Likert scale. The six attributes represented the criteria defined in the case design stage: aesthetics, safety, flexibility, comfortability, sustainability, and economics (potential cost). At the end, test subjects were also asked to provide a preference score ranking one design option over the other.

2.0 DATA ANALYSES AND FINDINGS

2.1. Questionnaires and EEG results

Altogether, six participants provided 56 scores for six attributes plus an overall preference score for each of the two design options. Design option B (OPT B) received a higher score than design option A (OPT A) in all six design attributes. In OPT B, comfortability, aesthetics, and flexibility were rated as the top three attributes, aligning with the fact that OPT B was created based on knowledge of the clients’ preferences. The much higher overall preference score of OPT B validates the point that giving more consideration to the clients’ preferences could result in a much higher satisfaction rate. One interesting finding was the fact that aesthetics was rated as one of the top three attributes by participants who favored the preferable option (OPT B) while aesthetics was not identified as an important design attribute by any of the three groups (architects, engineers, and members of the public) through the survey. This might be explained by the innate nature of human beings as visual thinkers who do not consciously or proactively acknowledge the important role of aesthetic value in our decision-making, particularly in design context. Scientists agree that humans possess five basic senses: smell, hearing, touch, taste, and vision. However, the human brain expressly prioritizes just one sense: vision (Hollander and Foster 2016). Furthermore, Kandel (2012) stated that about half of the sensory information reaching the brain is visual. The reason why none of the groups listed aesthetics as their primary design attribute needs to be understood and potentially represents the next research focus.

Next, we examined whether higher evaluation scores were correlated with a positive emotional state of the participants. Each participant had an approximate 20-minute recording, which generated more than 1,400 data points. Overall, OPT A stimulated more engagement, interest, and attention while OPT B generated greater relaxation and stress, with stress levels in the moderate range, which could indicate higher productivity (Emotiv). Unlike the scores from the questionnaires, which indicate a clear preference for OPT B from all participants, EEG data indicated that participants had varied responses—including negative, positive, and neutral—toward the two design options. In order to further understand the varied responses, we examined the data from individual participants and conducted a statistical analysis to determine whether there were significant differences in participants’ emotional responses to the two design options. The five emotional states were used as a proxy measurement of participants’ preference for design options. The following section explains the findings.
2.2. Statistical analyses

The EEG data did not directly lead to the overall evaluation of design options, and the emotional state could not be directly translated as negative or positive toward the design solutions. Therefore, instead of looking at the representation of the individuals’ emotional state, the authors examined whether there was a significant difference in how participants responded to the different design options. A null analysis was appropriate for verifying the hypothesis. The Wilcoxon signed-rank test is commonly used to test for a difference in a paired observation, and a sign test is often used to test the null hypothesis.

The analysis considers one null hypothesis: 

\( H_{01} \): There is no significant difference between the participants’ negative and positive emotional responses to OPT A and OPT B.

The alternative hypothesis is:

\( H_{a1} \): There is a significant difference between the participants’ negative and positive emotional responses to OPT A and OPT B.

Descriptive results: Wilcoxon signed-rank test:

Results from the Wilcoxon signed-rank test for OPT A, compared to OPT B, are illustrated in table 1. The equation used to obtain the statistic \( W \) was:

\[
W = \sum_{i=0}^{n'} R_i^{(+)},
\]

where \( n' \) is the actual sample size, \( R_i \) is the rank, and \( W \) is the Wilcoxon test score.

For null hypothesis \( H_{01} \), among the five different emotional responses to the two design options, three response types were higher for OPT A while the other two were lower for OPT A (figure 11). The Wilcoxon test score \( W \), 64, was higher than the critical value used for a two-tier test of 52. Based on these results, we could not reject null hypothesis \( H_{01} \). Instead, we should reject the alternative hypothesis, \( H_{a1} \). In conclusion, there is no emotional state difference between the participants’ positive and negative responses to the two design options (refer to table 1).

The rejection of the null hypothesis suggests that the overall positive or negative emotional state does not directly affect or correlate with how participants answered the design evaluation. Depending on the importance of design attributes, the preferred design solution might stimulate a negative emotion, and the less preferred design might stimulate a more positive emotion, such as interest and engagement. Participants clearly preferred OPT B overall, which

![Figure 5. Emotional state score from the EEG recording](image)
received higher scores; however, their emotional responses did not show clear negative or positive direction.

**Table 1. Wilcoxon matched pairs signed-rank tests for responses to OPT A and OPT B**

<table>
<thead>
<tr>
<th>Response</th>
<th>OPT A</th>
<th>OPT B</th>
<th>Difference</th>
<th>Positive [Diff]</th>
<th>Rank</th>
<th>Signed Rank</th>
<th>α = 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response 1</td>
<td>0.718</td>
<td>0.227</td>
<td>0.49</td>
<td>1</td>
<td>0.49</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Response 2</td>
<td>0.703</td>
<td>0.699</td>
<td>0.00</td>
<td>1</td>
<td>0.00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Response 3</td>
<td>0.497</td>
<td>0.648</td>
<td>-0.15</td>
<td>-1</td>
<td>0.15</td>
<td>9</td>
<td>-9</td>
</tr>
<tr>
<td>Response 4</td>
<td>0.355</td>
<td>0.370</td>
<td>-0.01</td>
<td>-1</td>
<td>0.01</td>
<td>3</td>
<td>-3</td>
</tr>
<tr>
<td>Response 5</td>
<td>0.325</td>
<td>0.054</td>
<td>0.27</td>
<td>1</td>
<td>0.27</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Response 6</td>
<td>0.533</td>
<td>0.471</td>
<td>0.06</td>
<td>1</td>
<td>0.06</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Response 7</td>
<td>0.564</td>
<td>0.631</td>
<td>-0.07</td>
<td>-1</td>
<td>0.07</td>
<td>6</td>
<td>-6</td>
</tr>
<tr>
<td>Response 8</td>
<td>0.406</td>
<td>0.667</td>
<td>-0.26</td>
<td>-1</td>
<td>0.26</td>
<td>10</td>
<td>-10</td>
</tr>
<tr>
<td>Response 9</td>
<td>0.372</td>
<td>0.467</td>
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<td>-1</td>
<td>0.10</td>
<td>8</td>
<td>-8</td>
</tr>
<tr>
<td>Response 10</td>
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<td>0.262</td>
<td>0.09</td>
<td>1</td>
<td>0.09</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Response 11</td>
<td>0.517</td>
<td>0.5</td>
<td>0.02</td>
<td>1</td>
<td>0.02</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Response 12</td>
<td>0.578</td>
<td>0.573</td>
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**CONCLUSION**

The research project has developed, tested, and validated a data-driven approach for design validation. Such a framework would facilitate participation and action by multiple decision-makers and stakeholders as well as lend insights into any design process marked by the characteristics of an architectural design process. Based on the available data from this experimental study, we cannot conclude that a positive emotional state (brain activity) can be correlated with a higher scoring design evaluation. Likewise, a negative emotional state does not automatically result in negative design evaluations. Additional experiments and data are needed for further studies. However, our research has demonstrated proof of the concept of a data-driven approach that uses emotional response as a method of design evaluation. This model has great potential to open new avenues for inquiry of how technology-based tools can be leveraged to influence mainstream design choices that incorporate clients’ and end users’ preferences. Furthermore, the use of an EEG device allows us to enter the research arena of
how brainwaves respond to different design solutions. Nonetheless, there are several limitations of this research that could be improved in the future:

- Interpretation of the brainwave is mainly conducted through a predetermined algorithm created and managed by the company that made the device. The mechanism of translating brainwaves into emotional scores is unknown. Future research should consider applying a more transparent approach by using third-party software.
- The small sample size did not enable us to run a multivariate statistical analysis. For future research, larger samples and datasets are needed for a full in-depth analysis.
- More design options could be built and tested in order to understand the correlation between design attributes and emotional response.

Despite the limitations, this experimental research project has shed light on how a design evaluation could be combined with neuroscience methods illuminating human response to proposed environments. The findings from this study enable us to identify a set of research questions for the next step. Since a theoretical framework explaining the attitude and behavior toward an architecture design evaluation does not exist yet, this study employs an inductive approach and attempts to move toward such a theory. Such experimental results suggest that the ERP approach and CA theory could be applied to the design field, opening the possibility of data-driven design decision-making.

REFERENCES


RESOURCE + PROCESS MANAGEMENT
Glass fabrication

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ABSTRACT: In architecture, the prevalence of computational design and digital fabrication has led to an increase in exploration of casting modulated geometry using fabricated molds. However, the use of mold making strategies are often limited to casting materials that conform easily to mold geometry (i.e. concrete, plaster, resin, ceramics, etc.). It is rarely that fabrication strategies are used to explore materials with challenging behavioral properties such as glass. As a result, glass in its non-flat form has been underutilized in contemporary architecture. Because of its complicated physical behavior and the technical difficulties associated with the fabrication processes, architecture education often avoids exploring such medium. One key challenge with casting glass using fabricated refractory molds relates to understanding the behavior of glass under certain physical conditions and temperature profiles. If such parameters are not anticipated, the geometry of the final casted elements can be substantially different from the design intentions. This research argues that computation can be used to predict glass forming behavior under different temperature profiles, which can inform the design and fabrication processes. The goal is to highlight the importance of integrating the complexities of the physical reality into the design and fabrication processes, especially within the context of the educational experience. To contribute to this creative discourse this paper explores the limits of precision from computation to fabrication as it relates to casting glass. The objective is to design and test an algorithm for predicting edge/corner geometry of casted glass under different temperature profiles. Physical experiments are used to evaluate and recalibrate the prediction algorithm. Results show that the digital predictions are within acceptable tolerance and can be enhanced using data from physical experiments.

KEYWORDS: digital fabrication; glass casting; mold fabrication; computation; precision

INTRODUCTION

Material fabrication is emerging as an active interdisciplinary sphere for design exploration and research, in which, the quest for sustainable and environmentally responsible processes and products has never been more pressing. According to the United States Environmental Protection Agency (EPA) 2018 report, landfills in the USA received approximately seven million tons of glass waste (found in municipal solid waste (MSW) in 2015 and only 26.4 percent of all generated glass was recycled1. In this context, design solutions that utilize glass recycling innovations can be invaluable for promoting sustainable, healthy communities and can be instrumental in the responsible management of our resources and waste.

Glass is a fascinating and unique material. Due to its astounding visual, optical and structural properties, glass can be suited for many applications in art and architecture; providing a rich source for exploring new formative and performative possibilities. However glass in its non-flat form has been underutilized in contemporary architecture. Because of its complicated physical behavior and the technical difficulties associated with the fabrication processes, design fields often shy away from exploring such medium. Recently, the prevalence of computation and machining is providing new platforms for material testing and fabrication which are readily available to support creative inquiries into exploring new controlled processes and precise applications. To contribute to this critical discourse, this paper investigates solutions through testing methods for glass forming using open face molds; highlighting the importance of integrating the complexities of the physical reality into the design and fabrication processes. The goal is to explore the limits of precision from computation to fabrication as it relates to casting glass. In this context, digital predicting modelling provides valuable tool for simulating behavior to inform the actual physical fabrication. This research is set to design an
algorithm for predicting edge/corner geometry of casted glass under different temperature profiles. Physical experiments are used to evaluate and recalibrate the prediction algorithm. The physical experiments were conducted within a context of an applied practical educational experience.

1.0 BACKGROUND
The discovery of glass can be highlighted as one of the most creative achievements of human history. By heating and melting a commonly abundant crystalline solid (sand), a new state of matter emerges that exhibits astonishing visual and physical qualities. Despite its solid form, glass is considered to be a liquid because of its non-crystalline structure. In the absence of any molecular structural order, glass can be defined as a “melted inorganic product that has cooled to a solid state without undergoing crystallization” (Beveridge, Doménech and Pascual 2005, 24). Because of its unique visual and optical qualities (transparency and translucency), glass as a unique medium offers many creative possibilities and the ability to fulfill to a wide range of aesthetic and functional needs. While there is a wide range of glass forming techniques (blowing, stretching, flashed glass, blow molding, pressed glass, etc.) this paper focuses specifically on forming glass using open face refractory molds (Martin 2006; Thwaites 2012). In this process, granular glass is places in refractory open face molds, heated to melt in a kiln and then annealed, cooled and removed from the mold. When glass softens, its molecules become mobile and flow and adapt to a mold’s geometry. With the increase of fusion temperature, the glass becomes less viscous; allowing it to flow easier filling more intricate geometry. As this viscous liquid cools down the molecules become rigid again and preserves the final geometry.

Today, glass as a building material provides an essential component of modern and contemporary architecture. Glass is mostly utilized in its sheet form (window glass) or structural glass (glass blocks), which serve primarily as part of the building envelop (Wigginton 2002; Eskilson 2018). Other mold forming processes (i.e. casting, glass slumping, etc.) are still underutilized in architectural applications. This research argues that the versatility of the mold forming processes can be invaluable for designers and architects; providing unique strategies for fabricating a wide range of innovative glass applications (Glass blind, glass walls, glass vessels, etc.). However, because of the challenging forming behavior of glass, it is essential that designers understand how glass geometry changes under different temperature and manufacturing parameters. In this context computation and predictive modeling provide valuable tools for simulating the behavior of glass based on data from actual physical experiments. Considerable amount of research into modeling, simulation and optimization of glass forming processes has been carried out. Most of this research, however, relates to container manufacturing by blow molding (Cormeau, Cormeau, and Roose1984; Cesar de Sa 1986; Burley and Graham 1991; Graham, Burley and Carling 1992; Groot, Giannopapa, and Mattheij 2011; Giannopapa, and Groot 2011) and to the fabrication and optimization of optical glass (Stokes 1998; Su, He and Yi 2011; Sarhadi, Hattel and Hansen 2014; Sarhadi, Hattel and Hansen 2015; Pallicity et al. 2015; Nguyen, Yuan, and Wu 2016; Zhou et al. 2017). In architecture, beyond the flat form, mold forming research has been very limited and mainly focuses on examining the structural aspects of glass (Patterson 2008; Lindqvist 2013) It is rarely that the limits of precision between computation and the fabrication of glass is examined. To contribute to this creative discourse, this paper explores computational strategies for the prediction and fabrication of a refractory mold system for forming glass.

2.0 MATERIALS AND METHODS

2.1. Research design
This research explores the limits of precision between design intentions, mold fabrication and the geometry of casted glass. Because of the challenging behavior of forming glass in refractory molds it is critical that fabrication processes are able to anticipate the accurate geometry of the final casted elements, which can be substantially different from the mold geometry and the design intention. This research argues that computation can be used to
predict glass forming behavior under different temperature profiles, which then can be used to inform the design and fabrication processes. The goal of this research is to design an algorithm that is able to accurately predict edge/corner geometry of casted glass under different temperature profiles. Physical experiments are used to evaluate and recalibrate the prediction algorithm.

2.2. Scope and limitations
For the purpose of designing the algorithm as well as conducting the controlled experimentation, research scope is limited to testing edge/corner geometry of one type of glass with 96 Coefficient of Expansion (COE). Open face ceramic molds are used to cast glass tiles with thicknesses ranges between ¼ - ½ inch.

2.3. Theoretical and technical grounding: prediction chart
In order to understand and map the geometric behaviour of different corner/edge conditions of the casted glass, both a theoretical study and a technical pilot study were conducted. Results from both studies were used to inform algorithm design. The theoretical study was informed by different recommendations from the manufacturers of 96 glass. In the technical pilot study, 96 COE glass frit was placed in fabricated high temperature molds, heated in a glass kiln to different temp profiles (1300-1700F), annealed and removed from the molds. The goal is to create an accurate prediction chart for mapping the different geometric behaviour of edge/corner geometry of 69 COE casted glass in open face moulds with ¼ - ½ inch thicknesses. Figure 1 shows the final synthesized forming chart for casting the 96 COE glass under six different temperature profiles.

Figure 1. Casting behaviour chart of 96 COE glass under different temperature profiles. Source: (Ajlouni 2018)

2.4. Instrumentation
This research utilizes an algorithm designed by the author using C++ Programming Language to predict the edge/corner geometry of casted 96 COE glass under the different temperature profiles synthesized in Figure 1. The Open Graphics Library API (OpenGL) is used to render vector graphics and the OpenGL Utility Toolkit (GLUT) is used for implementing windowing application programming interface. Code editing was done using the Visual Studio Integrated Development Environment (IDE).

The algorithm is designed to predict the corner/edge shape based on two main parameters: corner/edge mold geometry and temp profiles. Figure 2 (left) shows a visual chart of the
different edge/corner conditions under six forming temperature profiles. As an example, the predicted corner/edge of a right angle corner is shown in Figure 2 (right). By applying this prediction to different geometric patterns, it is possible to anticipate the edge condition of final casted glass geometry (Fig. 3).

Figure 2. Visual chart of the edge/corner conditions under six forming temperature profiles. Source: (Ajlouni 2018)

3.0. PHYSICAL EXPERIMENTATIONS

Physical experimentations were conducted in the context of a glass casting class within an architecture academic experience. Five groups of students were tasked with casting glass tiles based on five different geometric patterns provided by the instructor (Fig. 4). The first three patterns (Fig. 4 a-c) are periodic and were constructed by repeating two basic units (Ajlouni 2008). The last two patterns (Fig. 4 d-e) are quasi-periodic and were constructed by using non-periodic relational networks (Ajlouni 2012, Ajlouni 2013). The different geometric arrangements allow for testing different corner/edge conditions while keeping all other experiments variables constant.

The goal of these experiments is to explore the limits of precision between the mold corner geometry and the resulted corresponding casted glass corner geometry. All experiments were limited to testing a temperature profile range between “fill bas-relief molds” (1450-1475) to “fill sharp mold details” (1475-1550). This temp range allows the fully fused glass edges to ‘flow’ filling corner details while not sticking to the molds. Experiments were designed to generate variations of the dependent parameter ‘output’ (glass edge/corner geometry) based on testing ranges of variations across two independent ‘input’ parameters (mold edge/corner condition and temperature profile). All other parameters are kept the same (constants) (glass type (96 COE glass), frit size, glass thickness (¼ - ½ inch), fusing temp range (1450-1550), tile size (1-2 inch wide), open face ceramic mold, fabrication processes, material recipes, firing kilns (Paragon glass kilns, Delphi Ceramic kiln, etc.). The process includes the design and fabrication of the open face refractory molds and casting the 96 glass frit.

3.1. Fabrication of refractory ceramic molds

Glass casting requires the fabrication of a mold system that is able to withstand a temperature profiles up to 1800 Fahrenheit. Ceramic materials provide great refractory medium that can withstand temperatures higher than 3000 Fahrenheit. More critically, ceramic molds have a lower coefficient of expansion than glass, which is essential to allow the release of the casted glass tiles from the molds. The process of fabrication the refractory mold is explained in the next few sections.
Step #1: Design and machining of the master mold
The refractory ceramic mold making process starts by designing the master mold (positive) using a 3D modelling software (i.e. Rhinoceros 3D, 3D Max, etc.) The geometry of the master mold is designed with sloped edges to allow for easier release of the different castings. All molds were machined with a 3-axis CNC mill using a medium density polyurethane foam or machining wax. The molds were later sanded to smooth-out unwanted tool textures or sharp edges. Figure 5 (top) shows the final machined molds for repeated elements of the five different patterns.

Step #2 Slip casting the negative mold
Slip casting provides an excellent method for the fabrication of intricate and complex mold geometry. In this process, a liquid clay (slip) is poured into a plaster mold to form a layer of clay on the inside walls of the mold. After reaching the desired wall thickness, the excess slip is poured out of the mold and the clay is left to dry to a leather form before it can be released. The plaster mold (positive) is casted from a negative flexible mold material (i.e. rubber), which is casted from the CNC machined master mold (Fig. 5 (bottom)).
Figure 5. Top: The machined master molds. Bottom: Casting the plaster molds from a flexible rubber molds. Source: (Class reports)

Figure 6 (top) demonstrates the process of casting the ceramic mold (negative) using a positive plaster mold. Because the slip shrinks when drying, dusting the plaster mold with Talc was needed to help release the leather hard clay from the plaster mold. All experiments used the same slip recipe (cones 05-04 (1888-1917 Fahrenheit). The dried ceramic molds were then fired in a ceramic kiln to a peak temperature of 1945 Fahrenheit.

3.2. Casting 96 COE glass
To help release the casted 96 COE glass from the ceramic molds, 3-4 coats of kiln wash was brushed on the molds cavities. The same granular glass frit size was used to fill the ceramic mold geometric cavities. The volume of glass frit was calculated by weight based on the desired final glass thickness (¼ - ½ inch) (Fig. 6 (bottom)). Glass was then fired in a glass kiln (Paragon) according to the temperature profiles in figure 7.

4.0. RESULTS AND DISCUSSION
In general, the five groups of experiments were successful in casting the repeated patterns using 96 COE glass. The molds were used multiple times without any visible signs of deformation or structural defects. All casted glass elements have smooth and shiny surfaces with no signs of stress or visible defects (bubbles, devitrification, cracks, etc.). The casted glass results from the five experiments are shown in figure 8. The results show that glass edge/corner conditions were visibly rounded and none has sharp edges or corners. Variations of edge geometry of the same casted elements were also visible, however these differences did not affect the overall visual coherence of the pattern.

In order to evaluate the predicted corner geometry, a random representative three tile sample for each pattern were selected and closely analysed. Figure 9 shows an overlap of the initial design (black line), the casted glass geometry (green Line) and the geometric prediction lines for three profile temperatures (1420-1450: blue line, 1450-1475: orange line, 1475-1550: violet line).

The results show that the predicted edges seem to be more consistent with the physical results when the tile is a convex polygon, in which all interior angles are less than 180° and vertices are pointing outwards away from the interior of the shape. However, predictions were less consistent when, at least, one of its internal angles are more than 180° and the tile shape is concave. The change in internal angle from convex to concave resulted in an unexpected
deformation of the line connecting the two vertices. This suggests that the algorithm needs to be recalibrated to anticipate this condition. The results also show that the thickness of the tile affected the accuracy of the results. Glass volume within the thinner profiles (¼ inch) was not enough to fill-in the cavities of the mold to reach the mold walls; resulting in a more rounded edges than predicted. Nevertheless, this can be avoided by raising the lower limit for glass thickness as well as making sure that glass volume is calculated correctly.

Figure 7. Temperature profiles for firing the glass-filled molds. Source: (Ajlouni 2018).

Figure 8. The final casted glass results from the five experiments. Source: (Ajlouni 2018).
The physical results also suggest that the angle of tapered mold walls has some effect on the accuracy of the final casted edges. In the mold fabrication process, this slope was designed to allow an easier release of the final casted glass. While this factor (mold wall slope) needs to be accounted for in the calculations, more physical data is still needed to measure the deformation based on the degree of slope.

The experiments also show that when adding a texture relief on the surface of the tile, the sharp texture edges are rounded after casting (Fig. 10). In order to allow the viscous glass to capture the exact detailed relief and to fill-in all small cavities, the glass needs to be fired to a higher temperature (1750), which resulted in wetting the mold and glass edges were deformed because it stuck to the mold. Therefore, a delicate balance between design details and firing profile is needed to allow the glass to fill-in the mold cavities without sticking to its boundaries.
In general, the results from the experiments provided enough evidence to validate the tested hypothesis, however, in order to account for all glass casting parameters, additional data from physical experiments are needed to fine-tune the predictive modeling algorithm.

CONCLUSION
This research was set to explore the limits of precision between design intentions, mold fabrication and the geometry of casted glass using refractory molds. It argues that in order to improve tools for computational design and making, architecture education needs to integrate the complexities of the physical reality into the design and fabrication processes. Computation was used to predict glass edge/corner forming behaviour under different temperature profiles. Results from the experimentations provided preliminary evidence to validate the hypotheses as well as to evaluate and recalibrate the designed algorithm. More importantly, the glass fabrication experiments provided the opportunity for the students to directly interface with glass as a design medium; highlighting the importance of integrating the behaviour and complexities of the physical material into the design, computation and fabrication processes. This paper also argues that it is only through integrating cross-disciplinary knowledge and skills and through adopting a systematic and scientific approach to materials investigation that innovative glass design solutions can be achieved. Future research includes adapting this process to test the deformation and slumping behaviour of different types of glass (i.e. Sodium-Calcium glass, Lead glass, Borosilicate glass, etc.). Specifically, future efforts will focus on understanding the forming behaviour of recycled-post-consumer glass, which presents an abundant resource for reusable material in architecture. Methods for incorporating post-consumer glass into contemporary design applications can be instrumental in saving energy, resources and time.

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REFERENCES


ENDNOTES

Cultivating research: resource-based design as an activating agent for energy and water conservation

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ABSTRACT: Green and living walls are an old idea made anew through the use of conventional construction materials used in new and creative ways. There is now a broad market for mass-produced prefabricated living wall systems that are made from PVC, metal, and or geotextiles. There exist hydroponic living walls made from geotextiles and fabric materials, rigid modular living walls made from PVC, and green façade structures made from cable and steel mesh to support ground-based vines. Most conventional materials for green walls in the market are derived from raw material or recycled PVC. This study investigates alternative materials already in the solid waste stream that were ready for creative reuse. The purpose of this project was to explore if existing sheet metal by-products could be repurposed as green wall systems and provide beneficial ecosystem services. A secondary purpose was to educate the campus community about sustainability through improving the value of industrial by-products thereby reducing waste streams in the production of new materials, energy conservation and reduced water use for green walls through the use of drought tolerant vegetation. Initial readings for the living wall system surface was 2.68 to 3.92 and up to 4.6 degrees Celsius cooler than the adjacent concrete wall. Students and faculty at Texas A&M university worked through a dozen different green wall modular designs. One design was refined and was trialed for cutting using a water-jet machine and assembled with manual folding. Three hundred prism shaped modules were attached to a vertical steel frame. Drip irrigation lines deliver water to each module. Drought tolerant plants were used to minimize irrigation water. It is estimated that compared to conventional living walls, the proposed system uses about half of the volume of water needed for irrigation. More detailed analysis is currently under investigation.

KEYWORDS: Resource reuse, Living Walls, Energy saving, Automobile metal By-products, Fabrication.

INTRODUCTION

Green walls began many decades go as simple installations with hanging plants on buildings and vines selected and planted to grow vertically on stone walls and then later brick walls. Wood trellises and pergolas became popular beginning in the mid-sixteenth century formal gardens (Baran and Gültekin 2018, Köehler 2006). The Chrystal Palace built for the 1851 World’s fair in London was conceptualized by John Paxton and was perhaps the first inspiration for indoor and vertical greening with modern materials. The massive glass, steel and wood structure housed indoor trees, ferns, flowering and hanging plants. But these early versions of greening buildings only set the stage for the development of more contemporary hydroponic vertical gardens popularized by the French botanist Patrick Blanc since 2000 (Blanc 2008). Blanc’s vertical gardens were each a custom fabrication and installation derived from fabrics, however many vendors began exploring materials and methods to mass produce similar living wall systems. Over the years there has been a limited number of investigations documenting the ecosystem services that green walls can provide, thus the technology is in an early adoption phase (Köehler 2006).

There is now a broad market for mass-produced prefabricated green wall systems that are made from PVC, steel meshes and or geotextiles (Perini et al. 2013, Manso and Castro-Gomes
Green walls consist of a variety of techniques to establish live plants on vertical surfaces (Figure 1). Green facades are a type of green wall to establish twining vines on cable or on wire mesh panels. Hydroponic living wall systems make use of shallow rooted plants, fabric and nutritive irrigation water to feed plants. Each of these types of systems have limitations. Most vines have vertical growth limits and hydroponic systems may not be adaptable to climates with extreme heat or cold. Modular living wall systems attempt to grow plants vertically in small PVC containers. Many modular systems have fundamental problems such as: limited space to provide for growing medium and root growth, and some modular systems position plants in unnatural orientations such as perpendicular to sunlight. Initial installations of some of these modular living wall systems have demonstrated that some of these market-based modular systems have limited application outdoors in extreme climates and some may not be economically sustainable (Perini and Rosasco 2013, Dvorak et al. 2014).

This study investigated alternative materials already in the industrial solid waste stream that were ready for immediate use (Ali 2017). The purpose of this project was to investigate if sheet metal by-products could be repurposed as a green wall system and provide beneficial ecosystem services. A secondary purpose was to educate the campus community about sustainability through adding value-by-design to the industrial by-products thereby reducing solid waste streams in the production of new materials, energy conservation and reduced water use for green walls through the use of drought tolerant vegetation.

1.0. METHODS
A mixed methodology including empirical, qualitative, and quantitative methods was used to investigate the potential for alternative use of fabrication materials and methods for living walls. The investigators engaged conversations with potential industry partners and secured agreements with an automotive manufacturer sheet metal by-product. The authors invited a group of interdisciplinary students to participate in a resource-based design-build process to develop and fabricate new modules for a custom living wall, secured resources for fabrication, installed the living wall system and pre-tested the wall for micro-climate characteristics.

1.1. Design and Fabrication
To investigate the potential use of alternative materials and methods, the investigators secured agreements with a waste stream source in the automotive industry for available sheet metal. The automotive industry fabrication process typically disposes large quantities of sizable galvanized sheet metal as a byproduct of the automobile manufacturing process. Students at Texas A&M university were invited to take a special topics courses to conceptualize modular
living wall design alternatives and to assist in the fabrication process. Students and faculty prepared and presented materials to the university campus design sub-council to receive permissions to install the wall. After approvals, the modules and frame were fabricated, painted, planted and installed in place (Figure 2). Due to delays in the fabrication process, only the first third of the wall was assembled and planted in the month of May (Figure 2). Plant species included: *Dichondra argentea*, *Yucca 'Color Guard'*, *Phyla incisa*, *Agave lophantha 'Quadricolor'*, *Hesperaloe parviflora*, *Hechtia texensis* were placed in the modules and watered. The wall frame as shown in Figure 1 and comprises a support for the entire living wall. The living wall is approximately 5.48 meters wide and 4.26 meters high consisting of 23.41 m² of surface area. The remainder of the wall was fabricated and installed in place during the month of August.

![Figure 2. Students working on the green wall system during the module installation process. The concrete wall used to compare microclimate is visible to the right and left of the living wall. Source: Authors](image)

1.2. Microclimate investigations
Students investigated several potential methods to measure surface temperatures and heat gain. The first method was through thermal camera imaging. A FlIR® camera was used to capture a moment in time and reveal surface temperatures of the wall materials. A second method was used to determine the measure of the wall surface temperatures observed with a hand-held Extech IR® infrared thermometer. The wall has a south/southwest aspect and data was collected during the late afternoon generally one to two hours after direct solar exposure. Surface temperatures were captured with an infrared hand-held device and recorded on a table. By measuring after direct solar exposure, the effect of the wall was recorded at the end of the solar exposure period. Twelve surface locations were identified to be measured daily near the same time for twenty-one days between the months of June and August on days without precipitation. Each located was measured three times and recorded. The average of the three measurements was used in this study. Surfaces measured included the planted light
grey-blue colored modules and white modules, exposed brick, exposed concrete, two metal exterior doors and the immediate ground level pavement adjacent to the living wall. For each temperature reading, three temperature readings were taken and averaged. Additionally, A FIIR thermal camera was used to crosscheck thermal variance on wall surfaces.

1.3. Watering
Drip tube irrigation lines were installed to deliver municipal water to each module. A zone control valve was set to deliver water once daily at 6:00 am. Each drip tube is capable of delivering approximately 3.7 liters per hour. Irrigation was set to run daily for two minutes duration or 0.126 liters per day.

2.0. RESULTS
The living wall system designed and fabricated by students and faculty was successfully developed and installed during late 2018. The first phase included planted modules and was installed in May. The remaining modules and frame (without plants) were installed during the month of August. Twelve students meet once weekly to fabricate the modules in a fabrication lab at the university. Later, students installed the irrigation system, retention fabric in the modules, light-weight soils and plants.

By the month of August, all of the modules had been fabricated and the entire frame was installed. All of the modules had been hung on the wall. However, the remainder of plants will be installed during the spring of 2019, as faculty and students, and additional materials were needed to grow and purchase. Some faculty and students were not available until spring 2019.

Figure 3: Southwest facing wall with 300 modules installed. Photo taken during the early morning. Source: Authors

2.1. Waste stream reduction
Compared to market-based modular living wall systems, this system designed by students and faculty used materials already in the metal solid waste stream. By retrieving refuse sheet metal from the automotive industry, there was no need to extract raw materials. Figure 4 shows the
sheet metal used prior to fabrication of the wall. Each sheet was fitted for the module design and cut. Waste from the cutout of the module could be sent back into a metal recycling center. The module layout was adjusted to minimize cuts and reduce waste.

2.2. Microclimate

Surface temperature observations were taken over the summer from June to August. The thermal camera image demonstrates that the living wall modules (blue pixels) on average were 2.68 to 3.92 and up to 4.6 degrees Celsius cooler than the adjacent concrete walls (orange to red pixels). There was some variation between modules as the white modules were generally 1-2 degrees Celsius cooler than the light grey modules. Figure 5 shows the temperature variation in a thermal camera image of the wall taken in July. The image legend is located on the right side of the image and correlates pixel color to thermal temperature with a range of 28.3 to 32.9 degrees Celsius.

Although cloud cover was present during some of the observations, during the warmest time of the summer temperature readings were taken during cloudless days to measure potential effect of modules. Table 1 shows mean temperatures for several locations of different surfaces. As the modules are diamond shaped and protrude away from the wall, the sun and shade sides of modules were taken. The building wall also has two metal exterior doors and some exposed light brown brick. The grey-blue module in the shade side of the module had the lowest surface temperature at 39.78 °C for the living wall. The white modules had
temperatures similar to the grey-blue modules but were slightly warmer. Most of the living wall is in the blue temperature range, where the edge near the concrete wall can be seen in the green and yellow temperature range. This means that the concrete thermal mass is radiating heat to the living wall system (Figure 5).

Table 1. The handheld Extech infrared thermometer was used to observe floor surface mean temperatures taken at 15:00 hrs on August 1, 2018 approximately two hours after direct sunlight. Maximum air temperature for the daytime at the university was 36 °C.

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</tr>
<tr>
<td>2</td>
<td>Grey-blue Module (shade)</td>
<td>39.78</td>
</tr>
<tr>
<td>3</td>
<td>Grey-blue Module (sun)</td>
<td>40.66</td>
</tr>
<tr>
<td>4</td>
<td>White Module</td>
<td>40.8</td>
</tr>
<tr>
<td>5</td>
<td>White Module (shade)</td>
<td>40.72</td>
</tr>
<tr>
<td>6</td>
<td>White Module (sun)</td>
<td>41.22</td>
</tr>
<tr>
<td>7</td>
<td>Exposed Brick Wall</td>
<td>42.78</td>
</tr>
<tr>
<td>8</td>
<td>Right Concrete wall</td>
<td>41.42</td>
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<tr>
<td>9</td>
<td>Left Concrete wall</td>
<td>42.48</td>
</tr>
<tr>
<td>10</td>
<td>Metal door</td>
<td>42.59</td>
</tr>
<tr>
<td>11</td>
<td>Right Concrete pavement</td>
<td>44.77</td>
</tr>
<tr>
<td>12</td>
<td>Left Concrete pavement</td>
<td>49.77</td>
</tr>
<tr>
<td>13</td>
<td>Exposed Brick pavement</td>
<td>48.27</td>
</tr>
</tbody>
</table>

2.3. Watering
Irrigation water was delivered daily during the summer. During late July, the watering was changed from two minutes to one-minute duration. Some weeds were establishing in the modules and it was thought that it may be due to excessive watering. On October 18, 2018 it was discovered that the irrigation control valve was leaking. The irrigation was shut down for the winter, as natural rainfall was assumed to be ample for the remainder of the year. Compared to earlier studies on living walls on campus, this living wall system was set to half the water, due to the use of drought tolerant plants. The same type of water delivery system was used on three other living walls built from conventional systems available on the market. Irrigation run times of five to ten minutes was required to irrigate the entire wall thoroughly. In this study we found that the living wall planted with drought tolerant vegetation did not require more than one to two minutes of irrigation daily to maintain live growth.

3.0. DISCUSSION
Compared to other conventional living wall systems available on the market, the uniquely-designed galvanized sheet metal modules minimized the use of new materials, steel recycling, and therefore energy consumed. The custom modules required paint, similar to typical car finish to extend their life time and to protect the galvanized metal from oxidation and corrosion. The thermal data demonstrates that the living wall compared to a concrete wall has a capacity to reduce the heat gain on exterior wall surfaces. The effect of plants is not clear, as only one-third of the wall was planted. The cooling effect was largely due to the effect of unplanted modules. The additional systems layers of plants, soil, insulation, and moisture are anticipated to further reduce the heat gain on exterior surfaces. The thermal images show that the plants were the coolest features of the wall. Once the wall is complete, further investigation will be conducted. The warmest measured locations were the ground pavement near the wall. It is presumed that the pavement near the wall received direct solar exposure from sunlight and
radiated heat energy from the wall surfaces. Future studies will investigate the potential effect of plants shading and cooling on the wall and pavement adjacent to the wall.

CONCLUSION
This study demonstrated that sheet metal by-products can be harvested and repurposed to reduce solid waste streams and embodied energy through resource-based design approach, typically present in the manufacturing of living wall modules constructed of PVC materials. A more in-depth investigation is necessary to further investigate energy conservation of all phases of fabrication and to better understand the dynamics of the potential heat energy conservation of this living wall system. The use of drought tolerant vegetation allowed minimal watering to gain effect of shading the modules. Future studies will investigate the fully planted wall to extrapolate the results.

ACKNOWLEDGEMENTS
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REFERENCES
Collaboration in design: a study of James B. Hunt Jr. Library

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ABSTRACT: Collaborative design is a complex process that differs from the conventional system of sequential design by means of personal interaction, communication, and timing of design decisions. The complexity of the collaborative system, however, gives way to reduced cost and risk, increased project delivery speed, and improved building performance. As building projects become more complicated through technological advancements, and the architecture, engineering, and construction (AEC) practice embraces more integrated processes, it is important to understand the dynamics of collaborative design. Through the study of previous projects, intimate knowledge can be gained regarding partner interaction, oversights, team dynamics, processes, and benefits that are not always a part of a standardized list of collaborative benefits. This study will provide this insight by framing the design and construction of the James B. Hunt Jr. Library using a narrative case study format, beginning with designer selection and focusing on the collaborative aspects of the process. This transformative library is an example of innovation and success through collaboration. At many stages, the study of this project allows observers to gain insight into the personal interaction between Snøhetta and NCSU that enabled the project to be successful. This insight is provided through the review of construction and design documents, interviews of stakeholders and design professionals, and literature. The summary of the process will provide reviewers an example into how a collaborative process may differ from traditional methods, potential conflicts and understanding required for solution, and how collaborative design can benefit innovation and project success.

KEYWORDS: Integrated Design; Collaborative Design; Innovation; Professional Practice

INTRODUCTION

Positioned on the southwest corner of North Carolina State University’s (NCSU) Centennial Campus oval, the Snøhetta designed James B. Hunt Jr. Library (Hunt) rises out of the landscape. Its form resists familiar library iconography and is inspired by the power looms of North Carolina’s textile industry, even as the lawn begs for a grand Jeffersonian gesture. Completed in 2013, the exterior of the 221,000 square foot iconic building invokes the modernist tradition while providing little indication of its intended purpose. The grounds are a crossroad of academic and social interaction, aiding the library in its role as a magnet, grounding the rest of the campus. Embodying NCSU’s commitment to innovation and research, the library was intended to be a destination point that allows people to feel welcomed and inspired by the social spectacle of academic work.

While architecturally significant, much of Hunt’s renown comes from its adaptation of the traditional notion of a library by incorporating fast-changing technologies and placing an emphasis on collaborative spaces. Demonstrating that “libraries were never about books” (Webber 2013, 77), Hunt proves that even with the implications of the digital age, libraries are still relevant. Attesting this commitment, the grand electric-yellow staircase runs diagonally through the building guiding visitors past a plethora of technological advancements and collaborative spaces. Upon entry, guests are greeted by a fishbowl of technology and an unconventional circulation desk. At this desk, students and visitors can borrow iPads and make queries via a computer. Checkouts are done without the assistance of a librarian using a kiosk. Further, into the space users will find a selection of furniture, representing both modernist and NC designers. This furniture can be freely rearranged for singular or
collaborative study session and is as much utilitarian as it is another layer of education and information.

With almost 100 group study rooms and tech-equipped spaces, Hunt is not sparse in its inclusion of technology. Hunt even boasts immersive visual spaces that are used for the display of content ranging from the historical recreations of 17th-century architecture to simulated maneuvers for the NCSU’s Navy ROTC. In embracing this technology, one would be remised to notice during a tour the limited physical space allocated for bookshelves. Partially a casualty of budget cuts during design and construction, technology and collaboration was always intended to take center stage. To assist with this, and to make accommodations for the removal of a 6th floor, the library included one of its most innovative features. Prominently displayed through a glass curtain wall at the west entrance, a 50’x160’x50’ bookBot is submerged 20’ below grade. This companion to the library can hold up to 2 million volumes and is controlled by an application that has virtualized the bookshelves, allowing users to browse the “shelves” similar to a traditional library.

Costing $115.2 million to build, Hunt is as much a testament to the achievement of its mission as it is to the collaborative process that was undertaken during its construction. At a time when the architecture, engineering, and construction (AEC) practice is increasingly embracing collaborative delivery methods, it is important to understand how collaboration changes the design process and generates benefits pertaining to innovation and overall project performance. Hunt is a prevalent, early example of the integrated design process and can be used to understand how it differs from traditional methods. This study will look at the design process associated with this forward-looking library and evaluate how it changed the process and perspective of both NCSU and Snøhetta, overcame resistance to its design and financial obstacles, and resulted in a high performing library that centers on collaborative study. The design process will be framed in a narrative format, beginning with designer selection and focusing on the collaborative aspects of the process. This case study gained insight into the process through review of construction and design documents, interviews of stakeholders and design professionals, and literature. This information was used to create the summary of the process to provide insight into how a collaborative process differs from traditional methods, how collaboration can benefit innovation and project success, and allow individuals to reflect upon the information contained in this study to better evaluate their perspectives on the process.

1.0. NCSU AND DESIGNER SELECTION

NCSU was founded in 1887 as a land grant institute for agriculture and engineering studies. Opened in 1889 with 72 students, 6 faculty, and one building the university has grown into a pre-eminent research enterprise with 34,000 students spread over 65 departments in 12 colleges. This 130-year expansion resulted in the surrounding urban environment constricting the main campus. To access additional resources, the expansion of the campus required the use of nearby but noncontiguous undeveloped area.

In 1987 Centennial Campus was established on one of these locations. This campus is located approximately 1 mile from the historical main campus on 1,334 acres. Centennial Campus consists of residential housing, research centers, and recreational amenities. Eventually slated to hold all NCSU’s engineering departments, the site was envisioned as a collaborative research center where local businesses and students could interact.

One issue with the campus is that it is located too far from the main campus for students to walk between the two. Even with connecting bus routes, students residing on this campus have difficulty using D.H. Hill Library that is positioned at the head of the “Brickyard” on the main campus. As a result, the university realized this issue of convenience provided the opportunity to create an iconic structure that would not only provide support for Centennial Campus but aid in establishing NCSU as a top research university.
With the support of Susan Nutter, vice provost and director of NCSU Libraries, Mike Harwood, the university architect, and Marvin Malecha, the dean of the College of Design, created a design competition to select the Hunt design team. This method was atypical of the university's selection process and originated from Malecha's push to change the process due to his disappointment with earlier work. (StoryCorps 2017) Historically, NCSU used a long process that included interviewing design teams and the review of large packages of materials composed of resumes, recommendations, design proposals, and previous work. (Chung 2014) A competition-style selection process had never been done at NCSU but would be critical in establishing the collaborative nature of the project.

Six firms were shortlisted for the competition from a larger list of interested parties. These firms included Snøhetta and Pearce, Brinkley, Cease, and Lee (PBCL), now Clark Nexsen, who would later be selected by Snøhetta to be the "executive architect" for Hunt. The firms were invited to NCSU for a weekend of introductions and competition. On the first day, the firms introduced themselves and presented previous work. At the beginning of the second day, the firms were assigned two students and given a design problem. The firms would be sequestered to rooms with the selection committee members wondering between the rooms. (Ferris 2015c; StoryCorps 2017) Elaine Molinar of Snøhetta recalled, "We were basically locked in a room and told to design our way out of it by the end of the day." (StoryCorps 2017) This process was intended to allow NCSU to observe the team's reactions, process, and willingness to collaborate. Malecha and his fellow committee members were looking for a team that had "...the wisdom to work patiently with the library staff to really come up with ideas that hadn't been done before." (StoryCorps 2017)

Snøhetta’s collaborative spirit was recognized by Susan Nutter and the other members from the beginning in Molinar’s and Craig Dykers’ team breakdown and their demeanor. Dykers, a principle of Snøhetta and Molinar’s husband, is a well-known star architect but he did not act that way towards the NCSU community. He was inclusive and open to their inquiries. (StoryCorps 2017) This openness and willingness to include others extended to the competition. Snøhetta, counter to the rules, used Skype to connect the people at the charette with the entire NYC office. (Hill 2013) This was not viewed as a disqualifier as Snøhetta brought their wider resources to bear on the competition but their inclusion of the students in the process did pique the jury's interest. (StoryCorps 2017)

On the final day of the competition, Snøhetta presented their work. The results was an "awkward brick tower" that did not gain the praise of the Susan Nutter or the committee. (Hill 2013; StoryCorps 2017) This did not deter NCSU from selecting them as their designer. As Moliner stated, it was “clear that [NCSU was] not selecting a final product ... [they] were selecting a partner.” (StoryCorps 2017) Snøhetta had been the only team to incorporate the students into their presentation and this impressed the selection committee. This indicated to Nutter and the committee that Snøhetta was a firm that was willing to listen to the community and collaborate. In reflecting on the process with Moliner, Nutter elaborated on her disappointment in the charette design and her desire to work with Snøhetta: “So to heck with the drawing or whatever, the model, I did hate it, ... But it didn’t mean we weren’t going to work with the firm.” (StoryCorps 2017) Through the process, NCSU had found a partner in Snøhetta and together they would attempt to create an iconic building that realized NCSU’s vision.

2.0 SNØHETTA
Snøhetta was familiar with design competitions. The firm was founded for the sole purpose of entering a competition. In 1989, five architects joined together to win the commission of the Library of Alexandria, in Alexandria Egypt. This competition was a result of Richard Nixon's visit to Egypt in the 1970s. His desire to see the Alexandria Library, which had not existed for several thousand years, caused his host some embarrassment but would eventually lead to the U.S. donating money for its reconstruction. In 1988, UNESCO would take over the management of the project and establish the competition. (Merkel 2009) This would eventually
lead to the establishment of this group of designers, all in their 20s, and their company as world players in architectural design.

A year prior to the competition, in 1987, Kjetil Thorsen and Øyvind Mo, both of Oslo, Norway joined with a landscape architecture firm to incorporate architecture and landscape architecture into one design process. This concept of a combined process would later continue as a principal component of Snøhetta's designs. The firm was situated above a beer hall in Oslo called Doverehallen, named after the Dovrefjell mountain range in which Snøhetta is its highest peak. (Merkel 2009) This name would be adopted by Thorsen and Mo for this joint venture and later by the firm that is now known as Snøhetta.

Early in 1989, Thorsen independently discussed collaborating with Dykers, living in Los Angeles, California at the time, about entering the library competition. They would be joined by a mutual colleague, Christoph Kappeller. Kappeller was originally from Austria but was currently living in Los Angeles. Snøhetta would register in the summer of 1989 for the competition and would round out the team with Mo and his friend Per Morten Josefson. They would add others to aid in the competition and after five weeks they delivered a package that eventually won the commission.

Winning this competition led to the official establishment of Snøhetta towards the end of 1989. The firm would have eight equal partners. Kappeller, Dykers, and Molinar, Dykers girlfriend at the time, would move to Oslo and join their colleagues in the office space over Doverhallen. Molinar and Dykers, who met at the University of Texas at Austin, would eventually marry and spend significant time in Alexandria managing the library project. This husband and wife team would eventually arrive in Raleigh, NC to manage the Hunt project.

Today, Snøhetta has offices in Oslo and New York and work as an integrated architecture, landscape, interior, branding, and design firm. They have 130 employees from 20 different nations with an approximately 50/50 composition of male and female employees. The corporate makeup has changed since the Alexander Library competition but Thorson and Dykers remain as principles. They are democratically organized through an internally unionized structure in which there are no private offices and open work areas. Since their establishment, they have won a number of competitions and commissions including the National Opera of Norway and the Pavilion at the World Trade Center Memorial.

Over time, Snøhetta has become known for its “exquisite, thoughtful public work that grows out of its landscape context.” (Merkel 2009, 98) This focus on the built form integrating with the landscape is key to bringing depth to Hunt but also created a unique portfolio for the company. Their work stresses the relationship between nature, landscape, and architecture. This is achieved through buildings that are particularly sensitive to their surroundings. (Webber 2013) As a result, Snøhetta’s work does not have a particular unifying quality across their projects. Each of their buildings are unique as they have never been about directing a particular behavior but providing options. This sensitivity to the environment and the users of a building would provide Snøhetta with the foundation to create Hunt and provide NCSU with their visionary building.

3.0 DESIGN PROCESS

Snøhetta knew this would not be an easy project. “The university wanted something that showed NC State was forward-thinking in keeping up with the pace of technology and providing an opportunity not only to the students, but to the whole state.” declared Nicholas Rader, a Snøhetta project manager. (Madsen 2013) NCSU wanted an iconic library but as Dykers explained: “a library can mean anything to anybody” (Webber 2013, 76).

When you say “think of a library” you can't, there isn't one image necessarily that comes to mind. They're all very different. ...[Today] libraries demand much more space, a much wider variety of space, [more] spatial needs than they had previously. At one time libraries were seen simply as a resource but now they're seen as a place of activity. (Morgan 2008)
Snøhetta’s other libraries embodied this understanding. According to Dykers, “Our libraries have always been about creating a place where people can feel good about themselves. Where it makes you feel alive, because what the hell use is knowledge if you don't want to be alive?” (Webber 2013, 81) This did not mean that NCSU would hold the same understanding or vision for the project.

To help understand a client’s vision, Snøhetta takes a more deliberate approach to the design process and does not believe in jumping into a design and immediately drawing. It is essential to Dykers and Molinar’s team to explore and understand the future and present needs of the site and occupants. “We like to say that you can’t know what it’s going to look like until you know what it’s going to do first.” (Morgan 2008) The Hunt library would be a special case in which people were even more likely to not know exactly what they wanted their building to do. NCSU would have a general notion. Hunt was to be a library, it needed to function as a library and needed to have books and seats. This general notion would not be enough. There are numerous things inside of a program that need to be detailed and these items will eventually produce the look of the building. Hunt is an example of where a building's initial conception does not form in reality. Clymer Cease, a principle of PBCL, explained this paradox between the perception of a library and what Hunt would come to embody.

You know, the tendency in libraries, particularly academic libraries, up to that time, you put a couple of floors of common space in, they're stacked, maybe you’ve got a hole cut in a couple of places, so you can see up, and then you stack books on top of that. People come in, get in an elevator, and go hide up in the stacks somewhere where they won't be bothered, come down maybe once to the snack bar and go back up, and that's it. The whole notion behind [Hunt] is that we want people to interact, incidentally or structurally... (Ferris 2015a)

Hunt’s form would come to reflect this change in notion. The final product has much fewer books on display and as noted became more about the activity than the traditional concept of a library. To Dykers, this change influenced the look of the building; “There are books available…but actually what’s being provided more than anything else are variation of spaces for collaboration and that’s creating the look.” (Morgan 2008)

This outcome was a culmination of the exploration and collaboration that was brought to the project by Snøhetta and NCSU. Beginning with a six-month programming process, Snøhetta looked to understand the wish list of the stakeholders and the site. The goal of the programming stage was to understand the needs and aspirations for the building and how they translate into space. (Snohetta et al. 2008) Treating this endeavor more like a research project, they worked with the programming consultant DEGW to better refine the needs and priorities of NCSU.

A total of 6 rounds of workshops were used to meet with the Institute of Emerging Issues, a think and do tank that occupies part of the library, the College of Humanities and Social Sciences, and other stakeholders. These stakeholders were led by Susan Nutter and included the board of trustees, library staff, students, and faculty. The workshops focused on open-ended, creative thinking and used interviews and discussion. The participants engaged in exercises and activities to articulate their visions of the building; including imagining key spaces, creating staffing organization and developing key adjacencies. DEGW and Snøhetta would use this information to create a space attribute index and through discussion with NCSU map the spaces. This iterative process could gradually move towards specific reviews of key issues such as access, services, image and identity, growth, technology, and design. It would be used to provide input and refinement into the design and eventually result in Snøhetta better understanding the needs, wants and hopes of the client. It would also aid in reducing the size of the initial building by half.

With programing coming to an end, Snøhetta would traditionally work with the client through workshops but for Hunt, they would undertake a more collaborative approach for its design and construction. There would be hundreds of meetings about every aspect of the project. (Ferris 2015d) During the schematic design, they invited NCSU and the user groups into the
process on day two. Typically, they would have worked more in developing ideas and concepts prior to discussing them with the client but Molinar expressed a found value in NCSU joining earlier, “…this process starting out simultaneously has worked well and the result was a little bit surprising I think and it was a very positive and I think it gave us more strength to move forward.” (Morgan 2008)

Their process became more “…like a contemporary collegiate education, than a top-down handoff of a single idea.” (Hill 2013) The feedback helped in the design and development of the building. When expert input was needed on either side the appropriate individuals were consulted, such as the computer science faculty provided input regarding the game lab. Gwen Emery, the director of library environments, was brought in later in the process to aid in the interior design and furniture selection but was still required to familiarize herself with the needs of the users. Following a similar structure to the design process, she met with the stakeholders, including interior designers from PBCL, every two weeks to discuss the interior plans. In the end, the user’s needs or requirements were always the root of the decisions and provided the direction for the project.

As design progressed, the entire team was operating as a singular entity, without boundaries. However, even the most well-organized programs find resistance. The involvement of a number of stakeholders would result in its own conflicts. As Molinar explains, “We all experience architecture every day in a very real and tactile way. So, we know it the way we know it, in the way we experience it.” (StoryCorps 2017) This experience results in the formation of opinions. This experience is not comparable to training and design expertise of design professionals. “As a design professional, though, you have to be a little bit removed and objective from that process.”(StoryCorps 2017)

This understanding of the difference between the knowledge of a designer and a user’s experience was not held by all parties involved with Hunt. Malecha recalled an issue with the color of the prominent staircase. Snøhetta had designed the stairs as bright yellow to promote movement but some stakeholders felt they should represent the campus in Wolfpack red. A viable request from a branding perspective, this ran counter to Snøhetta’s design expertise. Malecha took it upon himself to help relate this proficiency in design and the trust associated with collaborative design. Using an impressive narrative, he explained to some of the stakeholders:

So, we invite a world-class chemist to campus. We invite him to sit down with us so that the vice chancellor responsible for facilities is going to teach him how to mix sugar into water? (StoryCorps 2017)

This helped instill a level of trust, leading the stakeholders to agree to the color choice, but would not be the only type of resistance that would be experienced with the design. A downturn of the economy resulted in a budget cut of $10 million dollars. This created significant hardship with planning as it impacted the vision of the building. With the project out of programming and schematic design, this revelation had the potential to sidetrack Hunt’s design and success.

Susan Nutter and the staff of the library were aware of the importance of collaborative spaces. This was an issue that had plagued them with the D.H. Hill Library on the main campus. They were against the removal of the study areas, but this new budget cut had the potential to eliminate them due to the need for book stacks and a reduction in floor area. Being aware of a potential innovative solution, they brought the inclusion of an automated shelving system to the attention of Snøhetta.

This system would later become known affectionately as the bookBot but even with the library’s support, it faced opposition. Lisa Johnson, the university architect, reflected:

At first, I think a lot of the faculty were not onboard with not being able to walk the stacks and browse the book stacks. So there was a lot of discussion about this and the library, being as forward-thinking as they are, decided well, we can develop a virtual browser. (Ferris 2015c)
By understanding the concerns of the community, a solution was created. This collaborative process addressed the issue with the budget and provided for a better experience in using the bookBot. As a result, the system allowed for the creation of more space and for a smarter and less expensive building.

4.0 CONSTRUCTION
After almost two years, the design process came to a close, but this would not end the collaborative process. Skanska, the construction manager, would continue the interactive relationship established by Snøhetta, PBCL, and NCSU. They would also experience the benefits of the collaborative design and the relationships it established.

One of the most productive benefits of the design process would be the use of Building Information Modelling (BIM). Skanska would be able to leverage this tool as a communication platform, enabling the project to be better understood and remain on schedule. Not originally considered for the project, BIM was implemented by Snøhetta at the request of PBCL. PBCL had used BIM for a few years but Snøhetta had not. This change in process would allow for better communication during the design phase and create an understanding of the project that is not possible with traditional plans and elevations. This use of the model as a means of communication and design deliberation would extend into construction.

Skanska made the model part of the onsite Mobile Resource Center. In this center, they had renderings of the model and the model itself, accessible on what they called the toolbox. The toolbox was a flat screen panel that allowed people on the site to look at the space they were about to work on. They were able to sketch on the BIM model directly using smart boards and even able to access it on site through iPads and Vela, now BIM 360.

The workers took quickly to this system and it was considered the most beneficial and widely accepted high tech tool used on the job according to Will Senner, the assistant project manager. In an example of its use, Senner recalled in one situation a superintendent used a drawing from the kiosk to help a subcontractor understand the finish detail for a stairwell. “He just navigated to that detail on the model, did a screenshot, printed it out and just handed the picture to the drywall sub who went and built it off of that picture.” (Judy 2012, 3) This access to resources and the sense of increased collaboration was embraced by the design and construction teams. It kept everyone informed of changes and facilitated their coordination and discussion.

This ability to quickly and easily communicate would be critical in keeping the project focused and able to adjust to unforeseen conditions. This would be especially true with the complicated systems associated with the library. Many of these systems, such as the chilled beams used for the conditioning of the space, found their execution made possible because of steps taken during the collaborative design process. Chilled beams are unusual for the Southeast due to the region’s humidity. As Senner, explained: “The humidity is a big concern… [with the wrong conditions] those chilled beams can start to sweat, which can be a huge problem.” (Judy 2012, 1) To address this issue, the project would use Computation Fluid Dynamics (CFD) analysis during design to investigate the operation of the chilled system, especially concentrating on operating temperatures for occupied and unoccupied times. (Aksamija 2016) This would allow the specialty contractor to properly install the system and its electronic monitors that constantly sample the library’s air and measure its conditions to prevent condensation.

Skanska would not experience this ease with all systems, however. The exterior curtain wall would present them with both small and potentially project damaging issues. Snøhetta’s design concept aimed to create a sense of movement along the wall. This required each of the approximately 800 curtain wall units to vary in size, shape, position, and color. This would result in the mullions along the wall to not line up horizontally and require modifications to the typical gutter system. Mo Arani, president of DEC, the curtain wall detailer, “...had to work with the architect to find an ideal place to have a continuous horizontal to make the gutter system...
work." (Judy 2012, 1) The solution was to use a two-story-high gutter system that was heavier and harder to handle but able to maintain the aesthetics of the building.

This would not be the only obstacle that the curtain walls would present. The wall incorporates approximately 2,500 vertical solar blades that vary from 2 to 18 inches wide. As Senner described, "It's just a beast of a system" (Judy 2012, 2). With over 4,000 pages of fabrication drawings, the system was to be designed, fabricated and installed within 13 months. This deadline was seen as almost impossible to meet by the majority of the subcontractors and would require the collaborative work of Skanska, DEC, Snøhetta, and Trainor, the manufacturer. Snøhetta's project architect Nic Rader recalled, "We locked ourselves in a room for two weeks and went through every single drawing." (Judy 2012, 2) At the end their sketches were incorporated into the design and, along with innovative asset tracking technologies, would allow Skanska to meet the deadline even with the closing of Trainor during the final stages of manufacturing.

In the end, the collaborative process resulted in the best ideas rising to the surface and for the alignment of expectations, design intent, and ambitions during construction. After almost 5 years, Hunt would be completed in 2013. The building would attain LEED Silver status and become an iconic structure, inspiring other institutions. It would also win several awards for its architecture and staff, however, the most cherished awards would come from its users and the experience gained by those involved.

5.0 RECEPTION

Hunt was shaped by the interaction between the design team, library staff, and others. Dykers recalled:

> when we first looked at this commission we really did image it to be a library like many other libraries. ...the librarian, the director and also their staff were enormously forward thinking and in fact I would say that it's turned out that the program for this library is so surprisingly modern and forward thinking we didn't anticipate that when we started.  
> (Morgan 2008)

The Institute for Emerging Issues, the library staff, and all the stakeholders provided opinions. These opinions did not always coincide. This can be daunting but according to Gwen Emery: "...when you disagree you always get another idea, a better idea." (Ferris 2015b) In the end, this back and forth makes for a better product.

This project has influenced both NCSU and Snøhetta. For Snøhetta, Hunt changed how they use the collaborative process in their offices. Since the completion of the project, Molinar states: "It's, I think, a model that we've practically insisted on ever since."(StoryCorps 2017) The process has allowed them to work toward a higher level of understanding and communication among the design and construction teams. The experience proved that the most successful architecture can be achieved when all the team members are aligned in the ambition and expectations of the project. (Hill 2013)

The Hunt project was made better through this alignment of stakeholders. For both sides, this point of collaboration made the project stronger. Lisa Johnson expressed:

> Sometimes there was some compromise from some of the stakeholders that were required, but all in all, it was a wonderful effort and one of the best projects I've ever been involved with here on campus. (Ferris 2015c)

This was an experience that was not lost on Snøhetta. Dykers found the experience and process strengthen the overall design.

> It's definitely improved the building. I mean, there's one thing you can say, that architects, for better or worse, often aren’t able to transcend many of the notions of design that are implicit in your education and so forth, and the user groups and the people that design the library from a user perspective aren’t interested in design in the same way that an architect is. ... they’ve pushed us to be more colorful, more informal, less hindered by straight lines and the kind of rational thinking that architects often have to have.

While there was accomplishment in the process, for NCSU true success would always be measured by the user's reception. Throughout the project, the designers and committees
wondered if the space would be accepted or rejected. The library went against conventional thought but brought to campus what individuals involved in the process felt was needed. On the first day of operations, overwhelming enjoyment was felt by Emery and others. “The students walked in and they just started using the space, you know, just as we’d imagined, and I sat there, and I just started crying.” (Ferris 2015b) The students quickly adopted the space to the enjoyment of the design staff. Cease recalled his excitement in seeing this process:

Yeah, it was fun to come in when it was first open and see the people just coming in and moving through the building and walking and talking about it and how quickly it got adopted by the students. I mean they were here right away in droves, and to come over here and see them actually using the building and enjoying the building was a lot of fun, very much like going to a town square on a Saturday. [Laughs] So it was a lot of fun to see that, and then see the faculty come and embrace the building, and then everybody, the public.

“Every corner of the Hunt Library is designed to be memorable and stunning”(Schwartz 2013), so there should be little surprise that students found intrigue and enjoyment in unexpected areas. As use continued, a selection of students even found pleasure in learning about the furniture. These students would establish a blog about the pieces so that they could share their delight with others. This enthusiastic reception would not mean that there was no need for adjustment.

The staff constantly monitors the use of the space and seeks feedback. As people used the spaces furniture has been added or adjusted. The mezzanine needed more tables. ADA tables were requested, as expected, and stand up desk were added upon their request. This is not an indication of an issue, however, simply an extension of the collaborative process and the continued evolution of Hunt Library. As Susan Nutter explains,

I believe it’s fully realized, the vision. And even more so, I think, for faculty and students. Now as we get through generations of students, they’re not going to really know the difference between what they had and what they have now. But faculty really do know...

What a difference this has made (StoryCorps 2017)

CONCLUSION
Hunt was achieved through the willingness of NCSU and Snøhetta to attempt a process was not intimately familiar to either party. The outcome was a revolutionary library that uniquely services the students, faculty, and community. While this outcome may have been achievable through other methods, this case study demonstrates how the collaborative process became an integral part of the design and operation of Hunt.

The narrative format of this case study allows individuals to formulate their own takeaways dependent on their perspective and tendencies towards design and collaboration. That is the intention of this study. Collaborative design is very personal and interactive. For this reason, it is important for individuals to evaluate their perspectives on the process. The review of the design and construction of Hunt provides this opportunity.

This study also provides evidence of key components of collaborative design. While common principles, the case study gives depth and insight into their application and value within the process. These include:

1. **Collaboration begins with trust.** All parties involved must trust the decisions and expertise of those involved in the project.
2. **Expectations must be managed and addressed.** Social norms, terminology, and experiences differ between disciplines. All parties must be aware of these differences and communicate to minimize any adverse impacts of misunderstandings or conflicting expectations.
3. **Goals must be shared.** The project must have shared goals and all parties must accept and support these goals. All efforts should be directed by the achievement of these goals and compromise must only come at a consensus.
4. **Measurements are needed to determine success.** Success can be subjective. A project is aided by a metric of success and this should be managed at both the project and individual levels.

**REFERENCES**


Ferris, Virginia. 2015a. “Clymer Cease Interview.” Raleigh, NC.

———. 2015b. “Gwen Emery Interview.” Raleigh, NC.


———. 2015d. “Patrick Deaton Interview.” Raleigh, NC.


Morgan, Chad. 2008. “Craig Dykers and Elaine Molinar Interview.” Raleigh, NC.


PRACTICUM-FOCUSED PEDAGOGY
ABSTRACT: As professional practices adapt and specialize to address the thorny complexities of real-world problems, it becomes increasingly important that practical applications of design research should be more quickly digestible, assimilated, and incorporated. This has motivated some practitioners to direct—or produce—the research studies they need. It is not always clear, however, that practice-based research ‘measures up’ to academic standards. The situation opens up discussions of alternative “practicum” research training—both for advanced (doctoral-level) research studies but also for applied research methods taught in professional design programs (Masters level). In particular, this study presents preliminary findings on a range of programmatic comparisons between Doctor of Design [DDes] and Doctor of Philosophy (PhD) in Design degree programs, exploring both their alignments and autonomy, in order to discuss the goals and methods of teaching practice-based design research. The study uses research training structures in Education as a model for comparison with Design. A typology is proposed to distinguish: (1) professional (entry-level) doctoral degree, (2) academic doctoral degree with a research focus, and (3) professional (advanced) doctoral degree with a research focus. Using ordinary text analysis tools, key passages describing goals and purpose; mission/learning outcome; structure; and delivery mechanisms from selected doctoral programs are analyzed. Then, keywords from professional doctoral programs (such as DDes, DArch, and DSc), are discussed. Emerging strategies, structures, and delivery mechanisms suggest that professional doctoral degrees may be able to engage more easily with professional practice and to offer clinical approaches for rigorous research as well as innovative design practices. This offers welcome opportunities to bridge academia and design industries. However, because not every concept-making practice constitutes “research,” a significant need remains for the development of workable definitions of research standards and systems. Student-practitioners in advanced doctoral-level design research programs thus require a command of professional ethics and research integrity, as well as setting clear boundaries between professional services and research investigations.

KEYWORDS: Professional design pedagogy; doctoral degree program models; Doctor of Design; applied research; research in practice.

INTRODUCTION

Across design disciplines, agencies, and sectors, practicing professionals increasingly appear to be integrating research agendas within their design processes and commissions. Over the past two decades, notable practices embracing and marketing their involvement in research include Olin Studio (landscape architecture); West 8 (urban design & landscape architecture); Kieran Timberlake (architecture and planning); Perkins+Will (architecture); SITU/Studio (architecture and fabrication); Kaleidoscope Innovation (product development); BresslerGroup (product design); RKS (product design and branding); SocioDesign (branding and packaging); and of course many more. In offering research as a service to clients, as well as a method to inform design, these firms assert that their professional merits are based in large part upon emerging expertise in their fields—expertise that benefits directly from engagement in practical research.

The integration of practice and research suggests that, in design, as in the fields of law or medicine, traditional or received definitions and boundaries of terms such as ‘design’ and ‘research,’ or ‘pedagogy’ and ‘praxis,’ are becoming blurred. This blurring has consequences for how design researchers are trained. In response to self-described practice-based research agendas, based on cues from websites, journals, and even corporate structures of many
leading design firms, how should design educators respond (and students prepare) for the co-construction of knowledge?

Obviously, not all research is created equal. Typically, the processes of data collection and analysis performed in the context of professional design services (such as market/site/program analysis, user needs analysis, or other forms of project-specific diagnostic work) will differ from those of academic researchers. Many professionals aspire to holistic synthesis in the context of their projects, while many academics aim to build and/or test focused theories contributing toward a shared body of knowledge. Given these differences, are there instances in which design firms and institutions may actually be driving toward the same, or even loosely related, goals? Certain commonalities suggest they might. One potential caution for blurring the boundaries between practitioner-researchers and academic-consultants is a weakness among untrained researchers who wish to lay claim to any study, any act of learning pre- or post-design—whether ideation process, case study, or product design, as a form of “research” (Craig and Ozga-Lawn 2015). Instead, for research to be considered legitimate and trustworthy, most will accept that appropriate training, systematic methods, neutral oversight, and dissemination, all remain necessary to assure high standards of research quality.

Yet, even given the intensified search for relevant new knowledge, most will also acknowledge that complex design problems demand coordinated attention from different stakeholders. Those engaged in research might include academicians, researchers, practitioners, economists, government policymakers, community members, and others who offer valuable alternative perspectives and experiences. Rather than decontextualize design problems by focusing solely on theory or methodology, as frequently seen in academic settings, practice-based research more often embraces an open-ended, situated clinical approach. This approach to learning research skills—and evaluating effective solutions—appears to be useful to industry professionals while also increasingly acceptable to the academy.

How then shall the changing needs of design industries, some of whom are increasingly taking (research) matters into their own hands, shape curricular response in design programs? First-professional undergraduate degrees (e.g. BArch, BID, BLA), along with pre- and post-professional masters degrees (MFA, MLA, M.Arch, MGD, etc), have traditionally helped to shape perceived distinctions between degrees focusing on traditional employment in professional practices and those leading to a role in design research. Within this context, the doctorate traditionally has served as the primary path for gathering, channeling, and training future design researchers. Today however, given the extensive list of leading design firms engaging in high levels of both design and research, it is no longer necessary to choose either an academic career in research or a professional career in design. “Both-and” options are not only possible and available, but are increasingly desirable for both future employers and future employees. Several emerging doctoral program-types, each having a distinct nomenclature, now play a role in meeting the evolving design research needs by expanding the research capabilities of design professionals.

This paper therefore offers a survey and assessment of doctoral degree programs in design disciplines, especially in architecture, using narrative analysis to examine institutional and programmatic statements from websites and handbooks. Within that frame, this paper is nested within a larger, ongoing study that explores the following questions: How are different educational models currently described, and how do institutions anticipate changes to doctoral programs in design? Occurring at the nexus between theory and practice, and given the range of common methods for design research, what are the focus areas of these programs? And finally: What is the domain of research claimed by emerging professional research degree programs, and how do their visions for design research align or differ from traditional doctoral programs?
1.0 BACKGROUND.

1.1. “Design research” in the context of practice-based research

The fundamental relationship between design and research (e.g. pre- and post-design research, or research by/of/in and through design) constitutes a vast and ongoing discussion, quite beyond the scope of this paper (Deming and Swaffield 2011; Groat and Wang 2016; Nijhuis and Bobbink 2013). What is significant, however—from the emergence of the topic of design research around the 1960s until the present—is that protecting both research autonomy and disciplinary boundaries has long been at issue. Nigel Cross describes how the emerging field of design research was first seen in techniques borrowed from other disciplines, such as computer science (Cross 2007; Asimow 1962; Alexander 1964; Archer 1965; Jones 1970). After briefly rejecting a methodology of design research during the 1970s, the 1980s witnessed:

…the establishment of design as a coherent discipline of study in its own right, based on the view that design has its own things to know and its own ways of knowing them. (Cross 2007)

Despite the fact that design researchers frequently borrow methodological tools and approaches from other disciplines, the basis for subsequent research has been established on an acceptance of Cross’s notion of design as a “discipline” having a semi-autonomous domain. While a toolbox of research methods may be borrowed or transferred from other disciplines, in design (as in law or medicine, etc), various methods are typically favored and can and may be modified to address the scale and range of different types of research problems, be they theory-based or application-based. Debates regarding disciplinary boundaries, e.g. what questions are ‘core’ or disciplinarily-appropriate and/or appropriate methods of inquiry frequently emerge. These questions appear not only because of the complex structure of different subject matters of inquiry, but also because of the changing role of the researcher-practitioner, who may translate related methodologies into applications for design practice. Design researchers thus increasingly work in ambiguous modalities, including practitioners conducting design research through or about their commissions, or research professors consulting with practitioners.

The desire and, indeed, the strong mandate for academic institutions to identify alternative research methodologies to address complex real-life problems is widely shared among clinical (practice-based) programs, such as education, law, or medicine, where the activities of teaching, research, and practice are certainly clinically related (Nielsen et al 2013; Bulterman-Bos 2008; Spencer and Atkinson 2015). Many clinical programs seek to increase their social and economic relevance by forming research partnerships with industry in order to contribute more effectively. This co-construction of knowledge by blended teams from industry and academia may target issues ranging from potential solutions to specific crises (housing, storm disasters, food systems, public health, etc) to new trends in technology and production (digital fabrication, prefabrication, etc).

Current research into other disciplines includes a range of perspectives concerning the utility and value of advanced study for their profession and practice (Wergin 2011; Javis 1999; Giddings 2010; Cahn and Gray 2018). Understanding the utility and value of advanced study to influence practice thus begs for similar attention be paid to the design fields. However, comprehensive assessments of the utility and outcomes of doctoral degrees in design-related research and practice is not yet available. As a first step therefore, we have undertaken a survey of the nomenclature, purpose, and range of doctoral programs in design in the United States. The intent is to provide a baseline for ongoing discussion of emerging pedagogical needs in design-related doctoral programs.

1.2. Analysis of doctoral programs in design

This study is focused on American universities appearing on the “Times Higher Education World University Rankings” list (THE Ranking 2019). Only the top 100 ranked universities offering “Art, Performing Arts, and Design” doctoral degrees were initially examined. The aim here is to understand the range and types of doctoral design programs based on institutional
frameworks and discursive perspectives. Primary data included text and imagery from official handbooks and websites for these 100 schools.ii

The main framework for classifying professionally-focused doctoral programs is borrowed from National Science Foundation (NSF) designations for professional degrees (e.g. Doctor of Architecture/ Environmental Design/ Engineering/ Fine Arts/ Education, etc.) (NSF Report 2003). Although it is outside the scope of this paper, the NSF taxonomy deserves closer study in and of itself; for instance, additional or alternative degree programs, especially those responding to emerging or critical definitions of “design” itself, may perhaps be added to the list in time. For now, however, this analysis takes place within the larger landscape of existing doctoral degrees across many disciplines in the United States. These can be characterized as follows:

- **Professional qualification doctoral degrees** tend to focus on application of current “best-practices”iii rather than on original research. There are many examples of doctoral degrees that serve as qualification for entry-level professional practice.
- **Academic doctoral degrees** tend to embrace academic research (theory building/testing) and applied research (in-between theory and practice). This pathway is typically chosen by those wishing to enter the professoriate.
- **Professional research doctorates** are advanced clinical research degrees. This option often features a variety of research methodologies and methods (e.g. case studies, diagnostics, prototyping) useful for reframing real time, real-world challenges faced by practitioners.

The main distinctions between these degrees can be positioned on a continuum of application (Figure 1). Exemplary fields and degrees include the following:

**Professional qualification doctoral degrees** typically lead to professional certification for licensure and practice, and are commonly used for disciplines of medicine, dentistry, law, pharmacy, etc. e.g., M.D. (Doctor of Medicine), D.D.S. (Doctor of Dental Surgery), Pharm.D. (Doctor of Pharmacy), D.V.M. (Doctor of Veterinary Medicine), J.D. (Juris Doctor), Psy.D. (Doctor of Psychology), and so on.

**Academic doctoral degrees with research focus** serve those students seeking to enter the professoriate in disciplines of design, education, humanities, science, and art, e.g. PhD in— (Design, Art, Architecture, Education, Geology, Management, History), etc. **Professional doctoral degrees with research focus** typically require a prior professional degree, often a terminal Masters or professional degree, in disciplines of design, education, humanities, science, and art, e.g. DDes (Doctor of Design), DA/DAT (Doctor of Arts/Arts in Teaching), DArch (Doctor of Architecture), DAS (Doctor of Applied Science), DED (Doctor of Environmental Design), DFA (Doctor of Fine Arts), DPS (Doctor of Professional Studies), EdD (Doctor of Education), DGS (Doctor of Geological Science), etc. (NSF Report 2003, 183).

The sample of design doctorates we examined (THE Ranking 2019) contains all three categories: 1) **professional qualification doctoral degrees**; 2) **academic doctoral degrees with a research focus**; and 3) **professional research doctorates** (Figure 1). Professional degrees are distinguished by accreditation and their focus on preparing students for entering specialized practice. These programs prepare students to play active roles in a chosen profession and are often mandatory for licensure. Based on disciplinary demands, the entry-level professional degree may be offered at the Bachelor’s, Masters, or Doctoral level. On the other hand, both **academic doctoral degrees** and **professional doctoral research degrees** share common ground—a focus on research and original knowledge. The distinctions between a **Doctor of Philosophy** (in any subject) and a **Doctor of—** (in any subject) are far from clear-cut, however, and while further exploration into specific research expectations for each discipline is begging, it is beyond the scope of the current work.
Within the 'ecology' of design doctorates, comparisons are most usefully made between academic research degree programs and post-professional research degree programs. These programs are distinguished by different audiences with different sets of interests: those seeking to engage traditional academic research and an emerging population of student-practitioners seeking deeper training in practical or applied design research. Our present purpose, therefore, is to question how design educators can assure that practice-based research ‘measures up’ to academic standards, and how alternative “practicum” research training in professional design degrees can produce useful and valid research in practice.

2.0. A CLOSER LOOK: DEGREE PROGRAMS in DESIGN AND EDUCATION

The field of Education provides a translatable example. The entry-level degree to be certified as a primary or secondary school teacher is the Master’s degree (in architecture or landscape architecture, this equivalent may be at either the Bachelor’s or Master’s level). At the doctoral level, the Doctor of Philosophy (PhD) in Education guides students through a research-intensive program as they prepare for an academic career at the collegiate level. The Doctor of Education (EdD) degree, on the other hand, more likely directs its graduates toward executive positions, nonprofit organizations, and administrative agencies (Nelson and Coorough 1994). EdD programs tend to support engaged practice, accommodating full-time practitioners as students with active roles outside of their academic endeavors. Therefore, EdD degrees might be more likely to have a focus on community engagement or organizational dynamics, while PhD programs maintain their position as research-based or theory-driven (Figure 2).

Research designs used in Education doctoral dissertations also illustrate some of the differences between the two programs: PhD dissertations mainly use correlational and experimental research designs, while EdD dissertations more often used descriptive and qualitative methods (Walker and Haley-Mize 2012). However, the distinctions between the two programs cannot be attributed solely to curricular or methodological differences; rather the distinction between the two programs is based on different research interests and purposes of graduate students. In other words, by welcoming student-practitioners, the EdD program is primarily shaped by their clinical, real-world approach and direct application to practice. Student-practitioners studying in EdD programs seem, therefore, to be reciprocal in shaping program objectives and methodologies. Student-practitioners are permitted to maintain a social or client-based focus without being confined to an academic domain (Aiken and Gerstl-Pepin 2013).

2.1. Parallels: doctoral study in education and design

This paper seeks to understand whether the principle of direct application of research in practice may fundamentally influence the direction of programs that teach design research. Disciplinary differences in research methods are almost immaterial. Given that ‘design
research’ is established as a legitimate and defendable form of research, responsible mainly to the field of practice, pedagogical strategies for doctoral degrees in design fields must also be governed by the field itself (Deming and Swaffield 2011; Groat and Wang 2017; Cross 2007; Cooper 2017, Craig and Ozga-Lawn 2015, Bono and McNamara 2011). Taking this as our lens, the parallels between Doctor of Design and EdD doctoral programs seem particularly salient, especially the shared focus on societal needs through engaged and applied research strategies.

<table>
<thead>
<tr>
<th>Doctor of Philosophy in Education (PhD)</th>
<th>Doctor of Education (EdD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic career-oriented</td>
<td>Executive/administrative positions</td>
</tr>
<tr>
<td>Research intensive</td>
<td>Engagement with education practice</td>
</tr>
<tr>
<td>Research-based or theory driven</td>
<td>Clinical praxis</td>
</tr>
<tr>
<td>Full-time, residential students</td>
<td>Practitioner-students, flexible</td>
</tr>
</tbody>
</table>

Figure 2. Comparison of PhD in Education and Doctor of Education (EdD). Source: (Authors 2019)

While EdD programs may rely on primary-grade educational environments to enact applied approaches to research, the ‘laboratories’ of DDes programs rely on spaces integral to the design industries, such as firm studios, manufacturing plants, and project sites, where physically designed objects, communications, buildings, and public spaces are produced. In other words, where EdD students may deal with organizational, policy-based, and programmatic challenges, DDes students may work in physical environments, urban communities, complicated supply chains, or processual logistics.

<table>
<thead>
<tr>
<th>Doctor of Philosophy in Design (PhD)</th>
<th>Doctor of Design (DDes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic career-oriented</td>
<td>Private sector/ industry</td>
</tr>
<tr>
<td>Research intensive</td>
<td>Engagement of practice (focus on society)</td>
</tr>
<tr>
<td>Research-based or theory driven</td>
<td>Clinical praxis (office as lab)</td>
</tr>
<tr>
<td>Full-time students</td>
<td>Practitioner-students</td>
</tr>
</tbody>
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Figure 3. Comparison of PhD in Design and Doctor of Design (DDes) Source: (Authors 2019)

3.0. FINDINGS: PRELIMINARY THEMES FOR DOCTORAL PROGRAMS IN DESIGN

This section shows preliminary findings of our ongoing comparison of traditional PhD degrees and professional doctoral degrees. One hundred design-related doctoral degree programs were identified and narrowed down through an analysis of specific narrative content from websites and program handbooks. For our present purposes, thirty-four (34) PhD programs in Architecture were found along with seven (7) additional design-related professional programs (incl. DDes, DArch., DS) that also encompass architecture. Their official websites and handbooks were manually reviewed, and keywords, themes, and program models cataloged. Work is currently ongoing; textual content is being coded in the aggregate using commonly available web-based text analysis tools.iv

The first level of analysis assesses descriptive themes (keywords related to programmatic content, mission, subjects, and learning outcomes). For example, keywords and themes from applied or practice-based programs (such as the DDes) include terms such as interdisciplinarity, distance-learning, student-practitioners, independent study, research teams, leadership, innovation, and transformative design practices. The second level of analysis identifies educational models (forms related to programmatic strategies, structures and delivery mechanisms). Key models from the findings include ‘versus’ pairs (PhD vs DDes): in forms such as structured versus independent learning; residential versus distance programs; earned credits from coursework versus thesis or dissertation; and traditional versus hybrid formats.
Content analysis so far actually illustrates many points of similarity between the two program types. For instance, there seem to be several overarching aspirations in common, in notions such as innovation and new knowledge, guided or independent study outside a classroom, instruction in research methods, and the thesis or dissertation as the primary output. Some themes used in applied and practice-based programs (for example “interdisciplinary”) are detected as themes in common with many PhD programs. Although our analysis is as yet incomplete, the details of specific themes are forthcoming as a subject for a separate paper. Below we share a few of the more significant preliminary findings.

3.1. Distinctions and similarities between program types

Residency: While most PhD programs typically necessitate full-time studentship and campus residency (at least during the first 2-3 years), some professional degrees offer a range of degree formats including online, in-residence, or hybrid models. Significant variations appear, however, when distance learning integrates technology and hybrid platforms.

Time to degree: Traditional PhD programs show a range of credits/years in the program leading to degree completion; although, in the end, the degree implies the same credential value regardless of time spent. In respect to duration of program, there is relatively slight difference between the two degree categories.

Content and deliverables: Professional doctorates (such as the DDes) and PhD degrees are frequently described as dissertation-oriented, however the content, format, and purpose of research may differ sharply. Typically, PhD dissertations are positioned to focus on theoretical elaborations (though not always), and often take the form of a discursive tome or published articles. Professional doctoral degrees are positioned to focus on practice-based design research (though not always) and may take alternative forms, such as engaged work, program development, creative works or projects.

Methodological focus and career pathways: In the aggregate, PhD programs in environmental design are described using terms such as: theory, building technology, representation, administration, publishing, etc. Professional degree programs (DDes, DArch, DSc, etc) do not seem to be sharply differentiated from these terms. Many of the PhD programs we studied also claim to combine theoretical and practical skills, and suggest the inclusiveness and responsiveness of professional doctorates to prepare for many career options.

Program mission: One major difference between the two types of programs therefore comes down to program mission and student-centered culture. These emerge as a kind of reciprocal response to the needs and position of the student-researcher. Notably, many professional degree programs (DDes, DArch, DSc, etc) do not clearly differentiate their coursework from their students’ real world practice environments—a point on which we intend to focus further. How he/she needs to frame and deal with real-world problems, or how the research design is integrated into real-world contexts, seems to constitute the main distinction of such programs.

3.2. Learning outcomes

Learning Outcomes: Overall, the purpose of the PhD degree is not primarily to turn out more professionals for the design industry, but to create more critical thinkers to move the industry forward by working toward new knowledge. In this respect, learning outcomes can be positioned along a spectrum between, say, critical and theoretical reflection, educating teachers, and participating in sponsored projects (e.g. technology). Beyond ensuring that research questions being asked are relevant and potentially impactful, PhD programs generally do not expect students to implement real-world applications of their research, nor to enter/return to industry practice. On the other hand, professional doctoral degrees (i.e., DDes, DArch) appear specifically to target professional practitioners eager to gain specialized expertise gained through research.

Interdisciplinarity: One significant difference between the two types of doctoral programs seems to be the expansive range of disciplines included (implicitly or explicitly mentioned) in
professional doctoral programs (such as the DDes), including: graphic design, industrial design, landscape architecture, architecture, engineering, cultural geography, interior design, fine art, (art) media studies, information studies, city planning, law and public policy, fashion/textiles, communication design, product design, interaction design, UX design, environmental design, service design, historic preservation, computer science, geography, (art) photography, environmental and design psychology, business, education, museum studies, design for social innovation, design research, design theory, construction, material culture, environmental policy, digital design, health and well-being, real estate, surveying, and so on. While not a mandate, the increased inclusiveness of professional degree programs suggests a growing trend towards complexity and interdisciplinary research approaches. And although interdisciplinary PhD programs (such as PhD in Design) may also respond to a broad range of disciplines, many if not most traditional PhD programs maintain their focus on the core discipline.

3.3. Discussion: practice-based design and the questions of ethics

Typically, the traditional purpose for both offering and undertaking a doctoral degree program is to produce new knowledge, whether theory or ‘know-how’, and thus to advance a disciplinary body of knowledge. In advanced design education, however, the boundaries between pedagogy and praxis are especially blurred, more or less porous according to discipline. Architects produce research as they tangle with design solutions while industrial designers may critically assess user-centered experiences through developing personas and behavior mapping. Rather than adhering to the historically strict dichotomy between theory and practice, with individuals settling on becoming either a practitioner or a researcher, there is an emerging hybrid third choice. The complex real-life problems now attracting many doctoral students necessitate the engagement of multiple subjects and approaches, resulting in emerging, alternative, and hybrid domains of study in both the academy and the professions.

New Markets: Preliminary content analysis of sampled doctoral programs highlights several emerging issues in design pedagogy at the doctoral level, including the transition of dissertation subject matter from theory-oriented to practice- or project-based research, in both types of degrees. Given increasing agency to frame their own research questions, it may be the changing student-practitioner who is defining a new educational market and thus reshaping doctoral education in design.

Intellectual Property: In professional doctoral programs such as the DDes, teasing apart the boundaries of professional expertise embedded in “best-practices”, from practice-based research, while simultaneously opening up potential alternative research applications, also raises critical ethical questions. For example, using the office environment as a “lab” for student-led research creates its own dilemma of intellectual property: who owns the new knowledge created? Is it the student/faculty team posing the question or the firm/owner/client who actually secured the commission and/or signed the contract for services that the research is addressing? Some advanced professional degree programs propose alternative forms of co-authorship between academia and industry. However, where money is concerned, co-authorship can complicate ethics as well as professional relationships. How this is addressed is a matter of clear communication between the doctoral program, the student-practitioner, and their professional reporting structure.

Research Integrity: Another question for student-practitioners relates to the tensions between time and responsibility. What are the rights and interests of the academic institution overseeing the research enterprise? How are human and environmental subjects protected? How can the method/process of research be controlled in a service-and-deadline-driven professional office environment—especially if it is also to serve as a space of discovery for the student-practitioner? During the design/production process of complex product lines or physical environments, inevitably multiple agencies from different disciplines will need to be involved. In gathering project data from an active project office, how can ethical research practices (such as confidentiality and protection of human subjects) be sustained?
Other dilemmas and challenges abound. Naturally, ethical considerations must comprise a significant component of pedagogical design for design-related professional doctoral degrees. The question of ethics is intrinsic to the construction of knowledge, as well as its implementations to real-world problems. And although a detailed exegesis of ethical considerations are beyond the scope of this study, in order to highlight emerging needs for new doctoral curricula, we are finding research ethics, leadership, and co-construction of knowledge are crucially important themes.

CONCLUSION
The paper has explored doctoral study in the design fields, specifically looking at the autonomy and potential alignments of DDses and PhD programs to question common understanding of how “design research” is taught and used. Even in this preliminary stage, analysis of doctoral program goals, learning outcomes, and structure may serve to illustrate how traditional PhD degrees in design schools and professional degrees (such as DDses, DArch, DSc) can be transformative for practitioners as well as the professoriate. Programmatic comparisons help open discussions of alternative forms of “practicum” training in relation to rigorous research training. This is not only important for advanced design students but also, potentially, in teaching research methods in entry-level professional design programs at the Masters level.

For design practices that are rapidly specializing to address complex real-world problems, there is a desire for research to be more quickly digested, assimilated, and incorporated into practice. Rigorous research training would give increasing agency and efficacy to design practitioners to direct—or even produce—the research studies they need most. This highlights an emerging need for alternative ways of thinking about strategy/structure, pedagogy, outcome, and mechanisms of design research. And because not every concept-making practice constitutes “research,” agreeing on workable definitions becomes a significant point of advance.

Professional doctoral degrees deliberately integrate research with professional practices, offering contextual approaches for student practitioners to engage with industry, government and other sectors. On the one hand, this attitude increases accessibility for both sides, creating welcome potential to bridge academia with design industries. On the other, practice-based approaches come with delicate ethical considerations and may create confusion between “best-practices” and research-driven practices. It remains to be seen how the design disciplines will solve these challenges.

REFERENCES


ENDNOTES

1 Determining the objectivity and accuracy of ranking systems, or positioning American universities within the full community of global institutions also offering design education is outside of the scope of this research.

11 It is accepted that official handbooks and the websites of the schools represent an element of marketing or institutional branding; the content they contain therefore only describes the intention, aspiration, or perception of a degree program rather than offering any comparative metrics.

111 It is accepted that the demarcation of “best-practice” could also be utilized as a marketing strategy, and that definitions of “best-practice” need further critical investigation. For instance, the dominance of single approaches to practice and production, without inclusion of “alternative” methods or markets, should be questioned.

1111 Preliminary content is currently being collected from publicly available websites, sorted and reaggregated using excel spreadsheet. We are experimenting with text analysis apps such as Textalyser http://textalyser.net/ and manual coding techniques using Excel. Once we have sorted and identified preliminary themes, we plan to use NVivo software for definitive coding process.

11111 Some PhD programs incorporate online courses and may provide flexibility for students to work part time and/or work on research off-site
ABSTRACT: With the promise that new technologies, and in particular smartphones and virtual reality, may make everyday life easier, numerous apps have been created over the last years for the architectural lighting and acoustic assessments of buildings. This trend opens new opportunities for teaching acoustics and lighting. Meanwhile, the possibilities of augmented and virtual reality are still largely unexplored. The pedagogical aim of exploring new pedagogical approach is to allow students to engage beyond the traditional building physics approach to these subjects and to get a better quantitative and experiential understanding of light and sound parameters. First, the possibility of massive use of auralization is described. Then, the present paper discusses some opportunities for introducing building acoustics and lighting assessments through apps in both courses and architectural studios. The goal is to support experiential learning opportunities for concepts such as the warmth or the enveloping of a space from both an acoustic and lighting perspective. Many questions raised from the first few years of experiences in using smartphone apps are discussed. Comparing different apps on the same or on different smartphones resulted in significant fluctuations in the observed quantities. Since illuminance or sound levels were better detected with professional tools than by smartphones, several challenges of using these apps are discussed. Knowing the limits of current smartphone apps, this paper reflects on how much apps could be integrated into both university teaching and practice approaches. The experience confirmed that smartphone apps cannot yet replace professional measurement tools, while there is evidence about the benefits that modern technologies and in particular virtual reality, can provide to architectural acoustic and lighting teaching and practice.

KEYWORDS: acoustics, lighting, smartphone, augmented reality, virtual reality, app.

INTRODUCTION:
This paper aims to reflect, based on the experience of the author, on the way in which acoustics and lighting are taught to architectural students and to which benefits modern technologies could provide to the pedagogy of these disciplines. A few years ago, the author faced the challenge to innovate the III-year undergraduate course "Light/Sound in Architecture" at Ryerson University in Toronto, Ontario. The goals of this course, similar to many courses offered in the third or fourth year of architectural programs in North America, are "to develop a basic understanding of lighting and sound and to become familiar with the primary modes of characterizing and quantifying light and sound in engineering terms. Basic design concepts and techniques used to manipulate and control sound and light in buildings will be explored."

Such a comprehensive learning outcome is not easy to achieve, especially considering that usually the introductory teaching of these subjects to students of architectural departments starts without the knowledge of basic physical background.

Acoustics is a broad discipline, strongly based on physics. Its applications nowadays cover several areas: from biomedical to aerospace, architectural acoustics or vibration control. Similarly, also lighting is a broad discipline, which in the building sector is often considered within the domain of electrical engineers whenever it refers to artificial lighting, but an integrated design requires its integration with both layout and façade design.

In order to understand some of the characteristics and constraints of the course of "Light/Sound in Architecture", it is useful to point that this course consists of 12 lectures offered once a week for 3 hours each. Typically, this lecture course was taught in large classrooms with over 100 students attending it. The course used to dedicate six classes to acoustics and
six to lighting, a surely short time to deliver its content properly and deeply. In fact, through the course, students were asked to master the design criteria and analysis procedures for the acoustic and lighting design from simple rooms up to performance spaces or museums.

Traditional, the course content of this course was divided into two modules. For the acoustics module included a general introduction to the fundamentals of sound, sound sources, and sound propagation; subjective and objective scales of measurement and laws of psychoacoustics; relationships between sound and listener in different scenarios: source and listener outdoor or in a room; noise control in buildings; building treatments for airborne and impact sound insulation. A similar approach was taken for the lighting module, with classes that covered first the basic principles of lighting and then looked into the design of lighting systems and the assessments of lighting quantity and quality in different building typologies.

The course has been traditionally based on describing acoustics and lighting using photos and graphs, while a visit to a notable performance space or a museum allowed students to discuss the spatial sense of a room, but often it failed at providing the experience of comparing different attributes of a room. Moreover, one of the elements that emerged in teaching this course is the somehow limited attendance of students who believe that the no-studio courses would deserve less attention than design courses. In the case of subjects such as acoustics, which is perceived as an engineering discipline with strong bases into physics, often students also consider such a course far from their future architectural profession. As such, and based on the many years of teaching experience of the author both in the U.S. and in Canada, it is evident that new pedagogical approaches are clearly needed.

1.0 TEACHING ACOUSTICS AND LIGHTING IN CANADA AND AT RYERSON

The process of updating the teaching approach of acoustics and lighting for architectural students started with the analysis of other similar courses offered across Canada. Currently, there are 11 university schools of architecture which have been granted CACB Accreditation in Architecture (CACB, 2017). Based on the information available on the websites of these programs, the analysis showed that while the Bachelor in Architectural Science program at Ryerson University as well as the programs in some other institutions include into a single course the contents of lighting and acoustics, many programs ignore the subject of acoustics in a specific manner (Table 1). The common reason behind this decision could be also related to the lack of a faculty member with expertise in acoustics or the other competitive requests to get the accreditation, which do not leave space for a dedicated course about acoustics. The comparative analysis of the available content related to lighting in the several architectural Canadian programs (Table 2) shows a better situation with on average at least one dedicated course, and sometimes more than one.

Table 1. Courses in Canadian architectural schools covering (event partially) acoustic topics.

<table>
<thead>
<tr>
<th>School</th>
<th>Program Name</th>
<th>Acoustics course code and name</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of British Columbia</td>
<td>Masters of Architecture</td>
<td>ARCH 531 - Architectural Technology II</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>Bachelor of Architectural Studies</td>
<td>ARCH 272 - Interior Environments: Acoustics and Lighting</td>
</tr>
<tr>
<td>Université de Montreal</td>
<td>Bachelor of Science in Architecture</td>
<td>ARC 5317 - Lighting Engineering and Applied Acoustics</td>
</tr>
<tr>
<td>Carleton University</td>
<td>Bachelor of Architecture</td>
<td>ARCN 3003 - Theatre Production</td>
</tr>
<tr>
<td>Dalhousie University</td>
<td>Master of Architecture</td>
<td>ARCH 5208 – Acoustics</td>
</tr>
<tr>
<td>McGill University</td>
<td>Master of Architecture</td>
<td>ARCH 555 - Environmental Acoustics</td>
</tr>
</tbody>
</table>

Looking more closely into the way in which both the subjects are thought, it seems that these subjects are often treated using a traditional “engineering/architectural design” approach which is challenging when large undergraduate classes with over 100 students need to be offered. Based on some successful experiences from Europe and Australia, it was hence decided to introduce several novelties. For example, modern technologies allowed to create auralizations
of different rooms that students could listen at home. Moreover, students were asked to visit and describe both architecturally and acoustically a performance space and to collect an impulse response (a kind of an acoustic fingerprint of a room) which was used to build a large database of performing spaces. This way students were challenged to learn how to survey a room and to experience the interlinked connections between acoustics and architecture. Similar experiences for lighting portion were performed, as reported in the following sections.

Table 2. Courses in Canadian architectural schools covering (event partially) lighting topics.

<table>
<thead>
<tr>
<th>School</th>
<th>Program Name</th>
<th>Lighting course code and name</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of British Columbia</td>
<td>Masters of Architecture</td>
<td>ARCH 513 – Environmental Systems and Controls I</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>Bachelor of Architectural Studies</td>
<td>ARCH 272 – Interior Environments: Acoustics and Lighting</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>Masters of Architecture</td>
<td>ARCH 226 – Environmental Building Design</td>
</tr>
<tr>
<td>Université de Montréal</td>
<td>Bachelor of Science in Architecture</td>
<td>ARCH 673 – The Science of the Building Envelope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ARCH 678 – Digital Lighting Design for Architecture</td>
</tr>
<tr>
<td>Carleton University</td>
<td>Masters of Architecture</td>
<td>ARCC 5096 – Building Technology I</td>
</tr>
<tr>
<td>University of Calgary</td>
<td>Masters of Architecture</td>
<td>EVDA 617 – Architectural Lighting Design</td>
</tr>
<tr>
<td>University of Laval</td>
<td>Bachelor of Architecture</td>
<td>ARC 2102 - Light and physical environments</td>
</tr>
<tr>
<td>McGill University</td>
<td>Bachelor of Architecture</td>
<td>ARCH 447 – Lighting</td>
</tr>
</tbody>
</table>

2.0 VIRTUAL ACOUSTIC TRIP

The idea behind this new pedagogical model epitomized the ambition of Ryerson University towards applied learning while constantly innovating its offerings in blended learning environments through creating immersive virtual acoustic experiences. In fact, while a great deal of emphasis is placed upon the visualization of space during the design, yet the acoustics of a space is often poorly considered by architects. Based on the architectural data provided by the students or by some partnering acousticians and architects (Fig. 1), the author created a repository of data about performing spaces, including impulse responses and auralization.

Figure 1. Example of the concert halls description in the e-book.
The project consisted of creating a repository of concert halls and performing spaces in the GTA and in the rest of Canada (Fig.2), similarly to what has been reported worldwide in textbooks such as Beranek (2003). The impulse response of a room is the acoustic fingerprint of that room, whereas an auralization is the reproduction of a given sound at a point in a room. Contrarily to conventional traditional acoustic pedagogy, this depositary of data enabled students to explore room acoustics beyond class hours and to create a new way to experience a room. Thanks to this effort, and the two new audio e-books (Fig. 2), Ryerson architectural students can now discover the acoustics of main Canadian performing spaces. This intent aimed to enable students to explore room acoustics beyond class hours and to create a new way to experience a room by allowing to listen to auralizations done in different halls. Once the impulse response collection and the auralizations will be completed, it will be possible to conduct a virtual trip in many Canadian performance halls to listen to many different sounds projected in these spaces. Together, the impulse response and the auralization allow users to experience the unique conditions of a room via a "virtual concert". The intended e-books offer the possibility to listen to different sounds in the same space, allowing to understand the importance of performing a piece of a given music in a space with a particular acoustics, being much more experiential than the technical validation of sound formulas. Thanks to the impulse response recorded so far, students are now able to play impulse responses in order to reproduce the acoustics of famous rooms using their headphones. Qualitative comparative analyses guarantee intuitive but perceived responses to the acoustics of spaces using a binaural reproduction, through high-quality headphones (Fig.3). This experiential learning is considered critical for students’ understanding of current professional design practices and possibilities. The available catalog of acoustic data of concert halls, is now justifying the creation of a proper setup for sound reproduction and listening at Ryerson University. Moving forward, the implementation of an ambisonic simulation environment will be created, eventually in coupling with a Virtual Reality headset, to create new possibilities and a higher level capability for students to listen to the acoustics of a room, similarly to what is available in spaces such as the LIVE (Large Interactive Virtual Environment) Lab at McMaster University.
3.0 THE USE OF APPS FOR COURSE ASSIGNMENTS

Another important novelty was the introduction of the use of smartphones into teaching delivering. Smartphones have evolved into powerful computing machines with exceptional capabilities thanks to built-in sensors such as microphones, cameras, GPS receiver, accelerometers, gyroscopes, proximity, and light sensors. Smartphone developers offer many sound and light measurement applications (apps) using the devices’ built-in microphone and cameras. This allowed to base two assignments on measurements done in real life environments with dedicated apps, similarly to experiences done in some architectural engineering programs in the U.S. (Berardi et al., 2014). Typically, acoustic and lighting assessments require the availability and use of specialized and expensive instrumentation technology and data collection expertise, and hundreds of man-hours to assemble and analyze such data. The ubiquity of smartphones and the adoption of smartphone sound measurement apps can have a tremendous and far-reaching impact in this area (Satoh et al., 2016, Sakagami, et al., 2016). The idea was to allow students to experience in real life environments and to do measurements of light and sound parameters, without using expensive devices. Several apps have been created recently both for iOS smartphone and for Android ones for sound level measurements. A total of over 100 iOS apps were examined and downloaded from the iTunes store, as well as more than 60 Android apps. Only around ten apps met some stringent selection criteria for consistency. Recent studies have compared and examined available sound recording apps for smartphones, and have found that only a few apps give good results (Kardous and Shaw, 2014). Unfortunately, these are also the apps that tend to have a cost, and so a proper assessment needs to be done to limit the risks of leaving the selection of the app to use to the students. Results showed that the most iOS devices have somewhat reasonable precision, e.g., for SPL measurement it is similar to Class 2 sound level meter, while several Android devices give lower precision.

Students were asked to use their smartphones for assignments such as: “in pairs, after having downloaded on your smartphones at least two apps each, conduct measurements of different urban sound environments (with different average sound pressure levels), and discuss the sound level results of the different apps.” Or “In groups of maximum three people, after having downloaded on your smartphones two apps each of you, you will conduct measurements of different sound transmission loss measurements of two couples of rooms”. Students could hence figure out common sound pressure levels but also inconsistencies of their devices as they became aware of the limits of these apps and of the importance of detailed reporting and professional writing (Fig. 4).
The assignment also focused on aspects such as ratios between low and high frequencies in an effort to allow building in the students, more awareness of qualitative parameters such as acoustic warmth and bass ratios. Finally, students had to discuss the time dynamics and fluctuations of real sounds and how they can impact people both within and outside buildings. SoundOut by Australian Hearing resulted in the app providing the majority of functions and a good accuracy.
Similarly, using dedicated apps on their smartphones, students were asked to perform lighting measurements in different spaces. The idea was to explore students to a direct capability to assess the illuminance and contrast levels in different scenarios. Beyond quantitative assessments of lighting levels, students investigated contrasts, shade efficacy, and glare conditions. Then, they had to build models of the room also importing HDR photos and to calibrate rendering in free to use software (Dialux).

![Figure 5: Samples of the submitted lighting assignment with app measurements.](image)

### 4.0 EDUCATIONAL OPPORTUNITIES AND CHALLENGES

Many questions raised from the first experiences about introducing new educational approaches in acoustic teaching. Auralization have already proved to represent an important way to allow students to perceive directly the acoustics of a room by projecting different anechoic (e.g. neutral) sounds in it. The availability of an ambisonic setup will allow to overcome the limits of headphone reproduction (head movements, low-frequency cut, etc.).

About the possibility for smartphone apps to replace professional measuring devices and about how much these apps should be included in our teaching. Even though these are only simple tools, they allow students to understand the relationship between their sensation and physical values. For Android devices, the measurement values showed large errors and individual differences, as well as, non-linearity in many devices. On the other hand, iOS devices showed fairly good agreement with Class 2 sound level meters. The results proved that sound pressure level measurements were sometimes poorly detected with smartphones. Comparing different apps on the same or on different smartphones resulted in significant fluctuations in the measured values. This means that smartphone apps are not very reliable, although they represent a resource for enhancing students’ participation and engagement beyond class hours. The limits of the app force to rethink their values in order to build a more scientifically...
valid exercise. Another key factor would be to have a controlled environment to ensure better results in measurements and eliminating unwanted background noise and lighting sources. The fact that some apps work with so-called calibration functions induces the user to a sense of confidence in their quality, but unfortunately, it is often not possible to set the value accurately. The values outside the calibrated value are subject to extreme fluctuations. In conclusion, even for daily uses, the apps are still not a good way to get a general measurement about the sound and lighting levels of a room.

ACKNOWLEDGEMENTS
The author would like to thank his students, who inspire and drive teaching improvements. He also acknowledges the financial support of Ryerson through two projects: Virtual Acoustic Trip: learning and teaching architectural acoustics by listening to a room (LTEF in 2015 and the FEAS Dean Teaching Fund in 2016-2017).

REFERENCES
CACB for Professional Degree Programs in Architecture, Conditions and Terms for Accreditation, 2017. www.cacb-ccca.ca.
ABSTRACT: Performing research under the umbrella of design engages various methodological approaches. Scholars such as Christopher Frayling (1993) position dominant modes of art and design research as research- into, research- through, and research- for, while more contemporarily Laurene Vaughan (2017) argues for the value and importance of practice-based design research as an embodied “research-all” approach. Through practice-based research, the traditionally distinct role of designer-maker and research-writer often merge for “making,” both in engaging theoretical frameworks and in focusing research activities. However, in disciplines such as architecture and industrial design that have traditionally favored investigating the measurable performance of “products” as primarily positivistic, the individual’s motivation to initiate directed research activities may be challenged by merging different modes of knowledge acquisition and production. This leads us to question in what ways understanding individual motivation and self-concept can inform the research process under the umbrella of design research. By more closely examining Jacquelynne Eccles (1987) educational model of Expectancy Value Theory, this paper focuses on the rarely acknowledged issue of an individual’s motivational beliefs and self-concept in the practice of design research. This exploration begins to conceptually connect these influential factors, especially a designer/researcher’s expectancies and values toward certain tasks, to their learning behavior and performance. Specifically, by looking at traditions in institutional pedagogy and their emphasis on visual and textual knowledge and content provides evidence of a separation between “thinking of things” and “writing design.” Using Donald Shôn’s (1984) concept of “reflective practice” in design, research practices and activities can be viewed as successions of representation and conscious learning that are accessible, manipulatable, and flexible. Through practice-based design research — or research-all — this paper posits that an individual’s motivation, expectancies, values, and experiences are reflected in their “knowledge performances” and research design.

KEYWORDS: research, design, motivation, practice, values

INTRODUCTION
In practice-based design research, not only are we concerned with understanding a variety of ‘making processes’ and design outcomes, but also with the nature of our learning. How do designers learn? We learn from a variety of experiences, including (but not limited to): informed failures as well as successes (praxis); learning from story-telling (case study); systematic investigation and analysis, and post-design evaluation, among other things. We disseminate what we learn through a variety of peer-reviewed and professionally sanctioned venues for publication. In fact, over the course of a career, designers must continue to learn on many levels: technically, organizationally, theoretically, and even personally.

The practice of design requires a “both-and” (Hannula et al. 2014) identity, or approach, in which the-one-who-practices is simultaneously ‘reader’ and ‘writer’, perhaps even learner and teacher, communicating through listening and talking, doing and relating, in many forms of discourse with fellow practitioners. The “both-and” perspective consequently places the one who performs in and through acts of doing, as the one who constitutes their own practice, producing self-evident roles of authority. These roles may tend to negate an outsider’s
opinions, while developing or consolidating the practice’s historical and contemporary criteria and values by performing articulations of those values (Hannula et al. 2014).

As a theory that helps explain how students learn to design, motivation affords deeper understanding of the intrinsic risks and rewards of design education and practice. Better understanding of various motivational systems of the design professions should enable and stimulate designers to improve their capacity to engage self-study. Critical reflection and research activities about how designers learn, should, in turn, deliver fully on the promise of the full self-actualization cycle of learning-by-doing and thus extend our reach and impact on society. This presentation therefore explores and explains some of the benefits of cognitive theories of learning for teaching design, as well as practice, and to suggest directions for further investigation.

1.0. PEDAGOGICAL MODELS and the PRACTICE of DESIGN

In the United States, across many fields, formal or institutional design education typically includes studio- and experience-based approaches to learning. In many design schools, the design studio class is conceived as a simulation of professional environments and relationships. In this educational model, students are prepared for future practice in professional and technical roles by design educators whose backgrounds (traditionally also in design practice) allow them to pass on specialized knowledge, skill, and values from the field. Specialized educators may also operationalize instrumental or extrinsic aims (Oxman 1999); these might include, for example, the advancement of specific theories and values (e.g. critical regionalism or user-centered design) or socio-professional values (e.g. advocacy for licensure or pluralistic design for product design or community engagement).

Design studio classes traditionally employ and/or aspire to distinct learning frameworks, including: strong mentor-student relationships; early initiation and framing of problems; formulated design processes; reliance on graphic (rather than only verbal/textual) representation; demonstration as communication; explicit or conceptual design proposals (proof of concept). While, in the main, learners execute their work independently, they can expect regular guidance and perhaps occasional intervention leading to periodic and/or final evaluation by a ‘jury’ or panel of critics. Here, too, the expected quality of a student’s design and work products, as well as the extrinsic aims of instructors and critics, may shape class rubrics and other methods of evaluation.

However, in traditional models of design education based exclusively on the replication of professional performance, some point out that the “cognitive properties of design learning have never been the subject of design education” (Oxman 1999, 105). This oversight is evident in a lack of design-specific educational theories developed for educators in professional design programs. Therefore, in an effort to focus attention on that gap in the literature, we explore a conceptual model for design education based on cognitive theories of design thinking and learning.

One argument holds that, in order to construct a general theoretical foundation for design education, learning tasks in design must be redefined from artifact-oriented to a cognitive approach (Oxman 1999). Fortunately, in identifying design-specific learning increments, (a series of learning exercises or benchmarks with an objective basis for assessment) measurable increments of cognitive strategies can be aligned with design learning’s visual and conceptual content (Oxman 1999). This same approach potentially may be developed as an evaluation tool for use in the traditional design studio format. To that end, we examine the concept of motivation in design learning constructs. As a theory that explains how students learn to design, it affords greater understanding for the intrinsic risks and rewards of design education: e.g. student time spent on task, risk of failure and criticism, and self-actualization. By extension, motivational theory may also begin to frame related questions as to why design practitioners may engage (or not) in practice-based design research, as a collectivized form of continuous learning.
1.1 Motivation and creative cognition
Motivation affects the initiation and continuation of directed activities for the attainment of a goal (Cook & Artino 2016; Eccles 1987). Motivational theories relate to beliefs of competence (asking “Can I do it?”), as well as the value or anticipated result of a learning task (asking “Do I want to do it?” or “What will happen if I do?”). Motivation is considered ‘cognitive,’ in that it involves mental processes and individual phenomena that cannot be directly observed or entirely explained without understanding the performances or interactions of an individual within a larger social context. Human cognition is thus influential in the perception and exertion of motivational control (Cook & Artino 2016).

While pervasive in all aspects of our lives, motivation also begins and sustains learning processes. Motivation to learn “is important as …a dependent variable”; that is to say, higher and lower levels of motivation may result from the nature of educational activities (Cook, Thompson & Thomas 2011, 45). In learning processes, motivation can also serve as an important independent variable (Kusurkar, Ten Cate, Aspern & Croiset 2011 33), as it may shape or manipulate individual desire and thus “enhance learning” (Cook & Artino 2016, 998). Practical applications that operationalize motivation theory should thus be able to affect learning outcomes and performance quality across many subjects and fields, in particular design education and design practice.

Cognitive approaches emphasize the process of knowledge construction and the importance of structures in learning. Specifically, the theory of “creative cognition” relates certain principles and knowledge structures to the creative process; it proposes that learning may occur through the structured manipulation of knowledge related to creativity. It is, therefore, assumed that cognitive characteristics assigned to design thinking, practice, and education, should establish techniques for supporting a representation of the student’s thinking and creative processes—including both visual and conceptual knowledge (Oxman 1999).

2.0 SCHÖN AND REFLECTIVE PRACTICE
In his influential work, The Reflective Practitioner: How Professionals Think in Action (1984), Donald Schön outlines the closely related concept of “reflection in action.” Shön posits that, during the design process, visual and conceptual interactions relate to cognitive characteristics associated with dialectic (synthetic) reasoning. In other words, in order for new knowledge to emerge through each successive representation, conscious learning must take place while individuals’ access, manipulate, and make existing knowledge more flexible (Shön 1984).

Therefore, “reflection-in-action,” along with the fluid functions, structures, and patterns of design practice, relies on a process of constant learning and self-awareness.

Reflection-in-action comprises a series of component learning processes: knowing-in-action and reflecting-in-practice, all of which describe various means of building professional knowledge through practical experience, competence, and artistry.

In the first step, knowing-in-action, Shön emphasizes type of tacit or ‘common sense’ knowledge or practical ‘know-how’ present in professional activities, evident through skillful action, recognition and judgment. In most skillful professional practices, knowing-in-action may be understood as ‘rules of thumb’ or implicit intellectual operations and behaviors, rather than a systematic set of rigidly predetermined approaches.1 Shön’s perspective on the performance of innate practical intelligence is supported by philosopher Gilbert Ryles, who writes: “…what distinguishes sensible from silly operations is not their parentage but their procedure, and this holds no less for intellectual than for practical performances…” (Ryles 1949, 32).

Another part of the reflective process, reflecting-in-practice regards the practice itself as a consideration for appropriate action. Practice is an ambiguous concept encompassing the performance and repetition of profession-dependent cases, accounts, commissions, or projects that help professionals develop specialized expectations or techniques. As an alternative approach, Shön’s reflecting-in-practice requires a corrective measure of criticism conducted in real time during the working process. It assists in recognizing potential divergent
judgments, patterns of behavior, or other affirmations unique to the course of action being taken.

The challenge of reflection-in-action, as a simultaneous “conversation” among practical actions, tacit knowledge, and self-critique, serves to “reframe” both professional knowledge and approaches to solving problems. What is critical is the need for the professional to be intellectually present in his or her practice as a means toward awareness as well as engagement within professional actions. As such, designers and architects will continue to be presented with complex situations related to human needs requiring responsive design processes. Reflection-in-action reflects the dialogic practices of professionals engaging equally and simultaneously with design processes, projects, and various schools of thought. In architecture, for example, a problem might relate materiality in a stylistic vernacular to the implementation of a community design process. An industrial designer might be concerned with sustainability and life cycle economies relevant to on-demand logistics.

In such ways designers strategize, plan a course of action, and develop a ‘knowing’ relationship to the present phenomena through tacit and reflective practices. The concept of “reflection” can be conceptualized as a rational analytical process that is an “activity in which people recapture their experience, think about it, mull it over and evaluate it” (Boud, Keogh, & Walker 1985, p 33) in order to fast track cognitive problem solving in practice. Jordi (2011) proposes that reflective practice encourages processes of integration and dialog between often seemingly disconnected aspects of human experience and consciousness. Further, as a process, reflection is considered influential in the development of an individuals’ selfhood, including the individual’s self-worth, self-image, identity, and more (Le Cornu 2009). According to Jarvis (2004), that is a lifelong process of understanding the world through meaning making that transforms the “whole person” affecting behavior and thoughts of the individual (Jarvis 2005).

It is through the critical reflective practice that the practice of critique distances and separates the individual from an object of attention. The result is the illumination of significant differences and similarities that further construct the individuals’ view of self and the object of attention. What is learned is responsibility for views the individual holds and the construction of a “separate sense of self” through processes of internal and externalization (Le Cornu 2009).

Therefore, as a continuous cognitive awareness, consciousness is the human sense of self and experience of the world that encompasses feelings, tacit knowledge, embodied experiences, and memories that mix internal feelings and meanings with outside stimuli (Gendlin 1993). With Shön’s reflective practice acknowledged as a foundation of experienced-based learning and critical reflection (Mezirow 1991), the question to be asked is, what motivation is there for designers to do this more constantly, more profitably, more collectively, and thus more effectively? This is where the theories of motivation become useful.

3.0. MOTIVATION & PROFESSIONAL EDUCATION and PRACTICE
The concept of reflection-in-action is useful for reframing the ‘conversational’ modality, both of design education and practice. As a powerful pedagogical structure, it also serves to examine the applications and consequences of practice-based design research set within the context of professional projects. In the next section we draw connections between active reflection in the professional practice of design and theories of motivation for learners, as well as practitioners.

3.1. Expectancy-value theory (EVT)
focuses on expectations of success and the perception of a task’s value to the individual participant (Eccles 1987). EVT’s theoretical roots stem from a social cognitive perspective that focuses on aspects of personality, social, and developmental psychology (Schunk, Meece, & Pintrich 2014). The key constructs of task value and expectancy of success are influenced by motivational beliefs, which are in turn determined by social influences that are perceived and
interpreted by learner cognitive processes (Cook & Artino 2016). EVT identifies two key independent factors that influence the individual’s behavior: 1) the degree of belief in the likely success of trying, and 2) the personal intrinsic interest or perceived degree of importance of the task’s value (Cook & Artino 2016).

**Figure 1.** Expectancy-value theory. This is a simplified version of Wigfield and Eccles’s theory (Cook & Artino 2016 1003).

An individual’s expectation of success in the accomplishment of future-oriented tasks represent convictions that are both general and specific. These expectancies and values are assumed to be task-specific (Eccles 1983), with tasks is valued as an individual's interest (intrinsic value), utility (extrinsic), attainment value (personal importance), and cost (the negative consequences (Cook & Artino 2016).

Ability Belief, the belief in one’s own ability is defined by an individual’s perception of current competence for an activity (Wigfield & Eccles 2000). Further, expectancies of success are shaped by three motivational beliefs: that goals are short- and long-term learning objectives; the self-concept is the self-impression of an individual's capacity within a task domain; and task difficulty, the perception of the difficulty of a task. In empirical studies, where an individual has a belief of success predictions can be made for learning engagement and achievement, it can also be postulated that expectancy of success may be a stronger predictor than past successful performances (Cook & Artino 2016). EVT theorists posit that motivation requires more than expectations of success to succeed at certain tasks; it requires a personal gain or value, whether immediate or in the foreseeable future. Expectancy-value theorist post that motivation connects expectations of success with a task’s four values, which contribute to and affect the learner's motivation (See Figure 1). First, the task value must be interesting or enjoyable (intrinsic value), and second, learning a topic or skill must be perceived as useful and propelling the learner toward a goal (utility or extrinsic value). Third, the self-concept or personal importance of the learner must be affirmed (attainment value or importance), and the focusing of time and energy on one task over another means other tasks will be neglected (opportunity costs). Affective memories and emotions inform these tasks based on the learner’s association with prior experiences, social influences, and the environment, which has either favored or diminished the perceived value of a task. Ultimately, motivational beliefs
include goal-setting, self-concept and task difficulty, which in turn determine the expectancy of success; these beliefs are shaped by affective memories and emotions associated with prior experience, the environment, social influence and life events. The individual's motivational beliefs are the personal perspective and cognitive processes that interpret and form perceptions, not necessarily reality. These motivational attributions shape the beliefs and future actions of learners through conscious or unconscious links to events, outcomes, and personal factors, which led to those outcomes (Cook & Artino 2016).

3.2. Practice-based research and the design disciplines
According to Linda Candy (2006) practice-based research is “an original investigation undertaken in order to gain new knowledge partly by means of practice and the outcomes of that practice” (1). In practice-based cases, the embedded nature of research principles, critical engagement, and debates of theory and practice are focused on the issues of originality and knowledge production (Scrivener 2004). That said, new knowledge, claims of originality, and contributions to the many forms of art and design in practice-based research, need strong contextual support. Even when presented in the form of written word, a full understanding of the significance of this type of research must make some “direct reference” to creative outcomes (Candy 2006).

Practice-based research is thus relevant to various fields of hands-on cultural production, including design, social sciences and universities of art, where teaching, community facilitation, and reflexive and open-ended research might take place. Practice-based research takes a context-aware ‘insider’ approach to open-ended practical questions using discipline-specific internal logic. Research activities may focus on practice-specific actions and decisions, while consciously connecting to and through the past, present, and future histories of production. In this way, practice-based research can be very useful for exploring, expanding, and/or reshaping the limits of practice. This type of articulation requires both a performative element and participatory nature, positioning who articulates and how by alternations and changes the practice, ultimately guiding views, approaches, and the possibilities of the research practiced” (Hannula, Suoranta & Vadén 2014).

In other words, within the “contested territory” of practice-based research we may find not the centrality of artifacts, but the accompanying methodological framework and methods created and tested as part of the evolving or emerging discipline.

As explained above, disciplinary frameworks are constructed through professional practice, reflection, research, and discourse, including processes of articulation and discussion that form, normalize, maintain, and renew expectations. Professional practices have routine performances and traditions that constitute, situate, anchor, and are imbedded in its internal structure. These routine practices or traditions illustrate the responsibilities and freedoms to be enacted through professional interpretations and decisions.

It seems increasingly evident that professional ‘traditions’ are being challenged by other contemporary practice cultures (Susskind and Susskind 2017) and thus questioned, perhaps even doubted, within historical/cultural and practical contexts simultaneously. This new challenge to the professions demands practice-based design research activities that are “context-serious and committed” (MacIntyre 2006), conducted (at least in part) by practitioner-researchers with a commitment to professional perspectives and debate. Questioning and investigating the frameworks of process-based and practice-driven research also re-contextualizes the conditions of designing itself (Hannula et al. 2014), where the needs and acts located within the structure or site to be contested thus marshal both knowing-in-practice and reflection-in-action.

Practice-based or context-specific research allows for a type of internal production that offers the duality of freedom and responsibility through an open-ended approach that is continually anchored to itself (Hannula et al. 2014). The researcher must choose and interpret existing materials and conditions from which they will ‘write’ and produce cultural products that are
contested, actualized, and reinterpreted from each project, site or situation (Hannula et al., 2014). These arguments and conditions, however, are under the constant challenge and changing conditions of choice and interpretation, which do not produce a priori or hierarchical structure within the same site or situation but provide conditions for the pluralities of reality including various values and traditions pushing forward the practice’s conditions (Hannula et al. 2014).

Philosophically, Feyerabend (2010) posits that “being able to ‘read’ a certain style also includes knowledge of what features are irrelevant” (178). If we extend this to practical learning, we may infer that acts of practice that may once have “take[n] place within a certain specified and historically well-entrenched framework” (Feyerabend 178), must today be considered within active, innovative, or shifting disciplinary boundaries and norms, in which outlier practices may function in shifting the mainstream of the profession.

CONCLUSION
Whenever key insights for the professional design practitioner and the practice-based episteme foreground “soft” or “intuitive” knowledge, it can seem to contradict or even threaten formal programs in other disciplines (for example engineering or structural physics), that rely extensively on “hard” knowledge or objectivist perspectives. Schön argues, however, that if all “research” may be considered transactional, an activity of “exchange” through the implementation of a concept, then all professionals use reflection in research leading to technical competence, and to develop priorities and themes for specialized disciplinary knowledge over time.

The general methodology and application of Schon’s concept of reflection-in-action exposes just how much tacit knowledge actually hides in the exploration, expectations, recognition, and judgments of professional practices. In fact, Schön describes many activities associated with practical competencies as reliant upon divergent, uncertain, and intuitive processes. Schön’s descriptions of reflective processes as applied to professional reasoning are exemplified in context for various professions.

In fact, without specific formulas or methods for uncovering, understanding and making visible tacit knowledge across design practices, there remains great potential as well as complexity in how design practitioners conduct reflective research. However, Schön believes this type of professional knowledge is essential to the social progress, indeed to the way our society functions, which is indicated by society’s traditional reliance upon professionals to define and solve problems. It remains to be seen whether continued trust will be sustained however. For example, the book The Future of the Professions (Susskind and Susskind, 2017), presents a radically different picture of professions in which traditional expertise gives way to a more democratized approach to knowledge construction, consulting, and information-sharing.

By understanding our individual motivations as practitioners and learners for both praxis and scholarly dissemination the initiation of goals and goal attainment can become more focused. With reflections on practice uncovering motivations behind decisions, realizing the values we place on tasks, and practicing our base knowledge with personal motivations we can increase learning and expertise.

REFERENCES


ENDNOTES

1 Chester Barnard, a business and management theorist, distinguished “think processes” from “non-logical processes” that are not capable of being expressed in words or as reasoning, and which are only made known as a judgment, decision, or action” (Barnard 1949, 302).

ii Shôn coins the term “intermediate reflection,” which is often followed by next steps in the design process as a reflective conversation, the “what if” with the medium and the design problem in order to produce and alternate solution. This “what if” is one reflective question that is often at the core of the design conversation, as a generative pedagogical tool, that is generic in its approach but specific to the vernacular and practices of design. This reflective conversational modality moves the design process forward through alternate potentials and differences of “what if” as consideration of explorative and potential commitments to the practice.

iii MacIntyre (2006) connects the interpretation of freedom and responsibility to aspects of tradition by stating that tradition is conflicted by the interpretation of a long-term activity.
ABSTRACT: Architecture as a discipline is focused on the architectural project. But whereas professional designers produce architectural projects, academic researchers use the architectural project as an object of study in order to produce new theoretical knowledge. This clear distinction between the goals of professionals and academics has divided the field into two groups, a polarization that mirrors the often-mentioned opposition between design and practice on one side and research and theory on the other. However, in recent years, what appears to be a hybrid model incorporating both these approaches has been emerging: the architectural laboratory. The scientific laboratory is a space where new knowledge is produced and is therefore naturally linked to academic institutions and to research. However, since their emergence at the end of the 19th Century, architectural laboratories have been appearing as much in the academic field as in the field of professional practice. If all the activities at the heart of the scientific laboratory are related to research and to the production of theoretical knowledge, one can wonder why architectural firms would choose to refer to this model to describe their design practices. Are these references to the laboratory model in the naming of professional architectural firms a sign of practices that go beyond “traditional” design? Do these professional “architectural laboratories” incorporate a research approach that was once only found in academic environments? What exactly is an “architectural laboratory”? This presentation will discuss the hybrid nature of the practices at the heart of the architectural laboratories by considering and comparing two remarkable cases. The first, the Laboratory for Visionary Architecture is a contemporary professional practice set up in 2007. The second is a series of interrelated academic laboratories that have been set up since 2002 within the Graduate School of Architecture, Planning and Preservation (Columbia University). Through a description and comparison of the productions of these cases, we will offer a clarification of the figure of the architectural laboratory and show how this emerging model is an indicator of a tightening hybridization of the once distinct activities that are theoretical research and design practice.

KEYWORDS: architectural laboratory, design thinking, architectural research, architectural knowledge

INTRODUCTION: THE “GREY ZONE OF ARCHITECTURE”
Architecture is often described in terms of absolute binary oppositions: practice / theory, design / research, profession / discipline. Two distinct characters emerge from such a point of view. On one side is the professional architect who solves specific pragmatic problems through the design of suitable objects. Opposite him, on the other side, is the academic architect who, by considering new questions and through a process of research, builds theoretical knowledge that contributes to the construction of the discipline as a whole. Even though both are seen as architects, one is called a designer and the other a researcher, and the wall separating them, sacred to many, often seems unbreakable. Challenging this viewpoint, architect Esa Laaksonen introduces the notion of a “grey zone of architecture” where practice and research are linked:

The borderline [between practice and research] has been increased in scale and could be interpreted as being extended into a kind of border zone, an area of architectural opportunities. When operating in this border zone, practice and research meet and intermingle, and perhaps in theory mutually benefit each other. What could this theoretical grey border zone of architecture be in practice? (Laaksonen 2001, 7)
According to Laaksonen’s hypothesis, the activities of architects in the context of practice (the designers) and those of architects in the context of research (the researchers) should not be seen as total opposites, but rather as complementary. From this complementarity would then emerge new activities relating as much to practice as to research, therefore bridging the gap between design and research. This paper will address the issues raised by Laaksonen’s hypothesis of a “grey zone of architecture” through a study of the figure of the architectural laboratory. It will specifically focus on the activities carried out within the walls of a number of such entities, and on the place occupied by design and research within this new space of production. Are architectural laboratories spaces of pure research exclusive to the academic context? What does the emergence of the laboratory say about the contemporary practices that constitute the discipline of architecture? These are the questions that this paper will address. Given the relatively recent apparition of the architectural laboratory, the knowledge available on this type of workspace is still limited. It is therefore necessary to first proceed with a more in-depth analysis of the architectural laboratory as a recognizable phenomenon. Two case studies presenting remarkable and complementary characteristics will be then covered. Finally, the observations from these two case studies will be discussed in order to offer answers to the raised questions.

1.0. ON RESEARCH AND DESIGN
As the notions of research and design are central to this paper, it is necessary to briefly but clearly explicit from the onset what they stand for and to highlight what differentiates them in order to better understand how they can be seen as complementary.

Design can be described as “a planned and target-oriented process,” of which the goal is “the creation of a project with specific circumstances and intentions that can be implemented” (Gerber, Unruh, and Geissbühler 2010, 27). The result of design is therefore unique and not generalizable as it is embedded in a particular context and related to a particular problem that requires solving. In this sense, design can be considered here as an artistic process: the architect-designer produces a new and unique work for every problem he has to solve. He is similar to the artist producing “works of art” in his studio: every finished work is unique, personal and distinct from the rest of the artist’s production.

Research can also be described as “a planned and target-oriented process, the results of which must be general and provable” (Gerber, Unruh, and Geissbühler 2010, 29). These results are also clearly expressible in words, and repeatable by other researchers, but above all, they are transmissible. They are ideas that take the form of explicitly formulated knowledge (a theory, a manifesto, a text), the sum of which constitutes the discipline of architecture. In the context of this paper, research is therefore seen as a scientific process: the architect-researcher builds new but generalizable knowledge that is added to previously available knowledge built by others to form an ever-evolving entity. In this sense, the architect-researcher is similar to a scientist in his laboratory, contributing to a body of knowledge constantly in progress.

This strong distinction between design and research as two extremes may appear too extreme. One could argue, with reason, that all designed objects include implicit knowledge that can be extracted and turned into explicit knowledge. For example, one could think of the very particular but important case of the villas that Le Corbusier and Pierre Jeanneret designed in and around Paris in the 1920s. Architectural historian Tim Benton describes these villas as “a radically new orientation for architecture that have made them central points of reference for all subsequent generations of architects right up to the present” (Benton 1987). These projects can be considered architectural precedents and influence future designers, but they cannot be considered, in themselves, as explicit knowledge. The implicit knowledge they hold is made explicit only when Le Corbusier adopts a reflexive stance on his own work and publishes, in 1926, his theory of the “5 points of architecture”. This theory, which Le Corbusier himself described as laboratory findings – “acquits de laboratoire” (Le Corbusier and Jeanneret 1929, vol.2, 24) – is very clearly generalizable, expressible and transmissible knowledge, and has
structured a large production of modern architecture. The difference between the Parisian villas (the physical objects) and the 5 points of architecture (the theoretical knowledge) is a clear example of the distinction we want to highlight between the design process and the research process.

2.0. ON THE ARCHITECTURAL LABORATORY AS AN OBJECT OF STUDY

The opposition between design and research can be linked to a discussion on the place of work of the architect. Unlike the places of work of the artist and of the scientist which are clearly identified as distinct spaces (namely, the studio and the laboratory), the place of work of the architect is defined by analogical associations. The strongest of these associations is the one that links architecture to the arts and that can be traced back to the Beaux-Arts origins of the discipline: following this association, the architect's workplace has always been commonly identified as a studio, a direct reference to the workplace of the artist. But a new type of workspace has been emerging in the field of architecture, that of the laboratory.

It would be tempting to directly tie the activities of the architect, the context in which they take place and the identification of the place of work. Following such an approach, the architectural studio would be a place of design in a professional context and would therefore be the space of the architect-designer. In the same way, one could envision a direct relation linking the laboratory, the academic context and the activities of research. This approach would yield the hypothesis that the architectural laboratory is essentially a place of research within an academic context, and would therefore be the space of the architect-researcher.

In order to test this hypothesis and address the issues underlying the “architectural laboratory”, it is necessary to first identify it as a structured and cohesive phenomenon. For the sake of clarity and impartiality, only architectural entities directly self-identified as “laboratories” (either by name or through their description) have been considered. This very important limitation ensures that what is measured is the actual fascination by architects for this type of space: in other words, the image of the laboratory in the mind of architects.

An exhaustive compilation of architectural entities explicitly referring to the laboratory in their identification clearly shows what a phenomenon that is characterized by an exponential growth ever since its emergence at the end of the 19th century (Figure 1). Since the beginning of the 21st Century, the number of architectural laboratories has increased three-fold as close to 150 laboratories are currently in operation.ii

Figure 20. Inventory of entities in the field of architecture explicitly identified as laboratories
A more in-depth analysis of this survey of architectural laboratories can be done by distinguishing the context within which they are set up. For the sake of this analysis, three contexts were considered (Figure 2). The academic context includes all activities set up within the walls of architectural academic institutions. The professional context includes all activities that are part of the professional practice of architecture. The broadcasting context includes all architectural activities related to the presentation, publication and broadcasting of architecture (such as museums, exhibitions, journals, etc.). This clarification shows that, although the first cases are set within the structures of architecture schools, architecture laboratories appear within the professional field of architecture as early as the middle of the 20th Century. Three phenomena take place at the turn of millennium: 1) the apparition of architectural laboratories in the broadcasting context; 2) a constant increase of the number of laboratories in the professional context; and 3) an explosion of the number of laboratories in the academic context. Today, most architectural laboratories operate in an academic context (over 77%). Today, almost 16% of active architectural laboratories are set up in a professional context and 7% are related to the broadcasting context. These numbers are significant and indicate that there could be more to the laboratory than implied by the hypothesis formulated at the beginning of this paper.

In order to properly understand what the architectural laboratory stands for, it is necessary at this stage to study specific architectural laboratories from distinct contexts. In this paper, we will focus on two cases taken from the compiled repertoire of architecture laboratories, the first set within the professional context, the second within the academic context. As we will see, these cases must not be considered as generalizable models, but rather as remarkable devices enabling new insights regarding the questions addressed here.

3.0. THE ARCHITECTURAL LABORATORY WITHIN THE PROFESSIONAL CONTEXT: THE LABORATORY FOR VISIONARY ARCHITECTURE [LAVA]

LAVA (the Laboratory for Visionary Architecture) is an architectural practice set in the professional context founded in 2007 by Chris Bosse, Tobias Walliser and Alexander Rieck, three young German-born architects whose work prior to the founding of LAVA has been widely recognized. Chris Bosse was a key designer for the Australian firm PTW Architects of the Beijing National Aquatics Centre built for the 2008 Summer Olympics whereas Tobias Walliser was UN Studio’s main designer for the Mercedes-Benz Museum (2001-2006). The naming of the young professional firm, the Laboratory for Visionary Architecture, is remarkable as it puts in relation the two complementary approaches of interest in this paper, i.e. research and design. On one hand, as previously discussed, the laboratory can be seen
as a reference to scientific theoretical research, and, as such, it is quite surprising to find it in
the professional context of architecture where design entities have predominantly been
identified as “studios”. On the other hand, the notion of “visionary architecture” is a direct call
to avant-gardist and innovative architectural production. This is not a “laboratory of visionary
architecture” that intends to study existing projects with special qualities, but a “laboratory for
visionary architecture” that wants to produce new architectural objects of a certain type, an
attitude favoring action which is in accord with the role of all professional firms.
The text presenting the young firm uses the same kind of rhetoric:

At the vanguard of a nonconformist and inventive new generation in architecture, LAVA
bridges the gap between the dream and the real world. LAVA operates as a unique think
tank with branches placed strategically worldwide. It has been formed by some of the most
experienced and forward thinking architects from around the globe (Laboratory for
Visionary Architecture (LAVA) 2012b).

“Vanguard”, “nonconformist”, “inventive”, “new generation”, “forward thinking”: all these terms
indicate a desire to cut from the past and project into the future similar to the one that moved
the artistic and architectural avant-gardes. In other words: an intention to design. But, at the
same time, this text presents LAVA as a “think tank”, which implies theoretical research carried
out within a collaborative structure. This collaborative structure is central to LAVA, as the firm
is composed of two distinct poles: LAVA Asia located in Sydney, Australia, and LAVA Europe,
located in Stuttgart, Germany. Chris Boss is the director of LAVA Asia, while Tobias Walliser
and Alexander Rieck are the co-directors of LAVA Europe. In addition to these two
headquarters, two new poles located in Abu Dhabi (United Arab Emirates) and Shanghai
(China) have been set up because of the amount of work the firm has been commissioned to
do in these regions. Because of this multipolar structure, work at LAVA is organized around
a series of exchanges, as the projects and the knowledge attached to it have to be continuously
transferred from one node of the network to another. This is so embedded in LAVA’s structure
that a world map presenting the transfers is available on the website of the firm (Figure 3).

![Figure 2. Map of the activities of LAVA (poles in yellow, projects in red, design transfers in green, research transfers in blue) Source: (LAVA, 2012)](image)

On this map, the main nodes of the LAVA network are identified in bright yellow (Sydney, Stuttgart, Abu Dhabi, Shanghai) while the projects the firm has worked on are the smaller red
dots. But what is of real interest here are the exchange vectors. These are separated in two
groups as a distinction is made between the transfer related to the design activities of the firm
(the green lines: site visit, workshop, presentation, launch) and the ones related to the research
activities (the blue lines: collaboration, technology, research). This classification clearly
underlines the importance for the architects of LAVA of distinguishing design and research,
while, at the same time, including both in the activities of the firm.

The research activities as identified on LAVA’s map can be seen as personal research, i.e.
activities intended to contribute to the evolution of the firm as a closed and independent entity.
Such a point of view is discussed by Michael Weinstock, Director of Research and
Development, and Director of the Emergent Technologies and Design program in the Graduate
School of the Architectural Association School of Architecture in London, England. In an article
focusing on Chris Bosse of LAVA, Weinstock identifies an evolution of the architect’s design through a number of elements that appear to be developed from project to project:

While not every architectural design project can truly be said to be research, the work of Chris Bosse confirms that design research is possible for architects even while they are in practice. It can be pursued in constructed designs that extend existing ways of making forms and spaces, and in the development of innovative material systems. The pursuit of larger ambitions and grander research goals may be advanced by finding opportunities in more numerous small and ephemeral projects. The development of a research agenda in the context of a continuing series of small constructed projects is an evolutionary strategy appropriate to both architect and client. The architect stands to gain knowledge and expertise, and the client stands to gain an innovative design that is built on a previous success (Weinstock 2008, 115).

This is certainly an interesting view of research, but it is one that is limited to the personal gain of knowledge and expertise by the designer himself. As we will see, what really makes research at LAVA stand out is the relation it implies with the discipline of architecture as an intellectual community. The close interrelation between the activities of research and design is also put up front in the presentation of the firm, as LAVA is described as having been “established as a network of creative minds with a research and design focus” (Laboratory for Visionary Architecture (LAVA) 2012a). Contrary to Chris Bosse and Tobias Walliser who were architecture practitioners before founding LAVA, Alexander Rieck, the third co-founder, comes from the field of academic research: prior to LAVA, Rieck was a researcher at the Fraunhofer Institute, Europe’s largest applied research organization, where he specialized in virtual reality environments. During his time at the Institute, Rieck led many research projects, participated in scientific conferences, and authored a number of publications on working environments and building processes. In other words, his activities were those of a researcher in the context of a scientific institution. Even though the research at Fraunhofer Institute can be considered as applied research (as opposed to theoretical research), it is nonetheless remarkable that an important member of a professional firm comes from a research environment.

One could wonder if the fact that one of the directors of a professional firm is a scientific researcher implies that the firm would develop clearly identified research activities in addition to the design activities it traditionally displays. That is precisely the case with LAVA, which has set up such activities through reciprocal exchanges with the Fraunhofer Institute. An example of these exchanges, highlighting the transfers from research to design, is the project of the LBBW Immobilien Headquarters (Stuttgart, 2008) which was based on the findings of Office 21, a research project Alexander Rieck had led at the Fraunhofer Institute. Another example, this time underlining the contribution of design to research, is the Future Hotel (Duisburg, 2008), a research project at the Fraunhofer to which LAVA contributed as external consultants. In this case, the work of the professional architects was essential to the production of theoretical knowledge.

The intertwining of research and design is also evident in the multiple roles the directors play. Parallel to their professional practice, all three directors of LAVA occupy positions in the academic context. Chris Bosse is Adjunct Professor at the University of Technology, Sydney. Tobias Wallisser is Professor of Innovative Construction and Spatial Concepts and Vice-President at the State Academy of Fine Arts in Stuttgart. Alexander Rieck is a senior researcher at the Fraunhofer Institute in Stuttgart. LAVA is a fascinating case of an architectural laboratory that is structured around design activities within the professional context, while maintaining, at the same time, strong links to research and the academic context. This case is a first example that appears to invalidate the hypothesis that the laboratory is only a place of scientific research set within the limits of the academic context.

4.0. THE ARCHITECTURAL LABORATORY WITHIN THE ACADEMIC CONTEXT: THE LABORATORIES OF THE GSAPP AT COLUMBIA UNIVERSITY
This second case study will analyze a group of architectural laboratories set within the academic context: the 28 laboratories of the Graduate School of Architecture, Planning and
PRACTICUM-FOCUSED PEDAGOGY

Preservation (GSAPP) of Columbia University, one of the major centers of the architectural pedagogical landscape. The number of laboratories at GSAPP has increased very rapidly, as all 28 laboratories currently active within the school were set up over less than a decade, between 2003 and 2012.iv

Following the idea that a laboratory is originally a space of scientific research, the fact that laboratories exist in the architectural academic context may seem natural. But this fact can be surprising in itself given that, most often than not, architectural thinkers, historians and philosophers have always done their research work alone, in their own offices. If they ever had a collaborative research structure, it was usually identified as a “research unit.” The apparition of laboratories in the academic context and their rapid increase (as shown in Figure 1) could possibly imply a new approach to research. Given the large number of laboratories at the GSAPP, it is reasonable to think that an analysis of the activities within their walls would give good indications of the real nature of the architectural laboratory in the academic context. This analysis has been carried out by focusing on the type of results the laboratories produce.v The results are only of two possible kinds: either explicit knowledge (through publications) or recognizable objects (i.e. projects). By its simplicity, this binary grid enables a clear understanding of the nature of the laboratories (Table 1).

According to this analysis, four distinct cases are possible: 1) the production of publications only, 2) the production of projects only, 3) the production of both publications and projects, and 4) no productions at all. The compilation of the results of this analysis paints an unexpected portrait of the architectural laboratories of the GSAPP (Figure 4). While 30% of the laboratories focus on the production of knowledge through publications, another 20% are more concerned with the production of projects. These laboratories can be seen as situated at both extremes of the design / research spectrum. Only a minority (13%) produces knowledge and projects at the same time: these entities can be seen as elements fluctuating between the two above-mentioned extremes. These cases bring back to mind the notion of the “grey zone of architecture” formulated by Laaksonen in which research and design meet. But what is most important is that a very large number of the laboratories of the GSAPP (37%) do not produce anything: neither projects, nor publications.

What stems from this analysis of the laboratories of the GSAPP is that the architectural laboratories are not of a single kind, and, based on the results shown here, one could make the distinction between four distinct types of architectural laboratory (Figure 5):

1. The first type of laboratory is exclusively a space of research and of production of knowledge (production of publications only) and can be labeled as a laboratory for thinking.
2. The second type of laboratory is a space of research that integrates activities of design (production of publications as well as of projects) which could be described as a laboratory for thinking and making.
3. The third type of laboratory drops completely the research approach and becomes a space dedicated to creation and design (production of projects only) which could be labeled as a laboratory for making.
4. The fourth type of laboratory goes beyond the opposition of design and research and therefore situates itself beyond the “grey zone of architecture.” This type of laboratory is hard to label by referring to the activities of thinking and making as it does not relate to any of these poles. A possible label would have to take into account the only clear characteristic of these laboratories, which is that they exist: the laboratory as a platform.

Of these four types, the most interesting is assuredly the last one. As of 2011, it is the type of laboratory that is the most present within the context of the GSAPP and, as such may prove to be an indicator of major transformations within the discipline of architecture.
Table 4. Analysis of the production of the architectural laboratories of the GSAPP (Columbia University)

<table>
<thead>
<tr>
<th>LABORATORY IDENTIFICATION</th>
<th>FOUNDATION DATE</th>
<th>PUBLICATIONS (EXPLICIT KNOWLEDGE)</th>
<th>PROJECTS (RECOGNIZABLE OBJECTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Landscape Lab</td>
<td>2003</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Technological Change Lab</td>
<td>2003</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Sustainable Urbanism International</td>
<td>2003</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spatial Information Design Lab</td>
<td>2004</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>HQ of Japanese Architecture</td>
<td>2004</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Columbia Lab For Architectural Broadcasting (C-Lab)</td>
<td>2005</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Laboratory for Applied Building Science</td>
<td>2005</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Conservation Lab</td>
<td>2005</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Urban Design Lab</td>
<td>2006</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>China Megacities Lab</td>
<td>2007</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Network Architecture Lab</td>
<td>2007</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Space Lab</td>
<td>2007</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>The Community &amp; Capital Action Research Lab (C2ARL)</td>
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<td>S.L.U.M. Lab: Sustainable Living Urban Model Lab</td>
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<td>The Data Visual (2009 symposium)</td>
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<td>Living Architecture Lab</td>
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<td>Non Linear Solutions Unit</td>
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<td>Latin American and Caribbean Laboratory (LatinLab)</td>
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<td>Studio-X Mumbai</td>
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<td>Global Africa Lab</td>
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<td>Studio-X Istanbul</td>
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<td>Studio-X Johannesburg</td>
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Figure 23. Type of production of the architectural laboratories of the GSAPP (Columbia University)
CONCLUSION: A COLLECTIVE BRAIN FOR THE EXPERIMENTAL AGE
The hypothesis set forth at the beginning of this paper was that the architectural laboratory could be seen essentially as a place of research within an academic context. The case studies presented in this paper have refuted this hypothesis in two major ways.
First, the architectural laboratory is not limited to the academic context but can now be found in all contexts constituting the large field of architecture (academic, professional and broadcasting).

Second, the activities within the walls of the architectural laboratory are not limited to research. The case study of the Laboratory for Visionary Architecture [LAVA] has shown that the laboratory exists in the professional context, outside of the academic context, and that it houses as much design activities as research activities. The case study of the laboratories of the GSAPP at Columbia University has also shown us that, although laboratories exist in the academic context, they are not necessarily dedicated to scientific research: some integrate design activities while others are entirely focused on the design of projects. The two cases have therefore shown us that the laboratories occupy a large space within the “grey zone of architecture” hypothesized by Laaksonen: they are on either side of this gap as well as occupy its centre.

But what the case of the GSAPP has shown us is that some very recent laboratories go beyond this “grey zone”, by acting as bridges and thus ignoring the traditional gap between design and research altogether as they do not produce any new projects or knowledge. What exactly are these particular laboratories and what exactly takes place inside their walls?
All the laboratories that do not produce any new knowledge or objects are part of the Studio-X Global Network Initiative set up under the direction of Mark Wigley, Dean of the GSAPP between 2004 and 2014. His description of this program is eloquent and deserves to be extensively quoted:

The vision of the Studio-X global network is to establish a unique exchange of ideas and people between key regional leadership cities around the rapidly evolving globe. […] The aim of this exchange is a global partnership able to offer support to the highest possible level of reflection on the new realities and active, intelligent, and productive engagement with those realities. […] Each Studio-X acts as an open platform for collaborative research and debate with a publication gallery, an exhibition gallery, a lecture space and an open studio workspace. During the day, the Studio-X is an active workshop, with combinations of ever-shifting teams of local experts and visitors from the region or globe working on designs, reports, exhibitions, books, competitions, films, magazines, etc. During the evening, the Studio-X acts a hub of social exchange and intense debate with a lively program of exhibitions and events. It is a hot spot in the city, buzzing with social energy,
invention, and dedication to a better future. […] With the addition of each hub in the network, this radical experiment in redefining the role, responsibility, and capacity of globally collaborative modes of education, research and action, increases its bandwidth exponentially. A new kind of collective brain is emerging (Wigley 2009).

The central notion on which the Studio-X Global Network Initiative is built is the idea of collaboration. In other words, the Studio-X global initiative is a series of interconnected super think tanks disseminated around the globe and organized within a structured network, each of these think tanks attracting local expertise in order to maximize the transfer of theoretical knowledge and professional expertise at a global scale. The “new kind of collective brain” that Wigley envisions with the launching of the Studio-X Global Network Initiative is not focused on design or research, but rather integrates both as complementary activities that need to be considered simultaneously and the laboratory is the place where this hybridization of design and research takes place. The vision of the Studio-X global initiative does not include the planned production of new knowledge or new projects. In this sense, the network envisioned by Wigley locates itself neither within the traditional opposition between design and research, nor within an intermediary “grey zone of architecture” suggested by Laaksonen where design and research “meet and intermingle” (Laaksonen 2001, 7). The Studio-X laboratories are simply closed boxes where anything related to architecture can happen without being necessarily planned or organized: in this sense, they are empty spaces waiting to be invested, occupied and turned into platforms within which architecture as a field is unified again. This is precisely how Brazilian architect Pedro Rivera, director of the Studio-X Rio, answered as he was asked to describe his laboratory: “The basic concept is very simple—an empty space with an espresso machine” (Studio-X Global Network Initiative 2011).

In conclusion of this paper, the architectural laboratory appears as an environment that is neither the result of a mutation of the artistic studio where works of art are designed, nor a direct analogue of the scientific studio where theoretical knowledge is researched. It must be seen and studied as an independent and hybrid type of workspace particular to the field of architecture where the focus is sometimes put on architectural design, sometimes on architectural research, and at times on the hybridization of both of these activities. But most importantly, it must be seen as a major new type of space central to the new “knowledge economy” where design and research are so closely intertwined as to become undifferentiated inside a new collective brain.

REFERENCES
ENDNOTES

1 This appears may appear overly simplistic, as one could argue that architectural studios can be found as much in the academic context as in the professional context. But, architectural studios in an academic context are pedagogical environments in which students must solve given problems through the design of architectural objects. In other words, they are, more frequently than not, simulations of real-life professional activity.

2 As a note of warning, the compilation of architectural laboratories presented in this paper is as exhaustive as possible. In the context of a vast research we have undertook on the figure of the laboratory in architecture, this database is continuously being updated in order to ensure a more precise reading of the phenomenon.

3 The Fraunhofer Institute is composed of more than 70 research institutes, and employs over 25,000 people, the majority of which are qualified scientists and engineers. Its annual research budget totals €2.3 billion.

4 It must be noted that, although the name of all these entities do not explicitly refer to the laboratory, they are nonetheless all part of what the GSAPP documentation clearly identifies as the school’s “experimental laboratories.”

5 The type of production of each of the GSAPP laboratories has been determined through the study of their public interface, i.e. their website. As the GSAPP website is constantly being updated, every possible effort has been made in order to exhaustively collect information even if it that has now been suppressed.
Theorem and practicum: order, value, result, interaction

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ABSTRACT: The Thesis is the last major step toward graduation with a first professional degree, or Bachelor of Architecture (B.Arch.), which traditionally prepares students for practice. As a threshold between directed studios and independent thought, the Thesis provides an opportunity for the student to systematically explore a coherent line of investigation of issues relevant to the field of architecture. The Thesis is an intellectual position laid down or to be advanced. It is the first stage of the dialectic–discussion, that is, discussion and reasoning by dialogue as a method of intellectual investigation. An architectural thesis demands that a student take a position and have something to say that is relevant to the discursive field that it inhabits and/or its wider cultural context. In the field of architecture such intellectual positions have implications that result from a critique and re-examination of the role of architecture as a critical participant in the conditioning of public and private space. Thus, while an undergraduate architectural thesis originates in a determinate intellectual position, it culminates in a designed artifact, but rarely the artifact itself. This paper takes a step in characterizing architectural research, where the interaction of Theorem and Practicum is used not only as a guiding principle in the critical thinking process, but also as a springboard for constructive practices in the built realm. This particular reading is an inquiry into the importance and influence of interaction between Theorem and Practicum, as well as, the importance of which is observed through different modes of cross-pollination occurring in various aspects of architectural discourse and practice. This investigation is explored in four perspectives, labeled ‘order’, ‘values’, ‘results’ and ‘interaction’ are categorized according to their relationship to the investigation of Theorem and Practicum. Furthermore, these four attributes permeate and connect the diverse areas of research explored, which in combination provides an argument that rather than questioning: “is doing architecture doing research” as articulated by Jeremy Till, instead asks: “is doing research doing architecture”. Our aim is to expand the pedagogical field where the interaction of Theorem and Practicum is not an isolated act, but one of making.

KEYWORDS: undergraduate research, architecture thesis, design thinking, theorem, and practicum.

INTRODUCTION

Architectural research is a broad term with a long history. In the 1960s, architectural research referred to the study of design itself, its purpose and processes. This is still how the term is often used in academia today. This paper takes a step toward characterizing architectural research, where the interaction between Theorem and Practicum is used not only as a guiding principle in the critical thinking process, but also as a springboard for constructive practices in the built realm. It is an inquiry into the nature of this interaction and how it may be understood through differential modes of cross-pollination occurring within various aspects of architectural discourse and practice. Specifically, the paper examines the potentialities of architectural research in the first professional degree, or Bachelor of Architecture (B.Arch) program, which traditionally is designed to prepare students for practice and licensure.

In A Theory for Practice: Architecture in Three Discourses, William Hubbard asserts that we must think about building (practice) in three distinct ways: order, values, and results. For Hubbard, these three modalities essentially frame the task of architectural practice. It can be argued that the academy does the first two very well. But the third ‘to bring about results’ is limited by the constraints of academia, where the deliverable is not the thing-in-itself, but rather
PRACTICUM-FOCUSED PEDAGOGY

a design articulated in a series of other distinct artifacts, digital media and/or interventions. Hubbard accordingly holds that a theory of practice should be defined in three modalities: 1.) as an instance of architectural order, 2.) as an embodiment of values about living, and 3.) as the instrument for bringing about results (Hubbard 1995, 12-19). In other words, Hubbard’s ‘modalities’ become the vehicle for an architecture of both product and process by suggesting that these three conditions define a particular mode in which an aspect or element of architecture is experienced. These modalities then in turn become the discourse of architecture as an all-inclusive approach or discourse. Reframed to consider the education of an architect, this paper questions how can the academy rethink pedagogy in a way that enhances the student’s ability to think critically in this third modality?

1.0. WHERE ARE WE AND HOW DID WE GET HERE?

For just over a century, Modern architecture struggled to adapt to a changing world, one where society, politics, economy and technology shifted with each advancing decade. As a result, the nature of architectural practice fundamentally transformed with each subsequent generation.

Early Modernism, in the form of the Neue Sachlichkeit, formulated a specific paradigmatic response to this proposed third modality. Most commonly translated as “the new objectivity”, the term refers to trends in architecture between the world wars that sought a ‘rational aesthetic’ or a ‘rational appropriateness’ in design. It was a reaction against both the romantic sentimentality and lebensphilosophie of the nineteenth century and the failures of the earlier avant-garde to address real world concerns following the first world war particularly the housing shortage. Emil Roh referred to this newly paradigm as ‘Technophoria’ and it would last into the middle of the century. At its core were concepts of not only functionalism, technology and progress, but also a non-ornamental aesthetic expression.

This paradigm would be challenged following World War II by Team X. The celebration of technology without consideration of the social and cultural aspects of the building’s context was now seen as a hinderance to the development of concepts with significant architectural and urban meaning. It was now necessary to distinguish the specific conditions and needs of a particular culture and society in their evolved historic conditions as subjected to various influences over time. The Dorn Manifesto of 1954 emphasized the importance of ‘human associations’ and the concept of dwelling as ‘habitat’.

Hubbard’s third modality—an instrument to bring about results—was now reformulated along the lines of anthropology and more closely aligned with the second modality; as an embodiment of values about living. According to Aldo Van Eck architectural practice was represented by three great traditions; the Classical, the Modern and the Vernacular that should be reconciled. Together they held the formal and structural potential necessary to find answers to the variable and complex reality of human relationships.

Robert A.M. Stern would later update Van Eck’s idea reformulating the traditions as Classical, Vernacular and Process, where the latter maintains a basis for form in the constituent facts of building productions and in an idealized condition of the possibilities of serial production. Thus, design is reframed as a process of cultural assimilation.

In our opinion, a relation with history, and all its social and cultural imprints, is essential for contemporary reflection and development of concept which can draw conclusions and find inspiration in it. Inspiration here is an interrogation about the state of being in the actual environment with its characteristic attributes to which innovative concepts should respond. This position is perhaps most explicit in Aldo Rossi’s 1966 book Architecture and the City. It proved to be a seminal text for its critique of naive functionalism, and for restructuring the traditional concept of type, in the process proposing yet again a new strategy for the third modality.

According to Rossi, the city is a constructed fact. It is a Manufatto that can be understood as the result of two processes the first the actual process of production; an object literally made
by the hands of men at a given moment in history. And second as a process of time which is
ultimately responsible for the production of the city as an autonomous artifact. iv Thus
architecture, and here we mean the rational analysis of the discourse, is only possible when it
can be related to historically given elements or typologies, it is an architecture of collective
memory.

The real significance of Rossi’s theory of Type lies in its conception as process and object that
transforms it into apparatus for analysis and invention. The ‘Distributive Indifference’ present
in his theory serves as a catalyst to invention that allows for a new analogical process of
design. The possibility of speculative invention is plausible with the type-form, because it is
now both, process and object.

More recently we have seen emerge yet another take on the third modality, one that is
projective, meaning it seeks meaning and validation in the actual project and the analysis of
its own conditions. This paradigm is a return to tectonics, but one that in addition to the
expressive aspects of the detail also places emphasis on its performative aspects. It is driven
less so by theoretic explorations in the academy and more by the inherent design strategies
of critical practices that engage in research.

We do not reject the earlier propositions for the third modality. It our opinion we may build upon
and learn from them even if we find them limiting in the contemporary condition. They present
different architectural concepts and thoughts about the characteristics of interactivity within
architecture, as they explore different strategies of relations between entities such as; research
and practice, constituents of architectural space and the understanding of them.

In his 1999 book The Practitioner-Researcher: developing theory from practice, Peter Jarvis
noted that it was the very rapid pace of change in the nature of practice in the late 20th
century that made it necessary for many practitioners to engage in their own practice-based research.

We have to be careful not to oversimplify the interaction between Theorem and Practicum
particularly as it relates to the design fields. In Practice-Based Design Research, Laurene
Vaughan uses Christopher Freyling’s (1993) taxonomy to note the distinctions in design
research and how it applies to the practitioner-researcher; 1) Into the practice – to understand
what has been done, a form of historiography, 2) for the practice – to use in practice, 3) through
the practice -to use the actions and sites of practice as a means of discovering something to
be useful in articulating the intentions and outcomes of the practitioner-researcher’s inquiry. v
We are specifically addressing Freyling’s third taxonomy ‘through practice’. As Vaughan goes
on to state; “The situated nature of practice-based enquiry ensures that research undertaken
will produce knowledge that both deepens understanding and provides tangible applications
for practice.” vi

It is just this form of ‘situated’ knowledge that prompted Peter Downton to claim that design
was a transformational process that; “. . . involves migration as well as transformation, for the
knowledge crosses boundaries from that of the designer to the designed. Research through
designing uses the knowing of doing to achieve productive outcomes which in turn indicate the
knowing and knowledge used in their production.” vii His argument echoes that of Marco
Frascari in his The Tell-the-Tale Detail where he refers to the tectonic detail as the ‘Logos of
Techne and Techne of Logos’.

It was Cameron Tonkinwise who identify a fundamental shift in the nature of research; from
one of mature expert practices deserving of a place in the university owing to the ways it
engages a wide range of social challenges, to more pragmatic inclusion of a higher-
performative approach to research in an era of competing knowledge economies. viii It was
against this intellectual background that Vaughan asserted not only the necessity for a new
kind of designer, but the migration of research out of the academy and the transformation of
design pedagogy into one that could contribute to leadership in all areas of design.ix
The contemporary critical practice is one based on a foundation of research that explores the real-world conditions of the tectonic detail seeking to maximize performance, improve economic efficiencies, while developing a significant expressive detail that adds to the aesthetic, phenomenological and economic value of the building. The question then becomes how does this impact design pedagogy in a way that supports and reinforces this new reality? In considering educational models, we would argue that what is needed is a pedagogy that emphasizes the primacy of a praxis that is demonstrative, practical, experiential and in the end proves didactic. Based on this pedagogical foundation, how then, do we approach teaching an undergraduate thesis to serve as a useful threshold between faculty directed, skill-based studios and independent thought?

2.0. THE PRIMACY OF A PRAXIS: THE UNDERGRADUATE ARCHITECTURE THESIS

The ongoing debate of the relevancy of an undergraduate architecture thesis presents numerous and significant challenges, which explains why many architecture programs have opted out. Of the forty-four NAAB accredited B.Arch. programs, only sixteen offer undergraduate students an opportunity to produce a thesis as a way to speculate on a topic of their own invention, while demonstrating the capacity to apply basic research skills. Besides requiring faculty to actively collaborate as well as being a complicated coordination task, why do so many programs remove thesis—the idea of individual speculation—from their curriculums?

One argument in favor for the inclusion of a thesis is that by having to propose a Theorem, it encourages the student to contemplate the Practicum. As a result of this interaction, students are required within the curriculum itself to actively engage thinking about the role of the architects in society and their impact on theoretical and technological innovations, while in turn, gaining practical knowledge and critical thinking skills. Before entering praxis, students learn research methods, study architectural precedents, develop problem-solving skills, and complete exercises that empower them to communicate more effectively. According to Diana Agrest, Professor at The Cooper Union:

"The Thesis project is of major importance to the education of an architect. Students have to define their interests and their questions about architecture through the definition of a theme, a site and eventually a program. These projects are not always or necessarily meant to be problem solving proposals, but rather the place where critical issues can be made explicit and tested. What unifies the Thesis projects is that they are all based on philosophical and conceptual values and beliefs, and in that respect, it is the hope of a teacher that this will be an experience that will inspire the students for a search that will last a lifetime."(1972)

At our University, the Thesis program represents the culmination of the undergraduate curriculum and it is the most significant test of the students’ and school’s ability to synthesize and produce critical and rigorous architecture. Undergraduate thesis fosters a broad culture of ideas, inquiry, and position-taking. Thus, the undergraduate thesis not only provides an opportunity for students to systematically explore a coherent line of investigation of issues relevant to the discipline, but to also build upon all of the skills they learned in the prior four years. Thus, while an undergraduate architectural thesis originates in a determinate intellectual position, it culminates in a designed artifact, but rarely the artifact itself.

Bringing back Hubbard’s theory of practice as defined by his three modalities: 1.) as an instance of architectural order, 2.) as an embodiment of values about living, and 3.) as the instrument for bringing about results (Hubbard 1995, 12-19), he seems to speak to a primacy of praxis without addressing the notion of speculation. Furthermore, within Hubbard’s multi-modality criteria, the productive contributions of architectural theory seem to be quantitatively immeasurable. Therefore, we argue that there is a missing link in Hubbard’s discourse by not considering practice for “what it ought to be” (Conrads 1964), as the speculative interaction of Theorem and Practicum. The question then becomes how does this impact design pedagogy in a way that supports and reinforces the speculative interaction of Theorem and Practicum?
2.0. INTERACTION OF THEOREM AND PRACTICUM: THE FOURTH MODALITY

The point of this investigation is not to take issue with Hubbard’s three discourses, but rather to build upon his theory of practice by proposing a fourth modality in order to consider the interaction of theory in practice, and practice in theory. Along with Hubbard’s: 1.) order, 2.) values, and 3.) results, we propose a fourth modality as defined as, 4.) interaction. By reframing the question to accommodate interaction, we then ask: how can the academy rethink pedagogy in a way that enhances the student’s ability to think critically in this fourth modality while not losing sight of its order, values, and results?

Here the four modalities begin to address the primary aspects of creating a more holistic design pedagogy by bringing together the two hemispheres of design that of Theorem, and that of Practicum as shown in Figure 1. The challenge Hubbard addresses is to see how architects can work together within a common language. He suggests that architects have a blind spot where they do not work incorrectly, but that they think incorrectly. In academia, the Thesis is the place in the curriculum where students are asked to produce a personal and original contribution to the discipline of architecture, a contribution that advances the realm of architectural research and ideas rather than one that simply revisits existing paradigms. Which makes the fourth modality to pose the question ‘what if’ an important consideration in attempt to confront that blind spot. To throw light on these different points of view, Hubbard asks us to ‘listen’ to the process of design practice. He poses the question: ‘How does it sound to produce a building?’ and takes us through the process from the understanding of the architect, the user and the client, with and from the notion of results, values and order. By including ‘interaction’ as a fourth mode of experience, we are arguing for an all-inclusive architectural discourse that takes into account a wide range of assessments, such as, the personal and common values of users and clients, the marketplace, and the shared experience of the dialogue of design.

By creating a cyclical relationship within these two hemispheres—Theorem and Practicum—as shown in figure 1, we can visualize relationships embedded within the process: ‘Theorem as order | why?’; moving on to ‘Practicum as values | what?’; and then, ‘Practicum as results | how?’; and lastly, ‘Theorem as interaction | what if?’. Rather than a linear process with the aim to successfully create things or architecture, we are proposing that, once the architect has listened to and participated in the four modalities, design, or this case a creation of a Thesis, becomes a process of shaping “knowledge, practices and sensations” (Hubbard 1995, 155), with the built realm as the catalyst for discussion and ordering.

The quadrant model (figure 2) is similar to Herrmann’s whole brain model that examines brain dominance in learning by challenging difference. Herrmann found that information is transferred from one hemisphere to the other, while each of the quadrants has its own specialized function (Herrmann-Nehdi 2008 and Tezcan 2017). As it is represented, this new fourth modality model also divides the primary relationships into four quadrants; however, unlike the Herrmann model, the x-and-y-axis are not merely divisions but play a more dominant role within the Theorem and Practicum relationship. The x-axis is concerned with ‘value’ and ‘interaction’ in terms of cognitive and intellectual operations; whereas, the y-axis is concerned with ‘order’ and ‘results’ in terms of logical and problem-solving operations. As a result, the beginning as indicated as ‘step 1: why?’ and the end of the cycle ‘step 4: what if?’ fall within the Theorem hemisphere and act as bookends to the Practicum that questions ‘what?’ and ‘how?’.

To reiterate, Hubbard’s Theory of Practice embodies three discourses: 1.) as an instance of architectural order, 2.) as an embodiment of values about living, and 3.) as the instrument for bringing about results (Hubbard 1995, 12-19). Here, Hubbard presents a straightforward and clear message: good building design should have order, reflect communal values, and achieve results. We’ve now argued for an additional modality: 4.) as a speculative interaction of Theorem and Practicum.
To unpack this fourth modality, the notion of interaction is further explored in four sub-frames, labeled A.) ‘about’, B.) ‘within’, C.) ‘explore’, and D.) ‘expand’ and are categorized according to their relationship to the speculative interaction of Theorem and Practicum. While recognizing the importance of order, values and results, the more speculative fourth modality ‘interaction’ does not see Practicum as an organized repertoire of units to be systematically practiced. Instead, ‘interaction’ asserts a more goal-oriented, meaningful activity and an important driver for education. Interaction serves as part of a system, and that system then becomes the force guiding the assimilation of all the modalities. To clarify the complexity of interaction as it relates specifically to an academic thesis, the concept is broken down into four qualities or traits to give a hand defining it. Interaction trait A.) About: surveys the environment both pedagogical and architectural that surrounds it. Trait B.) Within: is composed of student work produced within the walls of the academy, where a thesis student works in tandem with an advisor to develop a Theorem; Trait C.) Explore: investigative knowledge loops that suggests a palimpsest-like dynamism; and, Trait D.) Expand: pushing the frontier by examining the various fields that factor in the emergence of an architecture culture: education, practice, discourse and media (Figure 3).

Figure 3: by author

The four qualities of interaction permeate and connect the diverse areas of research explored that in combination with Hubbard’s ‘order, value and results’ provides an argument that rather than questioning: “is doing architecture doing research” as articulated by Jeremy Till; instead asks: “is doing research doing architecture”. Our aim is to expand the field where the interaction of Theorem and Practicum is not an isolated act, but one of speculation. This fourth position is that doing research through the act of speculation is a form of architecture in its own right, and should not be separated from the act of making. Thereby situating Theorem within
Practicum: knowledge + making are inseparable. It is for this reason that an investigation as Theorem is presented as ideas, but it is in the realization in built form, or Practicum, that convinces us (Smithson 1955, p.2).

CONCLUSION: EVERYTHING OLD IS NEW AGAIN

The interaction of theorem and practicum is perhaps not a new discourse, in fact it was first proposed by Vitruvius in his publication of De Architectura Libri in 30-20 B.C. In book I, Vitruvius begins with the education of the architect and then proceeds to a discussion of principles. These principles are intended to establish the Arche, or foundational principles of the discipline of architecture. This is followed in book II with a discussion of the origins of society, buildings and materials that constitute the causes, or Aitiai, of the discipline. As such Books I & II serve to constitute a demonstration on the order of Aristotle’s ‘official’ concept of techne through their elucidation of the basic principles of (Arche) and causes (Aitiai) of the discipline.

One should not think of Vitruvius’ definition of techne solely as abstract theoria in its epistemological sense. He begins his treatise with the statement that the knowledge of the architect is born of theory (rationcinatione) and practice (fabrica). Practice, Vitruvius defines as “the continuous and familiar practice, which is carried out by the hands in such material as is necessary for the purpose of a design.” It is the act of making or performing a given task, the bringing forward of the idea or design found, as he argues, in the drawing. Theory, Vitruvius defines as: “The ability to demonstrate and explain the productions of dexterity on the principles of proportion.” This ability he claims is common to all scholars, not just architects. Theory is not just the explanation, but the demonstration as well, and this implies an experiential component to his understanding of theory. The word used here is demonstrare. In Latin, it means to bring forth or to show a hidden truth; that is to reveal, and it is linked to the concept of inventio, or invention.

The theoretical and demonstrative characteristics of techne are stated up front by Vitruvius when he states that; “both in general and especially in architecture are these two things found; that which signifies and that which is signified. That which is signified is the thing proposed about which we speak; that which signifies is the demonstration unfolded in systems of precepts.” If we relate this directly to his idea of architectural invention, the columnar orders are the demonstrations that signify the harmonic ontology of the ancient world. Theory, as Vitruvius uses it, is inherently demonstrative; practical, didactic and experiential. It is achieved through the application of techne in the creation of inventions. He therefore follows Aristotle when he asserts that the techne of architecture consists of a teachable body of principles that are engaged in praxis. Moreover, its didactic character comes through an engagement within a process of invention.

Although the practice of architecture has evolved in the two millennia since Vitruvius’ seminal book, his assertion to the necessary education of the architect, and to the nature of critical practice is perhaps even more meaningful today. Despite its strong qualities, this Vitruvian foundation of considering a relationship between practice-based and theoretical-based research takes neither learning styles nor brain dominancy into account. There is a possibility that it is more appropriate for undergraduate thesis-based research to establish a positive and significant relationship within the academy by assimilating and accommodating learning style subdimensions and inquiry skills, resulting in a holistic approach. As with the practice of architect, this paper argues that our current undergraduate architectural thesis programs are also slowly losing their meaning and usefulness in the academy. In order to prop it back up, we propose in addition to Hubbard’s three modalities: ‘order’, ‘values’, and ‘results’, the fourth modality: ‘interaction’ consisting of ‘about, within, explore and expand’; where cognitive and intellectual operations co-exist with logical and problem-solving operations creating a more all-inclusive approach, or holistic design method. For this reason, we believe that by developing a more inquiry-based research method as defined by four discourses will generate a new
understanding of an analysis and development of undergraduate architecture thesis programs by enhancing the student’s ability to not only think but also build critically.

REFERENCES


Vitruvius, *De Architectura Libri*, Book I-III.

ENDNOTES


2 At its core was a functionalist doctrine that dominated both architecture and urbanism, specifically with regards to the propositions that served as the foundation of CIAM. The result was the concentration on topics like the ‘Minimum Dwelling’ and the ‘Functional City’.

3 Team X, Aldo Van Eck, Jaap Bakema, George Candelis, Giancarlo de Carlo, Shadrach Woods and Alison and Peter Smithson, sought a more complex and sympathetic relationship between old urban tissue and new functions and to reintroduce into modern architecture the experience of ‘community’. To achieve this they sought a more primal language in which form and meaning would be one. According to the
Smithsons; “Our Hierarchy of associations is woven into a modified continuum representing the true complexity of human association ... we are of the opinion that a hierarchy of human association should replace the functional hierarchy of the Charte d’Athenes.”

“... We can understand this through Rossi’s concept of ‘Permanence’ that affects individual and collective artifacts within the city in different ways. The two main ‘Permanences’ in the city are housing and monuments. The individual house is likely to change over time and in that sense has no ‘Permanence’, but a housing district is likely to remain. It has ‘Permanence’. With respect to monuments, the relationship is the opposite. The monument is a primary and persistent urban artifact it possesses ‘Permanence’. Rossi’s typology introduces the idea of memory into the object which now comes to embody both an idea of itself and the memory of its former self. Such forms occupy a material presence in the city and its history.

The real and functional significance of them can remain indefinitely obscure with regard to the past that has produced them, but their mythical image remains so clear and present in our imagery today that they take on the value of a forma mentis. They persist through our collective memory as self-evident archetypal forms; the building blocks of the autonomous language of architecture. For the architect to not recognize this or to make use of it means condemning him or herself to incommunicability.


Vitruvius asserts this himself, “But in respect to the meaning of my craft and the principles which it involves, I hope and undertake to expound them with assured authority, not only to persons engaged in building but also to the learned world.” And then again; “ When I wrote this comprehensive treatise on architecture, I thought in the first book to set forth with what trainings and disciplines architecture as equipped, and to determine by definition its species and to say from what things it sprang.:” Vitruvius, De Architectura Libri, Book I c. 1.8.

Vitruvius states this himself when he says; “ For this book [book II] does not declare whence architecture arises, but whence the kinds of buildings have originated, and by what ways they have been fostered and, by degrees, advanced to their present finish. “ Vitruvius, De Architectura Libri, Book II c. 1.8.

Vitruvius, De Architectura Libri, Book II c. 1.1.

In De Architectura Libri Vitruvius gives numerous examples of such inventions including the Aeolus, a bronze ball filled with water that when heated reveals the exchange of energy that transforms water to steam. He used this to explain how wind currents are produced when heat and moisture combine. In the preface to book IX he includes Plato’s use of geometry to determine the necessary length of the side of a square double the area of an existent one and Pythagoras’ ‘theory of the hypotenuse of a triangle. The most famous of the inventions discussed are of course, the columnar orders that serve to demonstrate the theory of right proportions. By relating their proportions to the human body he is able to relate them to the discovery of symmetria in the human body and his discussion of ideal proportions in book III c.1.

Vitruvius, De Architectura Libri, Book II c. 1.3.

To clarify, we believe a way to accomplish this is to establish a relationship between McCarthy’s 4MAT teaching model and Hermann’s whole brain model that will accommodate learning style subdimensions and inquiry skills.
ABSTRACT: Engaging architecture as an emergent, complex system, this paper examines the implementation of a critical design approach -- the Seeding Sequence -- in two diametrically different studio courses: A 5th year Integrative Design and a 1st year Beginning Design one. Drawing from a Systems Thinking approach to understanding relationships, this critical design approach trades the designer’s impulse for formal control and fixation of the architectural object for one of a complex adaptive system. Framed against three past pedagogical approaches to beginning design, the Seeding Sequence process guides the students to work in a recursive cycle between two competing modes and scales of investigation: a modeling method that revels in the detail and a drawing method which considers the context. The Seeding Sequence moves beyond procedural actions by requiring a level of abstraction between the two methods. This paper presents the process, final results, and selective answers from the students’ evaluation from both studios this paper concludes by discusses the effects of this design process on three aspects of the students’ work: 1) withholding the ability to preconceive the result. 2) framing one methods of investigation against the strengths of another. 3) establishing direct connections between the design decisions and the unique attributes of the materials, program, and site of the project. This paper concludes by critiquing that the specific methods of investigation are selected to challenge the skill level of the students and the resolution of architectural design thinking required by the course. But more importantly, the pairing of two methods -- specifically two with dramatically different benefits and outcomes -- establishes an awareness in the student to actively question what each new method brings to their design process.

KEYWORDS: Design Pedagogy, Beginning Design, Integrative Studio

1.0. PRINCIPLE ACTION

Being creative is not just a matter of casting about for something novel—anybody can do that, since novelty can be found in any random juxtaposition of stuff—but of making the novelty jump out of some system, a system that has become somewhat established, for good reasons.

--Daniel Dennett, Intuition Pumps and other tools for Thinking

As in all adaptive systems, maintaining a correct balance between these two modes [unfocused and focused] of exploring is essential. Indeed, the optimal balance shifts over time. Early explorations, based on little or no information, are largely random and unfocused. As information is obtained and acted on, exploration gradually becomes more deterministic and focused in response to what has been perceived by the system. In short, the system both explores to obtain information and exploits that information to successfully adapt. This balancing act between unfocused exploration and focused exploitation has been hypothesized to be a general property of adaptive and intelligent systems.

--Melanie Mitchell, Complexity: A Guided Tour

With a cursory comparison of the NAAB criteria assigned, student-to-teacher ratios, and project briefs it can be said Beginning Design and Integrative Design are quite possibly the most disparate studio courses in our B.Arch curriculum. In addition, as Integrative Design is the 10th and final studio of our sequence, these two courses exemplify an extreme difference in the accumulated experience of students entering their respective class. The Seeding Sequence is an attempt to identify a process of investigation that remains critical regardless of the studio level or student skillset. Drawing from a Systems Thinking approach to understanding relationships, this critical design approach trades the designer’s impulse for formal control and fixation of the architectural object for one of a complex adaptive system.
Implemented in beginning design to circumvent nascent students’ preconceptions of creativity and novelty in design, this critical design approach returns to confront habits adopted through four years of academia in the fifth-year Integrative Studio.

Framed against past pedagogical approaches to beginning design, this paper defines a series of key concepts of Systems Thinking with specific focus on Complex Systems as defined by Melonie Mitchell’s work on Artificial Intelligence, to outline a design process. The Seeding Sequence process is first presented as an abstract framework, removed from either studio. The individual year levels are then presented with specific focus on the methods of investigation and exercises that are employed by the students.

Through selective examples from both studios, this paper concludes by discusses the effects of this design process on the students’ ability to self-critique by: 1) withholding the ability to preconceive the result. 2) framing one methods of investigation against the strengths of another. 3) establishing direct connections between the design decisions and the unique attributes of the materials, program, and site of the project.

2.0. FOUNDATIONS

2.1. Beginning design pedagogy

For context, this paper is being written while I sit on an Ad-Hoc curriculum committee discussing a possible return to a Common Foundations studio across our entire College -- the Architecture, Landscape Architecture, Interior Design, and 12 tracks of the Art school. Discussions on this committee have led me to reflect on the aspects of my beginning design education that have been fundamental to the success I have found instructing beginning design and upper level comprehensive studio over the past 10 years. I believe it is this ability to separate the lessons learned from the contrivances assigned, that plays a significant role in an instructor’s ability to reach ever younger generations of students.

Through my first beginning design assignments -- Point, Line, and Plane -- I can trace the reductive formal studies of Bauhaus’ Wassily Kandinsky and Paul Klee through an American take on abstraction defined by Arthur Wesley Dow and Denman Waldo Ross’ Pure Design at the Graduate School of Design. Paul Klee’s Sketchbook, handed to us by the faculty, acted as a Rosetta Stone to the world of 2D compositional languages. With little direction given, the four-exercise sequence allowed the students (myself) to revel in Paul Klee’s concepts of composition; Proportion and Structure, Dimension and Balance, Gravitational curve, and Kinetic and Chromatic Energy.

Paul Klee replaced deduction by Induction. Through observation of the smallest manifestation of form and interrelation, he could conclude about the magnitude of natural order. Sibyl Moholy-Nagy

For both Froebel And Itten, students learned by doing, experimentation for its own sake was encouraged and “play” was considered key in imparting important theoretical discoveries. Fern Lerner

Later projects in my beginning design education drew directly from Steven Holl’s reinvention of Columbia Universities Master of Architecture First-Year in 1986 under Kenneth Frampton. Although we did not design a cabin for a Poet/Riveter, our project briefs made direct reference to the kit-of-parts and abstract site conditions of Holl’s Point-Line and Line-Plane projects. In this series the students explore the objectives, site, and materials to develop an independent approach to designing meaningful experience. In comparison to free play building off Klee’s manifesto, these projects represented a complete pedagogical reversal – project briefs that withheld a state lesson.

In each of these assignments, an introduction, and develop of, self-critique played a significant role. An internal question as simple as “Is this point so large it is now a plane?” introduces the self-critique and authorship in design. Whereas, with Steven Holl’s projects at Columbia, self-critique as an internal voice is nurtured as each student is tasked to discover ideas within themselves that elevate the initial prompt. In both examples the process of designing is left to
the students. As integrative design criteria highlighted in NAAB C2 Integrated Evaluations & Decision-Making exemplify today focus on transparency and quantifiable accountability, how can a beginning design course develop the self-critique inherent in past pedagogy while facilitating today’s professional agendas?

2.2. Systems thinking
Scientist, instructor, and author, Donella Meadows earned the MacArthur Foundation ‘genius’ award in 1994 for her contribution to the understanding of dynamic complex systems. Her international bestseller, The Limits to Growth, along with the follow up The Global Citizen and Beyond the limits introduced a Systems Thinking approach to understanding the relationships between social and economic systems and today’s environmental concerns. Meadows discusses Systems Thinking as a problem-solving technique in her final book, Systems Thinking: a Primer. Here she defines a system simply as an interconnected set of elements coherently organized in a way that achieves a result. She goes on to explain that all systems have three key elements: components, interconnections, and a function or purpose. This approach to understanding relationships is scale-less, with examples in the book ranging from balancing-systems, such as, the cooling of a cup of coffee in a cold room, to reinforcing-systems like “success to the successful” playing out at national economic scales. In either case, using a Systems Thinking approach to understand the Elements at play, the Interconnections between those elements, and the Purpose that come from these interactions, creates a framework for an inclusive, multidisciplinary approach to problem solving.

2.3. Complex systems
Melanie Mitchell, a Professor of Computer Science at Portland State University, received her PhD from University of Michigan in computer science, where, in collaboration with her advisor Douglas Hofstadter, her dissertation focused on the development of artificial intelligence through a computational understanding of analogies. Her most recent book, Complexity: A Guided Tour, chronicles the history of complex systems leading to her exploration of cognitive science and complex systems as a means of approaching artificial intelligence. She begins by defining complex systems as networks that exhibit three identifying characteristics. First, they have a bottom-up logic -- there is not a central leader, but rather, complex systems are made up of individual components that have simple, established rules. Second, these individual components communicate with other internal systems (their neighbors) and external systems (their context). Thirdly, the individual components have the ability to adapt to the information they have received. Mitchell further describes emergent behavior within complex systems as unique organizations developing at the macroscale from component-level interactions. These emergent responses are considered self-organizing and allow for heterogeneity and unpredictability. Examples of these emergent responses range from the study of the complex interactions between ants in a colony to the synapse-exchanging neurons in our brain. Regardless of scale, political scientist Herbert Simons argues that the complexity of these systems can be measured by the depth of their hierarchy (the nesting of subsystems within a system) and the near-decomposability of the systems (the notion that individual elements in the systems have stronger logic within themselves than that which ties them to their neighbor).

2.4. Correlating systems thinking vocabulary
Adopting Donella Meadow’s Systems Thinking logic as a framework for architectural inquiry, the Components are identified as the students developed assemblies, program requirements, and site characteristics. The Interconnections refer to the relationship, or organization, of these components. For use in these design studios, the Purpose is to design architecture that is responsive to its internal and external systems.

Drawing from Mitchell’s definition of complex systems, the proposed design process -- Seeding Sequence -- prioritizes establishing a simple structural logic at the cell level. For this paper, and in both studios, a cell is identified as an Adaptive Assembly. This process demands the Adaptive Assemblies demonstrate a structural logic that responds to the composed
materials. In addition, the Assemblies’ internal connections are investigated as nested subsystems to demonstrate near-decomposability.

2.5. The seeding sequence
In the sciences, models are discussed as simplified representation of “real” phenomenon. Appreciating that all models are wrong, but some are useful \(^{11}\) we recognize the need to acknowledge the focus or benefit of one modeling method over another. Within architectural design, if we consider this idea of modeling the “real” as methods of drawings, diagrams, physical and computational models, we can appreciate each represent inquiries into the “real” with varied benefits. In both studios presented, the instructor specified the two methods for their ability to complement -- not necessary coordinate -- each other. By introducing these methods as a competition for leadership in the design process, students develop the ability to identify for themselves the benefit of each method.

Pitted against each other in a recursive cycle, a modeling method explores the impact of structural logic and material characteristics at the Adaptive Assembly level, while a drawing method facilitates the exploration of emergent behaviors at the macroscale. In each studio, the Adaptive Assemblies are developed first. Once the Adaptive assemblies have been constructed in one modeling method, a diagram of the Adaptive Assembly is seeded on a site in the competing method of investigation. (It is important to note an act of translation at this stage. The modeling method is not “rendered” in the drawing method, rather, the structural logic of the assembly is diagrammed. This moves the Seeding Sequence beyond a procedural process. With this abstract linkage, the designer’s ability to distill and diagram the essential logic, allows the Adaptive Assemblies’ compositional qualities to remain in the domain of the modeling method, while enabling the drawing to pursue emergent opportunities.) Emergent behaviors are discovered as the diagrams are allowed to rotate, repeat, and scale in response to internal system relationships (logic between assembly to assembly) and the external system opportunities of the program (circulation, spatial adjacencies, views...) and site (topographic, environmental, historic relevance...). In both studios, as the student adjusts the priority of various qualitative and quantitative elements of the project, the emergent behavior of the complex system responds accordingly. After multiple emergent scenarios are nurtured, the behaviors are assessed through inductive reasoning. This bottom-up approach allows for the discovery of an unpredicted intent or general concept. With the concept clear, a deductive process of design research refines the project efficacy. A recursive folding of this macroscale intent returns the designer to question the Adaptive Assemblies. How can the emergent order influence the evolution of the Adaptive Assembly? How in turn can the evolution of the Adaptive Assembly refine the macroscale results?

3.0. BEGINNING DESIGN STUDIO

3.1. Project outline
For the first semester beginning design project, students are asked to conceive a path that integrates five spaces into a given site. Through the semester, a single site is repeatedly challenged with increased programmatic and site requirements that demand a re-evaluation of prior design decisions. The iterative nature of the project sequence reinforces the benefits of a critical design process while allowing craftsmanship to develop.

The students begin by framing an architectural prompt into components, interconnections, and purpose. Within this process the purpose is to design an architectural intervention that is site-responsive to its landscape. Although subtle, the term “intervention” allows tectonic and stereotomic design decisions freedom from the student preconceptions of the word “building.” The components consist of the Adaptive Assemblies, the assigned architectural program, and site information. The program remains abstract with minimal area and adjacency requirements between a large “A”, medium “B,” and three small “C” spaces. As the project progresses, several spaces engage the topography as they must be embedded into the landscape. The final attempt includes the investigation of human scale circulation, sequence, and specified...
views. The site opportunities begin with the consideration of the sun path and rough topography and as the project gains complexity, an entrance and exit to the site along with attracting and repelling points of interest must be responded to by the nascent designers.

Two distinct methods of investigation are employed in this beginning design project: the Adaptive Assemblies are developed through physical models made of found woods and metals while Emergent Behavior is explored at the macroscale through a multimedia drawing. The physical models begin with a series of material investigations to develop a catalog of connection types -- binding, pinning, and joining. These details are employed in the construction of Adaptive Assemblies. The Adaptive Assemblies must clearly communicate primary, secondary, and tertiary structural members while developing complexity within the connection details (subsystems).

At the beginning design level, Interconnections are discussed as the formal organization strategies of the assemblies. The students are challenged to communicate an understanding of the balance between order and novelty through a multimedia drawing. Formal order systems are disrupted as emergent behavior of elements respond to the site and program.

**ADAPTIVE ASSEMBLY**

Physical Model:

**Material Characteristics**

**Structural Hierarchy**

**EMERGENT BEHAVIOR**

Mixedmedia Drawing:

**Site Circulation**

**Program Adjacencies**

*Figure 1. Process of Translation between competing methods of investigation, Beginning Design. Student C. Welch. (Author 2018)*

The 2D method introduced this semester is a mixed media drawing consisting of a pastel base layered with 4H, 4B, and ink. The goal of this method is to develop the student’s ability to fluidly move between the ambiguous (in this case pastel exploration drawings) to an analytical resolution (defined Euclidean elements) in ink. Each medium is paired with a purpose: *Gestures* in Pastels capture the site context. *Explorations* with light 4H graphite strokes explore emergent behavior in ordering strategies of the Adaptive Assemblies due to program and site opportunities. *Definitions* with 4B clearly articulate and annotate the emerging design elements. *Execution* in ink facilitates a level of resolution in design decisions that were previously unattainable. Although first stated as a sequential (linear) process, erasers are referenced as design tools which allow a continual fluctuation between the mediums -- a reworking of design decisions. Success is demonstrated through the ability of the process drawing to communicate an awareness of ordering principles -- grid, linear, radial -- while allowing complex emergent behavior to respond to the program and site. Once the students have become facile with the Process drawing, a class discussion frames that the use of multiple mediums had several agendas: one, establishing a range of 2D foundational skills; two, shifting a desire form a goal of achieving perfection for one of continual exploration and refinement. Once the students accept these ideas, the mediums selected are themselves irrelevant and more importantly is developing the ability to question how to think through the process of drawing.
Student comments on the Seeding Sequence

“In the class, “drawing” quickly became more of a study tool and less of an art. Therefore, the ability to understand how blind exploration was used and could eventually provide certain ideas didn’t come easy in the beginning. It took overcoming that hurdle before I could understand how exploration meant seeing/finding new opportunities, and then how concentrating those opportunities meant seeing/finding an end product.” Beginning Design Student 01

“This design method has really helped me to loosen up with my design. Coming into the class, all of my pencil lines were hard and dark and every one of my designs are pretty set in stone after the first or second drawings. Through this method, I learned that if you are loose with your design, the possibilities are endless in what you can create.” Beginning Design Student 02

“I feel that I learned how to more efficiently experiment in designing, and how to explore more options and opportunities on the page in front of you. We learned to find some element of our work or create something special and fall in love with it and nurture it into something beautiful.” Beginning Design Student 03

“I found these processes very liberating in helping me to experiment without having a definite end result.” Beginning Design Student 04

4.0. INTEGRATIVE DESIGN STUDIO

4.1. Project outline

As the tenth studio in a Bachelor of Architecture program, this Integrative design studio is assigned a collection of NAAB’s synthesized criteria. A single project runs the entirety of the
semester exploring a complex building program on a complex site. The projects presented are proposals for a community radio station and adjoining 500-seat theater in a disaster-prone region. The projects will be measured on their ability to connect community engagement with the required functions of a relief shelter.

Utilizing the Systems Thinking framework, the students divide the prompt and their group research into components, interconnections, and purpose. In this studio, the components consist of the Adaptive Assemblies, the assigned architectural program, and site information. Within this process, the purpose is to develop an architectural design that is explicit in its response to the unique attributes of the materials, program, and site of the project. Two distinct methods are employed in this Integrative design project; a digital model is utilized at the Adaptive Assembly level while axonometric diagrams nurture emergent behavior at the macroscale.

**ADAPTIVE ASSEMBLY**

**Section Drawings:**

**Material Characteristics**

**Structural Hierarchy**

**TRANSLATION**

**EMERGENT BEHAVIOR**

**Axonometric Drawing:**

**Spatial Adjacencies**

**Passive Design Strategies**

**Circulation**

*Figure 3. Process of Translation between competing methods of investigation, Integrative Studio. Student A. Verastegui. (Author, 2018)*

As a group, the class defines key characteristics of the site and building program to research. Rather than a broad overview, this research forms a constellation of factors. The Adaptive Assemblies must demonstrate architectural responses to both the composed materials and a selection of these key factors. Three Adaptive Assemblies -- a porous wall, a retaining wall, and a green roof assembly -- are modeled independently. Each begin as simple diagram where selected program and site areas of research are notated. Self-selected precedent projects aid the students in the development of architectural resolution of the assembly models. Success for these Adaptive Assemblies is measured through the design and communication of details (subsystems) that respond to the program and site opportunities prioritized.

At the macroscale, the interconnections are the spatial and circulation systems exhibited by the assemblies. The axonometric diagrams communicate each building system’s response to various adjacency requirements. Emergent behavior in the spatial and circulation systems form as passive design strategies address alternate theater arrangements -- a Thrust, a Proscenium, and a Theater In-the-Round. The success of the axonometric diagrams is assessed in their ability to communicate the emergent behavior by the Adaptive Assemblies as they respond to spatial and programmatic requirements.
Figure 4. Development of an Adaptive Assembly, Student B. Ponvelle, E. Knapp. Emergent Ideas responding to context and program, Student (Author 2018)

**Student comments on the Seeding Sequence:**

“The layout of the course was different than past years but helped me develop a part of design I've usually lacked in the past.” *Fifth-year Student 01*

“The instructor provided a unique method of teaching this semester that helped me understand the methods in which I was building and designing.” *Fifth-year Student 02*

### 5.0. OUTCOMES

The Seeding Sequence design process presented in this paper, along with the student work and selected evaluations, demonstrate a design approach that relishes the complex nature of architecture and its design. In doing so, fundamental skills of self-critique were established while through a framework that facilitates today’s focus on transparency and accountability of design decisions.

**Was this Seeding Sequence successful withholding the designers' preconceptions of form and concept?**

At both studio levels, the developed the Adaptive Assemblies first, specifically one that exhibits near-decomposability with nested subsystems, focused the students’ attention away from preconceived ideas of form and concept of their final designs. As seen in nature’s complex systems, this initial investment of design into the base unit level, allows complexity to emerge at the larger scale from the simplest of organizational strategies. In Beginning Design, with the deployment of only a handful of Adaptive Assemblies, the students witnessed their projects achieve a complex design response far beyond their design vocabulary. Although very complex, the logic established in the units remains legible, allowing for the reading and refining of novel design decisions. This sets a respect for design process, rather than a design epiphany. At the integrative studio level, with the Adaptive Assembly (wall sections) matured, each initial spatial adjacency scheme quickly communicates a complex layering of decisions. As the students’ progress with the work, challenging the design to respond with greater sensitivity to programmatic and site opportunities, the emergent design ideas move the student’s design responses far beyond a reductive concept.

**Did the process actively question design decisions made in one method of investigation with those of another?**
Within beginning design, introducing the multimedia process drawing and Adaptive Assembly model making methods stages a moment when the student must come to terms that there is not a single correct method, tool, or digital program to design with. The student perceives how each method falls short in representing the others strength: The Adaptive Assembly model explores the design possibilities of the materials and techniques used in construction, whereas the multimedia Process Drawing nurtures a stronger understanding and evolution of formal organizational strategies. The Seeding Sequence pairing of two opposing methods, with dramatically different benefits and outcomes, establishes an awareness in the student to actively question what each new method brings to their design process. At the fifth-year level, the Adaptive Assembly Sections Drawings and Emergent Axonometric Diagramming focus the student on integrating professional communication skills into their design decision process. The rigor of the construction drawings as a means to express the design response to site and program through scale and tectonics while the holistic axonometric diagrams document the internal and external systems at play at the macroscale. The programmatic, environmental, and structural concerns that influence the initial axonometric diagrams lead to an evolution of the Adaptive Assembly section drawings. As the assemblies find resolution, the axonometric drawings can take on greater depth of systems integration. It is important to note that in both studio levels, the paired methods of investigation were selected by the instructor to challenge the skill level of the student and the required resolution of architectural design thinking for the course. Unlike Integrative Studio, where the methods are taken from the profession, it is important for the beginning design students to reflect that the drawing materials themselves are irrelevant. More importantly, is the ability to question how to think through the process of drawing.

How does the process demonstrate design response to the unique attributes of the materials, program, and site of the project?
Developing Adaptive Assemblies prior to establishing a general theory or concept, allows the student to make direct relationships between the architectural decisions at the assembly and sub-system levels that respond to the material, program, and site considerations. The
elimination of glue for the beginning design students' Adaptive Assemblies demands tangible response to the characteristic of each material used. Whereas the Integrative Studio's isolated approach to developing the Adaptive Assembly sections, allowed the student to focus on the design decisions relationship to the immediate human figure and site context. Once these design decisions have been embedded into Adaptive Assemblies, at either studio level, their deployment at the macroscale facilitates a general theory or concept to be drawn out of the emergent behavior. This bottom up approach allows the concept to form from the students' architectural design decisions, rather than a concept with which they struggle to find architectural resolution. Once identified, a deductive investigation of an emergent theory or concept focuses the design resolution with each recursive iteration of the two methods of investigation.

REFERENCES


Donella H. Meadows, as found on https://www.macfound.org/fellows/495/

Phi Beta Kappa Award in Science Winners as found on https://www.pbk.org/Awards/BookAwards/ScienceWinners/

Conditions for Accreditation National Architectural Accrediting Board, Inc.

ENDNOTES

1 (Dreamer, 2004)

2 (Ockman, 2012)

3 (Lerner, 2005)

4 (Klee, 1968)

5 (Johnson)

6 (NAAB 2014)

7 (Meadows 2009)

8 (Mitchell 2009)

9 (Meadows 2009)

10 (Simon 2002)

11 (Box, Draper 1987)

12 (NAAB 2014)
ABSTRACT: This paper presents an undergraduate design studio as a site for research. In discussing the validity of design research, Groat and Wang point out that Ellison and Eatman (2008) define public scholarship as a form of socially engaged research (2013:51). This paper posits that design is often a form of exploratory research or hypothesis-seeking. Although this project is socially engaged, considering design research as exploratory opens the door to a broader group of projects. Business researcher Dudovskiy defines exploratory research as investigations that explore the nature of a question without requiring conclusive results. He points out that “the researcher ought to be willing to change his/her direction as a result of revelation of new data and new insights.” (2018). Here we argue that when an architectural design studio involves research to analyze and develop evidence (including literature searches, site visits, input by experts and engagement of community members), as well as rigorous investigation of design hypotheses (evaluation of alternative designs, documentation of architectural characteristics, generation of evaluation criteria, and rigorous assessment of options), the design studio becomes a site of research scholarship that informs design. The design studio presented here originally focused on reconceiving youth rehabilitation, but was reframed as preventing youth incarceration. The diverse final project proposals explore the general hypothesis that providing appropriate youth and family services in the community may contribute to the prevention of juvenile incarceration.

KEYWORDS: Pedagogy, Studio, Youth, Incarceration, Studio-Based Research

1.0. THE EXPLORATORY RESEARCH

As a part of the 5th studio undergraduate experience,1 the studio was organized to take an exploratory approach to the study of youth detention facilities. Recently at the University of Minnesota School of Architecture, the curriculum at this studio level has been structured to bring architectural firm practitioners as studio instructors and critics to design and develop a building as a professional project including design details. The youth rehabilitation studio was structured somewhat differently, in that the author, a faculty member, working with Angela Cousins, a Hennepin County Department of Corrections and Rehabilitation professional, brought the research project into the studio, inviting BWBR, a local firm with expertise on incarceration and therapeutic settings to co-teach and participate as experts. Several firm members cooperated on developing the syllabus, architect, Dan Treinen, the firm design leader joined the studio as instructor for approximately one class per week, and firm members participated in presentation/discussions with students as well as on developmental and final project reviews during the semester.

Hennepin County had launched a project to redesign residential services for ‘Department of Community Corrections and Rehabilitation (DOCCR) – involved youth to create a continuum of services for DOCGR-involved youth who are in, or at imminent risk of out-of-home placement to address their complex behavioral or mental health needs.‘ Having previously proposed a regional joint facility with neighboring Ramsey County that was rejected by community members as being too institutional, too large, and also too far from families (suburban), the county was interested to find a different way to develop the continuum of services. The collaboration with the university sought innovative design approaches to rehabilitative, de-institutionalized, inner city treatment for youth, rather than the current punitive, non-urban orientation.
Working with the county, the community, university experts and architects, the original idea was to explore how attitudes such as education, normalization, rehabilitation and healing are expressed in architecture. As with most design projects, exactly what this meant was to be discovered.

2.0. RESEARCH APPROACH

The previous semester in a seven-week graduate design module, the instructor and author had focused on the design of settings for adult incarceration, using sketch models, and a programming approach that included the rigorous development of assumptions, hypothesis and design directives (Robinson and Weeks, 1984) at each phase of design, as well as citation of research that supported decision-making. This time the same approach was taken, but the project examined the issues related to youth instead of adult, incarceration. In both studios, because in Minnesota there are no private prisons, we did not address the question of public versus private funded institution.

Information gathering included class reading of literature on incarceration broadly (Alexander, 2012; Davis, 2003), literature on existing traditional and innovative approaches to incarceration and non-punitive, therapeutic settings (e.g. Benko, 2013; Ferro, 2014; Krueger and Macallister, 2015; Foster, 2017; Slater, 2017; Slade 2018), on youth psychology (e.g. Requarth, 2017) and literature on architecture reflecting attitudes (Canter and Canter, 1979; Foucault, 1979; Robinson, 2006; Hertzberger, 2008; Alt Architecture & Planning, 2016). The readings were debated and analyzed in a series of discussions in the context of site visits and discussions with experts and community members.

After the initial exercise on preconceptions, the students completed a precedent analysis. Teams of three students analyzed four precedents each, a traditional prison, an innovative prison, and two non-incarceration settings (e.g. addiction treatment, student housing, hotel, monastery/ convent). Some of these settings were designed for youth and some for adults. Students were asked to identify the assumptions and attitudes that the places communicated and to detail what aspects of the design communicated these (design directives). This exercise was intended to help students appreciate the wide range of architectural expression that might be employed in design.

During the initial weeks of the semester, students visited three different settings, a juvenile detention center, a traditional prison now serving short-term prisoners with sentences less than one-year, some of whom were working in the community, and a high-end youth addiction treatment center. Also during the semester, but mostly at the beginning, students had the opportunity to learn from various experts on topics such as Treatment Goals for Youth Offenders, Changing Landscape of Juvenile Detention, Trends in Juvenile Mental Health/ Juvenile Versus Adult Responses, Discussion of Challenges of Youthful Offenders with Parents, The Spectrum of Care for Youth, Design for Youth Mental Health Treatment, Alternatives to Juvenile Detention, an Staff Perspective on Design for Troubled Youth. Although these events generally began with the experts in design, child psychology and juvenile treatment, and parents presenting information, they ended up with student questions and discussion. Additionally, experts, including parents/ community members sat on the reviews of student work, providing important information and feedback.

After the precedent analysis exercise, students participated in a ritual-place exercise that involved the use of sketch models to study how one type of place could express different attitudes depending upon its design. Each student studied a variety of social places and activities (eating, relaxing, entering, etc.) and how each place could be designed differently to represent two of the attitudes. Subsequently, students identified a program that addressed the spectrum of services, and using analogies, as well as assumptions, hypotheses and design directives, developed two possible building arrangements in the form of sketch models. Students then chose two sites in a specific neighborhood, analyzed each one, and located the
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two programmatic arrangements on each site, evaluating the four alternative schemes to choose a scheme and site for development,

3.0. RESEARCH FINDINGS

Security. The precedent analysis, site visits to the incarceration settings, and statements by the expert on adult incarceration facilities, showed that a driving factor in the design of such settings is the perceived need for extreme security. Discussions with the prison staff and readings from literature also revealed that while high security was considered important for the entire facility, actually a very small percentage of people at any of the settings was sufficiently dangerous to require such high security. Furthermore, we hypothesized that the stigma of incarceration, which affects the reception of incarcerated people in the community, was due in large part to the assumption that all incarcerated people were so highly dangerous to society that they required such security. The class concluded that rather than design incarceration facilities around security, any very dangerous residents could be treated independently, and in general, but especially for youth, such facilities should simply be seen as housing. In Germany, for instance, youth under age 18 are rarely incarcerated, and what the Europeans call “emerging adults” aged 18-24, are placed in normalized settings with almost no security (Schiraldi, 2018; Pruin and Dünkel, 2015). This is based on the understanding of human development recently found by neurological researchers indicating that emotional maturity and self-control are typically delayed in males until the mid to late twenties (Requarth 2016). Legal scholars have concluded that we need to reconsider what we see as the age of legal maturity.

Hypothesis: Since creating hyper-secure incarceration facilities stigmatizes people who are incarcerated, and prevents them from living in normal housing, the level of security should not exceed that necessary to protect society. Thus high-level security facilities should be reserved for extremely dangerous people. To provide humane treatment and a setting that promotes rehabilitation, people who have been found guilty of crimes and are not dangerous should be housed in what Nirje (researcher on normalization for adults with developmental disabilities) described as “providing the conditions of everyday life which are as close as possible to the norms and patterns of society’s mainstream” (1969: 181). As the Europeans are coming to see, removal from one’s own home is sufficient punishment, and a non-punitive form of housing contributes to rehabilitation (Benko, 2015).

Hypothesis: It is counter-productive to incarcerate young adults. They should be considered to be troubled youth, and their problems should be addressed with specialized treatment. Unless they are a danger to others, youth should remain in their communities to be treated and rehabilitated, which will eliminate transition problems, and reduce recidivism.

Mental Illness and Addiction. Based on research that students did independently in this class and in the previous studio, on mental health and youth incarceration using the National Alliance on Mental Illness (NAMI) website (supported by research from the Department of Justice website, e.g.), and also on information received from the child psychologist, from parents and from visits to the youth centers, we discovered that incarcerated youth are very likely to have been traumatized themselves (e.g. Olafson et al, 2016), and are more likely than other youth to have mental illness (e.g. Shufelt and Cocozza, 2006). Additionally, we learned from parents that there is inadequate full-time mental health treatment for youth in the State of Minnesota, resulting in young people being sent far out of state to places such as Michigan and Texas. Furthermore, research indicates that “Involvement with drugs or alcohol increases the likelihood of continued and serious contact with the juvenile justice system” (Young et al, 2007). We concluded not only that residences for youth needed to reflect an attitude of healing, but also that mental health and addiction treatment facilities for adolescents needed to be provided in the local community.

Hypothesis: Many youths are incarcerated because of mental illness and/or drug addiction. Instead they should receive treatment for their problems. Because of proximity to family, and advantages in transitioning after treatment, young people with mental illness or addiction who are adjudicated, should not be incarcerated, but should be treated for their illness in their
communities. Sufficient mental health and addiction facilities should be provided for adolescents in their local communities.

Hypothesis: Because troubled youth are subject to trauma themselves, punitive designs augment their problems. The facilities that served troubled youth should be designed to be therapeutic and healing.

Homelessness. Another problem faced by many youths in Hennepin County is homelessness and lack of a family. Other young people may choose to live apart from a difficult family, or may have been rejected by their family for a variety of reasons including addiction, problem behavior, mental health, and/or gender identity. Adolescents who are homeless are vulnerable to involvement with the justice system. While residential facilities exist for this group in the county, they are insufficient to meet the need. Sufficient facilities to meet their needs will help them avoid getting into trouble.

Hypothesis: Creating community-based housing for young people who are homeless that includes counseling and treatment will help them avoid becoming involved with the justice system, and help them develop into productive adults.

Location and Family Support. The visits to the adolescent detention facility and information from experts revealed why the community had been unhappy with the county’s proposal for a new treatment facility to be located in the existing suburban location. First of all, the facility was far from the places where the youth’s family lived, and there was no public transportation available. The county supported transportation at certain times during the week, but not necessarily at the convenience of parents. Also, the distance meant that parents had to find a large block of time for the visit, which was an economic disadvantage to people already in a difficult economic situation. Second, although the available education was able to be tailored to the needs of the particular youth in the facility, which often contributed to academic success for the first time, the time able to be devoted to this was about three hours of education. Additionally, the lack of facilities affordable to such a small population of young people (30 typically in 2018) meant that the program was very limited compared to a typical high school. Third, the treatment, including individual and family counseling, was typically successful in improving the situation, but once the term of stay was complete, it was impossible to maintain the type of advice and counseling that had been so helpful, because of the distance from the community and the lack of transportation, so the transition back to the home environment was fractured.

Another important set of findings came from the parents’ description of their experiences. The two parents who spoke to us represented Native American and African American experiences. Both were women who had had a child in the youth detention system. Both had been single mothers raising several children, working two jobs to support their families, who could only afford housing in neighborhoods with significant problems with crime and drugs, who couldn’t afford child care, and whose relatives were looking after their children, not always with ideal supervision, especially of adolescents. The problems they faced were due to poverty, lack of child care, and in general lack of family support in their neighborhoods. When our students studied the neighborhoods where most youth in the county detention facility came from, they discovered that after-school activities were strong for elementary school children, but weaker for middle-school youth, and activities appropriate for high school youth, with the exception of sports, were almost non-existent.

We also learned from the child psychiatrist that what made youth vulnerable to gangs was the need for acceptance. Children traumatized by their family situations, children bullied because of such things as learning disabilities are susceptible to the what often appears to them to be the security of being in a gang. This elevated the need to help families with their child-rearing practices, and to identify children with disabilities at a young age, so they could be helped before they would begin to struggle in school. This suggested that provision of child care and
family support was an essential part of preventing youth from becoming troubled. The youth too, some of whom are parents, would benefit from the provision of child care and parental support.

**Hypothesis.** If troubled young people need 24-hour a day treatment, that should be provided in the community where they live, to facilitate transition to community life after care.

**Hypothesis.** Provision of child care is an essential ingredient to support working parents as well as youth with children. Child care should be made available to all, along with parental education about best child-rearing practices.

**Hypothesis.** Child care and family support need to be designed to identify disabilities early in a child’s life so that treatment, and family education can prevent later problems in school and adult life.

**Hypothesis.** By providing facilities in local communities for young people and families that assist with activities such as parenting, child care, family counseling and support, job training, literacy training, college preparation, mentoring, and after-school activities designed for older youth (including athletic recreation, expressive arts, digital and other skills development, and tutoring), families will be more able to address the needs of their youth members, and the young people will be less likely to get in trouble.

Institutionalized Racism. Perhaps the most significant finding came from our comparison of visits to the county detention facility and the high-end adolescent addiction treatment center we visited. At one time the county treatment center, built in the 1960’s with some more recent renovations, held a hundred or more young people, but in fall of 2018, there were approximately 25 youth. The Addiction Treatment Center, in contrast held about 100 young people in a facility that was built in 2016 to the highest therapeutic rehabilitation standards. One difference between the two places was that costs of the young people housed in the county facility were borne by the county, while those in the private center were covered by private insurance.

But more significantly, at the time of our visit, all the youth in the county facility were African-American, and in the private center, the youth were almost entirely Caucasian. Despite having read *The New Jim Crow*, we were very shocked. There was no avoiding the conclusion that we as a society were defining troubled youth as either “criminal” or “having problems,” depending upon their race and economic status. The difference in attitude at the two facilities can be best seen in the way that “time out” spaces were designed. At the county facility, “misbehaving” kids were sent to the crisis intervention unit, an area under 24-hour surveillance, with a sally port and secure metal doors. Here the windowless rooms were designed very much like prison cells with exposed concrete block walls some of which were covered with padding on all surfaces. At the addiction facility there were no equivalent spaces, although entering youth experiencing addiction withdrawal were housed in the health facility under similar surveillance, but in typical dormitory-style rooms with windows, sheetrock walls, and carpeting on the floor. When in crisis, the African-American youth were placed in a punitive environment like criminals, while the Caucasian kids were treated as health patients needing care.

**Hypothesis:** Instead of calling youth who are in trouble “criminals,” we should call them “troubled,” and treat them for their symptoms, whether as mental illness, drug addiction, problem behavior or other challenges, which will prevent them from getting into trouble with the law in the future.

**Hypothesis:** The environments that serve adolescents should not be criminalized. By giving youth with the tools to treat their symptoms, whether mental health, addiction, anger management, and providing these tools in settings that are non-punitive and non-institutional, youth will be less likely to get in trouble with the law. More appropriate attitudes are: healing, therapeutic, educational and normalized.
Spectrum of Care. At a mid-point in the semester, it became obvious that the problem we were considering went beyond the design of housing. When considering the “spectrum of care” as a housing problem, we assumed was that the spectrum to be addressed was how to design youth facilities for incarceration, mental health treatment and addiction. But when determining a design program to address youth rehabilitation, we realized that we needed to address the whole family situation, not just the youth. We came to see the spectrum of care as needing to serve each child, family member, and family as a whole. We held a meeting to figure this out, identifying out the needs of the child and the parent at each phase of a child’s life, asking “What do children, parents and family members need at each phase?” Devising a matrix on the white board, with the developmental stage at the top (infancy, preschool, elementary school, middle school, high school, young adult), for the rows we developed four factors to consider: 1. the child, 2. the parents, 3. the challenges and 4. the programs or institutions that could help. The students based their proposals on this spectrum of care in a variety of architectural and service programs, some of which incorporated housing, and others of which served families more broadly.

Hypothesis: Providing a spectrum of care that addresses the needs of infants, children, youth, adults and families as addressed above, especially in areas of the city facing poverty and crime, will significantly reduce youth involvement with the justice system.

Hypothesis: Developing a justice system that does not incarcerate troubled youth, but discovers and develops appropriate treatment will reduce the number of youths who are involved with the system as youths and adults.

4.0. APPROACH TO THE DESIGN
The students saw the importance of their designs being neighborhood specific. As mentioned earlier, we had information on where in the city the juvenile facility residents’ families lived. Within these two primary areas of the city, each student or student team selected a small neighborhood to serve, typically about ten blocks square- a subset of what is defined as a neighborhood by the city. The students studied these smaller areas in the context of the surrounding areas, discovering which services already existed in the area, so they would complement rather than duplicate what was there.

As described earlier, they placed their alternative program arrangements on two possible sites selected from their chosen area, and evaluated the four possible options, selecting one site and one program approach, often adjusted for new insights gained from the analysis. At this point some students chose to pursue their project individually, and others chose to do so in teams of two.

5.0. STUDENT PROPOSALS
Of the eight student proposals, three included housing, the group home proposal, the mental health proposal and the vocational training proposal. The others proposed community service buildings, a teen center, two athletics-based community centers, and an after-school activities center linking two existing service providers.

Group Home & Treatment Center Proposal. This project addressed the problems caused by the distance of the existing juvenile treatment center from the communities it served. The approach distinguished between housing and treatment, housing being either a group home or a family residence, and the treatment center, which could serve youth in the incarceration system, youths who had served their terms and lived at home, or other youths in need of assistance. Treatment includes after-school activities (physical recreation, academic assistance, creative activities), and rehabilitative support (individual therapy, family therapy, etc.). The key idea is that throughout their sentence, release, and transition consistent, stable treatment can be provided, as well as the ability to attend a local high school, so that the living pattern of housing-school-treatment-housing can be maintained whether a young person was living in a group home, a family residence, or possibly, independently.
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The group homes were conceived of as treating people with particular problems such as chemical dependency, mental health, homelessness, or problem behavior. Each design would be unique, fitting the need of the youth program, regulation requirements, and the adjacent neighborhood context. For example, a building could be a newly built apartment-style building for twenty-four homeless youth located in an area of single family and multi-family units, or a renovated house for a group of eight youth challenged by addiction in an area exclusively of single-family dwellings. The Treatment Center is centrally located next to an alternative school, and is easily accessible to two other high schools. Residents would be bussed between housing, school and treatment.

![Figure 1. Community-Based Adolescent Care, Undergraduate Student Project by Luke Walsh, University of Minnesota Fall, 2018.](image)

**Figure 1.** Community-Based Adolescent Care, Undergraduate Student Project by Luke Walsh, University of Minnesota Fall, 2018.

**Mental Health Treatment Facility.** Located at the edge of one of the neighborhoods, and designed to be welcoming, the facility is adjacent to the river and parkland. It designed to serve, short-term, long-term and drop-in youth, providing a needed service for the city and the neighborhood.

**Community Centers.** The projects that developed community centers were primarily focused on the needs of youth. In one case, the project was designed to provide after school activities and athletics for older children and youth, with each having their own spaces, as well as space for service providers (food assistance and counseling). In the second example, the building, intentionally located between two existing service providers (a YMCA and a Health Care Provider), offered post-treatment, prevention and integration, in the form of hang-out space, mentoring activities, and counseling, filling the vacuum of support not offered by the adjacent projects. The third project was designed to attract youth as a hang-out spot. Having observed that the neighborhood after-school options were limited to activities that would interest elementary school kids, this center provided social space.

The fourth community center project, “Prevention at Farview,” designed by a team of two, addressed especially male youth in context of the entire spectrum of care. Based on the comments by park staff that the kids who came regularly to the center stayed out of trouble, the idea was to make it a place where kids would want to come. The proposed building was designed to replace a very busy, but outdated neighborhood gym and community center. Discussions with community members showed that the site was highly used by one ethnic group, but not at all by others. The goal was, therefore, to make sure that the new facility would be designed to welcome all. Designed as a neighborhood beacon, the design includes a large amount of glass, with a long-activated corridor that leads to the well-lit, and visibly prominent, upstairs gymnasium.
To serve two objectives, recreation and focus, the athletic facilities are primary, with the park site including many different types of game fields. But under the category of focus the building also provides space for child care, individual and family therapy, college prep, tutoring, and mentoring as well as literacy and job training. At the top of the hill the center straddles, is a café that overlooks the playing fields with cool drinks in summer and hot drinks in winter.

**Forest Child Care.** The final project is a child care center for disabled and normally abled children between the ages of three and five. It is designed to provide high quality care for kids, while specializing in identifying disabilities, providing therapy through nature-based learning and play, and training parents to deal with their children. The student provided statistics on the on the importance of child care in relation to juvenile success from research in Chicago that demonstrated 40% reduction in special education placement, 29% higher high school graduation rate, 33% reduction in juvenile arrests, 41% reduction in violent arrests, (Newman et al, 2000). Additionally, the student presented information on the success of outdoor or forest education of very young children in Finland and Denmark (Bentsen, 2013; Walker 2016) as the basis for his proposed forest school, located in the larger neighborhood in parkland along the Mississippi River. Having also learned from the adolescent psychiatrist that learning
disabilities were highly associated with crime and belonging to gangs, this project that allowed identification, and early treatment of disabilities seemed very appropriate.

6.0. IMPLICATIONS FOR USING THE DESIGN STUDIO AS A SITE FOR RESEARCH

Exploratory research studies are intended to explore an issue without knowing what will be discovered. As mentioned earlier, such research addresses questions that may not be well understood, requires being willing to change direction, and attempts to develop understanding without providing conclusive findings (Bukowski, 2018). This can also be called hypothesis development as opposed to hypothesis testing.

Design studios often take on issues that are not well-understood. Typically, studios develop designs with implied hypotheses, but most often this is done without a rigorous research approach, and without explicitly stating the hypothesis that is implicit in the design. This studio engaged a rigorous research process, a process of identifying assumptions, identifying key research sources, including expert participants, identifying hypotheses and developing designs that consciously address the research findings.

There is an advantage to work with co-instructors that bring expertise to a project. There is also an advantage to working with a group of students who bring a fresh look at issues, and a willingness to find information. Having so many perspectives focus on a project is highly valuable to exploratory research. Finally, working with advanced architecture students brings an ability to see the design implications of findings. It can be a challenge, however, to get all the students on board with the rigorous methods required. This group of students were excited and willing to take the necessary steps to do valid research.

In terms of the research findings (security, mental illness, homelessness, location, family support, institutionalized racism, spectrum of care), we addressed some of them directly, and others more indirectly. The most difficult finding to address was that of institutionalized racism. We did our best to not describe or treat the youth as offenders, and to treat all of the people in our building designs with dignity, creating places that well-designed and non-stigmatized. By focusing on the neighborhoods where the youth in the justice system come from, we have discovered neighborhoods where it is difficult to raise children, and the problem of locating facilities near the families that need them. The student projects provide a variety of ways to address the spectrum of care, including family support and treatment of mental illness, and chemical addiction. Further we found ways to design both residences and community facilities that do not require a stigmatizing level of security. Although we have identified ways to help families improve their situation, we are unable to address the underlying reasons these neighborhoods are sites for troubled youth, factors such as poverty which causes problems with drugs and gangs. As designers we cannot eliminate these factors, but through good program development, thoughtful proposals and strategic dissemination of our findings that lead to improved services in their neighborhoods, we may be able to help people to overcome such problems. In the next phase of this research, the studio will be working with a neighborhood group to address these needs more directly.

In sum the studio effectively developed and analyzed research in a way that allowed a reframing of the juvenile rehabilitation project from fixing a problem to considering how to prevent the problem. Students were successful in using the research to develop innovative designs that could prevent youth from getting into trouble by aiding their families and helping the young people and their families to develop better futures.

REFERENCES


Dudovskiy, John. “Exploratory Research” Research Methods website, 2018


Pruin, Eneke and Frieder Dünkel, Executive Summary: Better in Europe? European Responses to Young Adult Offending, University of Greifswald, Germany, [Wissen Lokt Seit, 1456] 2015.


Slater, Dashka, “North Dakota’s Norway Experiment: Can humane prisons work in America? A red state aims to find out” Mother Jones, July/August 2017.

ENDNOTES

¹ The students who participated in this research studio are Jared Eichberger, Tyler Gaeth, Nicholas Hess, Joshual Meiners, Andrew Mercier, Kelly Mork, Austin Rudin, Hana Saifullah, Adam Schellberg, Luke Walsh, and Belinda Xiong.
Hybrid studio: blending research, service and practice

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ABSTRACT:
Within the allied professions of architecture, engineering, and construction, there is an imminent need to creatively hybridize the disparate realms of research, public interest design, and traditional practice. This hybrid has the potential to reinvigorate these professions and shift the relevance of the industry in line with the current and future issues facing the built environment. Snow Kreilich Architects, has begun to combine these disparate realms of practice/inquiry into a hybridized studio model in Minneapolis, Minnesota. This paper will use case study methodology to document and summarize the process of forming such a hybrid. The topics discussed will include: (1) Drawing precedent for research-oriented and purpose-oriented organizations and from the fields of medicine, law, and technology. (2) The underpinnings of hybrid design organizations, drawing precedent from the University of Minnesota’s Master of Research Practices in Architecture (MS-RP) program (3) evaluate and discuss the successes and shortcomings associated with hybridizing an existing studio-based architectural practice. (4) Discuss the potential benefits of combining these realms from a financial, operational, and relevance point of view. As a case study, Snow Kreilich Architects’ existing architectural practice explored how research within the firm has potential to elevate the everyday work we do and also provide design services through alternative means to marginalized topics and populations, both domestically and abroad. Critically, both types of service are arranged logistically to behave in symbiosis. Within this evolving environment at Snow Kreilich Architects, the unlikely combination of research, architectural services, and public interest design agendas found common ground to be pursued through an innovative business model. Identifying alternative, recurring sources of funding was a critical step in forming an operational and budgetary plan for how research and pro bono activities could function alongside the existing structure of the firm. These two modes of practice were already an integral part of the way the studio worked but both research and pro bono projects were treated as entirely philanthropic activities. Leveraging interdisciplinary partnerships under the umbrella of a non-profit status allowed previously anecdotal research and philanthropic design projects to go further and have larger impact backed by calculated research methodology and dedicated research staff. The hybrid studio offers possibilities for the profession to broaden its lens, work with unlikely interdisciplinary partners, and design for segments of the population outside the profession’s traditional reach. The hybrid structure piloted and evolving at Snow Kreilich Architects allows the studio the flexibility and capacity to deal with complex problems presented in the world. We see the opportunities for this type of hybrid operational model to expand its application and to grow in importance as the architectural profession, and other professions, are asked to creatively produce thoughtful solutions to urgent issues in the built and unbuilt environments.

KEYWORDS: Integrated, Practice, Hybrid, Public Interest

1.0. INTRODUCTION
The impetus for hybridizing the traditional architectural firm, or studio, is driven by two overarching agendas. The first is to uncover a purpose-oriented culture and work environment wherein architects and allied professionals are engaged in work that is personally fulfilling and professionally enriching. The second agenda, or goal of hybridization is to create an integrated
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research-oriented workflow which informs both the product and the process of the architectural practice. By relating these somewhat altruistic agendas with a traditional, for-profit business model, a hybrid firm structure has the potential to create an environment in which the architect takes on multiple beneficial roles within and outside of the constraints of the profession.

1.1. Purpose-oriented:
The first goal in hybridizing the architectural studio was to orient a portion of the work towards clients, project types, and issues that were in service of pressing societal goals. This type of reorientation creates a new venue for architecture and allied professionals to have an impact beyond the building, and engage in civic activities. This has been referred to as the “civilian architect” by many but this agenda also engages these activities within the profession instead of as a service, with no recognition or value to the time spent. This type of work is a growing demand of top-level employers and the employees alike. For example, “In 2015, 28% of the U.S. workforce [was] Purpose-Oriented. They define the core role of work on their lives as providing personal fulfillment and contributing to society. These 42 million people work in diverse roles and industries from baristas to Fortune 100 CEOs.” Beyond the obvious societal benefits that purpose-oriented architectural work inspires, the reasoning behind the integration of this work within the professional architectural realm is layered and faceted. While many benefits are realized, two factors are omnipresent and important to highlight within this study; (1)“Employees who are purpose oriented have: 20% longer tenure, 47% more likely to self-promote the company, 50% more likely to be leaders, 64% higher levels of fulfillment and (2)“87% of millennials believe the success of a business should be measured in terms of more than just its financial performance. 46% [of Millennials chose their employer based on their approach to] Corporate Social Responsibility [and another] 32% [noted they chose their employer based on] Prestige. Further, these two factors are of incredible importance to the architectural profession in particular, as both create professional workplaces that thrive on diversity of thought and talent, capable of dealing with complex issues in the public realm.

1.2. Research-oriented:
The second overarching agenda for the hybrid studio is to leverage knowledge gained through research to improve process, product, and impact within the expanding scope of the architectural profession. Incorporating a formalized research agenda into an architectural office shows that the firm is concerned with the broader impact of design within the real world. It shows a firm’s dedication to creating design solutions that are based in inquiry and optimized by iteration instead of blind pragmatism or egotism. While the idea of integrating research within the architectural studio is not new, it is important within the confines of a nascent dialogue of hybridization, to reference the tested value and methods of research within the architectural design process.

“Before we start designing anything, we’re almost anthropological. Before we put mouse to pad, we have a really good understanding of how people will work in a given space and what the pragmatic and conceptual goals are.” -Stephen Cassell, Architecture Research Office (ARO)

“Our commitment to research has provided a way for deep investigation to be conducted during design—and for the results to stimulate and augment the processes of designing and building at KieranTimberlake. As our research activities are engaged during pre-design, project delivery, and post-occupancy, our building sites and buildings are the test beds that provide substantive feedback for future solutions. A transdisciplinary research group with backgrounds in fields like ecology, chemistry, physics, anthropology, economics, and materials engineering, works alongside design teams to define and support project-based research initiatives, as well as independent research pursuits” - Kieran Timberlake Research Group

As these two quotations from well-known architectural firms describe, using research as an integral part of their process lends a wealth of opportunity and value to both the workplace culture and resultant architectural solutions. Further, there is reciprocal and hidden value in this duality. Research should not be considered a purely sacrificial activity to the architectural client or to firm leaders. Although sometimes the benefits of somewhat altruistic activities are
intangible or not directly quantifiable using traditional methods of evaluation, they exist. There is a similar dialogue occurring within the realm of ecological design wherein ecosystems evaluation proves to be tangled up in a multitude of factors, not discretely quantifiable but its benefits realized in multiple realms. The value of ecosystems, or in this case, intangible value of non-linear systems, is viewed, evaluated, and expressed differently depending on cultural conceptions, philosophical views, and schools of thought.\textsuperscript{vi} Therefore, within the context of this paper and the development of the hybrid studio model, research and informed architectural solutions were designed to work in concert, both financially and logistically. Research is given space to expand and inquire meaningful questions that often do not have a foothold within the design process. This type of applied research feeds design solutions with reason and a creative edge not present with a "straight-ahead" design process. As applications and agendas for project-based research grow in number within the hybrid studio, feedback loops from previous projects inform further inquiry and add credibility to findings. This feedback loop and the resultant body of knowledge has tangible benefits for both the firm and, more importantly, the allied design professions as a whole. Adding to the comments above regarding attraction/retention of top talent above due to purpose-oriented agendas, a research focus within top architectural firms is yet another means of attracting and keeping top talent who have aspirations to explore that part of the field while still being able to practice architecture, gain licensure, and create design solutions in a traditional sense.

2.0 METHODOLOGY: WORKING IN CONCERT

It is important at this juncture to reiterate that this project and its effect are nascent and have not been in existence for long enough to fully evaluate the strengths, weaknesses, opportunities and threats of such a business model. However untested, it is equally important to define a clear set of goals, document the underpinnings and logistics of this arrangement, and establish benchmarking strategies for evaluating the effect(s) of such a hybrid firm structure.

The idea and process of hybridization started with a simple set of rules or goals that defined the trajectory forward. (1) Leverage what the for-profit firm already does. (2) Expand our existing research capacity and formalize the process/products. (3) Use our architectural skill set to assist others outside of the traditional for-profit architectural scope, specifically within the public domain. (3) Reduce the cost to the firm for these activities by realizing value. (4) Increase the breadth and depth of the professional network through hybridization and, (5) Attract and retain new clients, partners, and employees that were invested in both the traditional firm model and a culture of research and purpose-oriented work. These five principles served as the basis to chart a course through new, and somewhat uncharted waters. At this point, it is necessary to cite the work of a group of architects and designers who have compiled a set of case studies that served as a menu of operations for this effort. Proactive Practice Research Collaborative \textsuperscript{vii} has assembled an online resource that describes in great detail, the business approaches of several design and architecture firms who have taken on research and/or public interest design work as part of their operational model. This resource, along with an extensive evaluation of the existing business operations served as a platform to contemplate how and why a hybridized firm structure could provide mutualistic benefits for a multitude of partners, clients, and affiliated organizations.

The process of designing the hybridized model was iterative and open ended. It involved looking at existing cash flows in and out of the for-profit firm over an arc of a decade. This included evaluating specific project fees, profit, loss, unrealized gains, and time dedicated to non-billable activities. Further, a deep investigation into what pro bono projects the for-profit firm had performed revealed that the for-profit firm was already donating a significant amount of time to non-billable projects/clients as part of its business plan. The existing firm structure consists of a somewhat traditional architectural model. This model provides a robust way for the firm to be nimble, versatile, and design oriented while remaining profitable. Individuals, corporations, and governments are the primary paying clients bringing profits to the firm. Pro bono design services are allocated as needed to support various activities that are either self-
initiated by members of the firm or by external entities looking for assistance. Further, research within the firm is handled in a similar way. Internally initiated research agendas are supported by the firm by allocating time and resources to these efforts without pay. The question became, “What if these research and design activities could be part of a business model that not only informs the studio’s for-profit activities but, they could pay for themselves and offer myriad unrealized benefits to the firm?” As the investigation into the existing firm structure and operational model grew in detail, potential avenues for hybridization began to sort themselves and a system which blended certain elements while allowing others to remain completely separate rose to the top.

The resultant business model proposes to develop two separate and discrete entities, one within the existing for-profit firm structure and one outside of the existing structure: a separate 501(c)3, not for profit organization which operates independently. The existing business model is altered to include research as part of the normal operations, compensated partially by research and development tax credits. Research activities within the architectural design process are generally seen as expenses from a financial perspective, but when re-framed within the context of qualifying R&D activities, they begin to take on a new value - one that is an asset to the financial stability and knowledge base of the firm instead of an activity that is a financial drain with unknown potential. A 501(c)3 not for profit organization would operate outside of the for-profit firm structure and be managed by a diverse and discrete board of directors’ majority without affiliation to the for-profit firm. This entity allows a combination of external funding generated by fee-for-service work and donations from traditional non-profit funding sources (Grants, private donations, fundraisers, etc). Grant-based funding for research initiatives within the 501c3 and federal/state R&D tax credits within the for-profit allows both of these discrete entities to dissipate the financial draw of these somewhat altruistic activities while allowing their effect to be realized within a formalized business model. Further, this process of dividing purpose-oriented and research-oriented work into two discrete entities with separate funding sources and leadership allows two main objectives to occur simultaneously.

1) The whole aggregation of for-profit and non-profit entities are able to conduct and formalize research and partially compensate the time/expense of such activities. (2) Allows a diverse group of stakeholders to be involved in an otherwise siloed collaborative.

Figure 1. Existing business model showing flows out in orange and flows in as blue. Source: Matt Tierney, Snow Kreilich Architects (2016)

While the benefits of this type of firm structure could be limitless, adding complexity to a system that already runs well financially and logistically could create risk due to the process of meshing personnel and objectives within two discrete entities from a tax perspective. Strict boundaries,
rules and protocols are developed to keep R&D funded research and non-profit funded research/design discrete is paramount to the success of this hybrid. A clear support system and team of legal, accounting, and operational professionals who specialize in these niches is also of critical importance to reduce risk. Another critical item in the structure of this hybrid is to implement bookkeeping systems that ensure employee time is being allocated accordingly so activities can be tracked in detail.

Figure 2. Hybrid business model showing flows out in orange and flows in as blue. Source: Matt Tierney, Snow Kreilich Architects (2016)

Through conversations with multiple firm leaders and within an internal evaluation of our records, it becomes fairly clear that existing internal funds within architecture firms are very often being allocated to internal research efforts and pro bono projects. Approximately 1-2% of the overall annual budget within the case study firm was being spent on non-billable research efforts and pro bono architectural projects annually. This step of self-evaluation is critical to the trajectory and magnitude with which a firm would hybridize its operations. Further, it helps establish baseline goals and types of work/research are already present in the interest of the studio. Within an existing architecture firm especially smaller firms without expensive and complex time card software, reports are often difficult to generate because there is not often a set system to track and monitor research, pro bono efforts and these efforts likely span over multiple project phases, if not over multiple projects. The goal of any such evaluation is to start to develop and quantify the existing contributions of time and resources towards efforts that are of philanthropic or public interest. This is a powerful exercise that led the case study firm to develop methods of formalizing both research and philanthropic work within the studio environment so that this type of important work could be managed and funded from a multitude of sources.

The goal is to establish the baseline and then imagine if these resources were still allocated to research and pro bono work but was managed differently and bolstered by a set of external funds that allowed for greater capacity, the impact could be significantly increased while bolstering the existing firm structure. By combining internal funding, new external sources made possible by a new 501c3 entity, and federal/state R&D tax credits, a substantial budget could be allocated to firm activities that both add value and knowledge to the work the firm already does and open doors to new arenas where architecture could have dramatic impact.
Some external sources of funding would need to be identified and courted, others would need to be handled within our financial/tax management.

Figure 3: Hybrid business model showing multiple streams of discrete partnerships working together. Source: Matt Tierney, Snow Kreilich Architects (2016)

Benchmarking, and self-evaluation of a new operational model is critical to success. As stated before, this project is still being actively developed and will continue to morph and become malleable throughout its adolescence. With that in mind, scientific results will not be presented in this paper but rather, it is important to show a methodology for evaluation, in this case, based on the principles that were presented at the beginning of this section as markers. While certain elements of the evaluation such as resultant project wins, marketing potential, attraction of top talent etc. are intangible or hard to quantify, there are other aspects that could have a more rigorous and predictable scientific method. Each firm or set of partners will need to develop and modify the means of evaluation as part of the process. While there is not any conclusive evidence to report at this time, there is anticipation that by integrating applied architectural research and public interest design within and adjacent to an existing organization, there are wildly mutualistic benefits and relationships.

3.0 PARTNERSHIPS AND IMPACT

An overarching principle, and intrinsic quality of the hybrid studio involves, developing collaborative working relationships with a diverse group of professionals, clients, and stakeholders. These partnerships can and should be forged between and within allied professions, educational institutions, other not for profit entities, NGO’s and multiple governmental agencies. All of these partnerships have the collective perspective and skills to positively affect the public realm through collaborative problem solving. With specific focus to the architect in this entanglement, collaborative partnering presents a limitless arena for architectural design and applied architectural research in which the products of such activities have benefit for all. The architect not only can provide skills and products that are in line with traditional modes of operation, (The design of buildings, interiors, programming, etc.) but it also allows the architect to serve as a creative problem solver and a hub within a radial arrangement of impactful partners. This type of collaboration requires a departure from traditional methods of forming design teams. It requires looking towards unlikely professions and project types that could benefit from a more interdisciplinary and collaborative working environment. One way to create a researched-based value proposition within the public realm is by leveraging a deep knowledge of place in a diverse group of team members. Having the
ability to navigate complex political situations in the built environment is an asset that clients seek. One organization that has managed to make this value proposition a reality is Utile in Boston, Massachusetts.

“Utile’s progressive and entrepreneurial approaches help public-sector clients think about how to physically and legally shape their cities in ways that are mutually beneficial for governments and the public. While this approach requires more work in the early stages of a project, it allows Utile to win over potential clients by demonstrating the firm’s deep knowledge of the underlying systems and constraints that a project must respond to”

Developing potential collaborative teams around real or hypothetical projects is an effective means of strategizing partnerships with consulting firms, non-profits, and educational institutions. In this projective exercise, each project could have a different team makeup of partners within a loosely formalized network where a project only calls certain ranks to participate based on their expertise and interest. Establishing this network of collaborative professionals, academics, and stakeholders at the onset of the formation helps increase the capacity of this initiative monetarily and logistically and would help cater the goals of research and social impact design to areas that could be tackled by such a diverse network effectively. Establishing this network of resources provides for ready-made project acquisition with teams that are equipped to deal with the complexity inherent in the public realm. Further, a diverse set of partnerships under one organizational agenda adds almost unquantifiable means of getting projects and attracting others to participate. In an developing an organization based on collaboration, it is omnipresent to have diversity and inclusion to be effective. The diversity of age, race, ethnicity, religion, gender identification and a host of other attributes of people who have an interest in the process and/or products of such an organization exponentially increase the odds of success for everyone. It is truly an organizational platform where there cannot be too many people or too much diversity.

4.0 CONCLUSIONS AND NEXT STEPS
This proposed addition to and divergence from more traditional models of architectural practice has many potential areas wherein the scope and relevance of the architect and her allied collaborators expands. This open-endedness, and invitation to collaborate across disciplines inspires a more resilient creative processes that seeks answers embedded in a multitude of perspectives. Within this pluralistic design agenda, architectural work could be presented in many incarnations and through many mediums having impact across the globe. While the discussion housed within this paper has focused on the reasoning and nascent application of these principles within a particular studio environment, further quantitative investigation into the success of such a hybridized studio environment needs to be carried out across multiple firms and across a longer time scale to realize the effects of such an addition. The work done by the Proactive Practice Research Collaborative and other organizations seeking to bring an understanding of multiple means and methods of integrating public interest design and research oriented operational models is the necessary first step in exploring this potential across scale, geography, and specialty. Continued monitoring within Snow Kreilich Architects, and ideally other firms, will bring greater understanding of both tangible and underlying effects of the research-oriented and purpose-oriented portions of the hybrid studio model.

ENDNOTES

1 Impact Design Hub, An Introduction to Social Intrapreneurship, 2017
2 Imperative/NYU, Workforce Purpose Index, 2015
3 NSHSS, Scholar Millennial Career Survey, 2015
4 Philip Nobel, Interview with Cassell, Yarinski and Yao, Metropolis Magazine, The Research in Architecture Research Office is No Joke, March 1, 2013
Between research and practice: a comparative analysis of daylight design predictions in atriums

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ABSTRACT: Internal, multi-story atria present an opportunity to harvest daylight as well as create connections to the outdoors in commercial and educational buildings. They also have the potential to help moderate well-being for occupants and provide informal gathering spaces that form social interactions for buildings’ users. Despite the increased deployment of atria in contemporary, sustainable buildings, there is a lack of studies investigating the relationship between atrium design strategies, expected outcomes, and their realized impacts on occupants’ comfort, health, and experience. The intent of this paper is to investigate the effectiveness of two different atria typologies in two LEED campus buildings from both building performance and occupants’ perspectives. A comparative field study was conducted in these two buildings to assess how the shape, form, orientation, and geometry of the two atria impacted daylighting autonomy, glare, chronobiological light response, occupants’ perceptions, and functional use of both spaces. This paper concludes with insights on the relationship between daylighting design metrics employed in practice and their consequential impacts on the real space as perceived by the occupants. It attempts to answer whether an atrium that meets building performance standards necessarily translate to a healthy indoor environment and positive human experience. Results from this study suggest that atrium design can be optimized to balance daylight quantity and quality through prescribed design parameters. However, the success of the design with the intent of a space that encourages social interaction requires more attention to human behavior, atrium function, and typology.

KEYWORDS: Daylight, Metrics, Post Occupancy Evaluation, Health

INTRODUCTION

To achieve sustainable design strategies in green buildings, designers are becoming increasingly interested in employing effective daylighting design in their buildings. Introducing daylight into a building’s deep core can offset electric lighting loads. This is usually achieved with employing different atrium designs. An atrium can be defined as a multi-storied covered light well in a building, usually with a skylight. These specific atrium typologies have gained popularity because they not only allow daylight to reach core areas that cannot be reached by generic side lighting strategies, but they also create a social center and an intermediate state between inside and outside spaces in buildings.

Building science researchers have extensively measured daylight parameters with regards to meeting instrumental energy efficiency and visual comfort benchmarks. Though these buildings may excel in performance as per benchmark requirements, how does this translate to an overall success of the atrium design? These atriums are intended to create spaces for social interaction. If occupants are to spend extensive periods of time in these spaces, shouldn’t there be more assessments of the spaces with regards to occupant well-being rather than just instrumental metrics that fulfill other requirements in sustainable designs? This paper compares and contrasts the performance of two atrium types in LEED certified buildings pertaining to both the instrumental building performance parameters and those parameters concerning occupant well-being. It aims to highlight the difference and importance of addressing both aspects when designing atriums.
1.0. ATRIUM DESIGN

1.1. Atrium allometry
An atrium, open air or skylight covered, is a product of modifying many variables. Parametric studies have investigated the effects of modifying its shape, form, orientation, and geometry. Buildings, regardless of their typology, tend to be oriented parallel or perpendicular to streets. Older cities had no grid patterns or planned street systems. This resulted in a large variety of atrium orientations due to organic growth and unplanned development. New, planned and systematic cities comprise of streets that followed cardinal points (North - South, East - West). Thus, atriums started to follow those axis with an occasional 45° tilt off the cardinal points for a more evenly distributed amount of sunlight on all facades when desired (Reynolds 2002). Decisions regarding which orientation is optimum should be based on which functions are zoned on the long and short sides of the building. The assessment should also consider which aspect is more problematic: winter heating or summer cooling. Spaces are then allocated more precisely within buildings with respect to seasonally and hourly changes according to the effect of solar radiation (Moradchelleh 2011).

Quadrilateral atriums can be elongated in different directions. Plans elongated North-South have longer walls facing East and West. These receive direct sun across the length of the courtyards around noon but can be partially shaded by the long walls during the earliest and latest hours of the day. This is typically ideal in hot and dry climates where courtyards are commonly oriented between Northeast-Southwest and North-South. Atriums have been used in buildings in a variety of geometries and may also take on the form of non-quadrilateral shapes: pentagonal, hexagonal, heptagonal, octagonal and even irregular cases. These have an adverse effect on shading. Parametric studies have analyzed the effect of increasing the number of sides of atrium wall enclosures and the results indicate that the percentage of shaded areas decreases with the increase of number of walls in the geometry (Muhaisen and Gadi 2006).

The height to width proportions of an atrium’s enclosure play a role in regulating the microclimate within a building. Simulations investigating ambient air temperature changes in atriums indicate that with the increase in height of wall enclosure, temperature decreases significantly by as much as 30°C. This is due to the fact that direct solar radiation is blocked during specific hours of the day (9:00 to 18:00), resulting in larger shaded areas which are critical to prevent overheating in hot climates. However, when the sun is directly above the atrium, with a low solar zenith angle (12:00 to 15:00), thermal conditions may be uncomfortable. Higher walls reduce the sky view factor within the courtyard and compromise illumination levels. A balance should be optimized between thermal comfort and illumination levels whilst considering human subjective assessments and objective measurements since occupants may be more tolerant to some thermal conditions due to psychological adaptation.

On the other hand, it has been noted that atriums with low surrounding walls worsen the condition indoors than outdoor areas in hot climates. This can be explained with simulations that show that low walls do not block the sun at all, so there is no shading. Furthermore, though these low enclosure walls may not block sun, but they do in fact block wind in exposed atriums and so reduced wind speed minimizes comfort. Ideally, cold climates would decrease the height to one level (1:6). Temperate, hot and dry climates would increase the height to two levels (2:1). Hot and humid climates tend to increase the height to three levels (3:1) by following the imperative that the use of deep courtyard forms are beneficial for hot climates and shallow courtyards work best in cold climates (Ghaffarianhoseini, Berardi, and Ghaffarianhoseini 2015).

1.2. Occupant behavior and spatial analyses
Architecture plays a major influential role in how much light exposure a building occupant receives and how an occupant might behave inside buildings, respectively. On a large exterior scale, light penetrating a building’s interior can be predetermined based on the surrounding...
environment’s exterior geometry. This can be mediated with the building’s orientation and façade design by altering window parameters: ratio, size, position, glazing type and whether shading devices will be allocated. On a smaller interior scale, light penetrating the building’s envelope is either enhanced or diminished based on the indoor profile, surface properties and interior reflectance. Designers can also modify indoor light exposure through the use of electric lighting. They specify the lamp type, spectral properties and position. Occupants have the freedom to distance themselves from certain light sources and based on the degree of control they have on indoor lighting controls.

Access to daylighting in a building can impact human behavior in spaces. Many of the methods of spatial analysis and indoor space modeling explore the dichotomy between the social (human occupants) and physical (building fabric and structure) parameters of human occupancy and use of space. They investigate the general patterns of usage including movement and flow within a building, as well as physical analyses to improve usability of a building (Worboys 2011). The concept of the depth of building zones should not be simply interpreted as the accessibility of a space but more fundamentally, its connectivity. This is especially important when assessing an occupant’s exposure to available daylight, for the space-to-space permeability and the relation of visibility which passes through connected spaces. This can be assessed using computer simulation methods where the resulting axial lines in an axial map can be regarded as the fewest number of visual paths in the existing space where each intersection plays as a turn of sight, which becomes a depth (Kim et al. 2008). The spatial and functional differences between spaces that we find through the analysis of permeability in the building also appear in the analysis of visibility. Two of the measures Benedikt (1979) focused on in particular were the area of the isovist which describes the total amount of area visible from a point and the perimeter length of the isovist boundary which describes how quickly the view changes as you leave the point. These measures quantify different aspects of how a person may experience the space, and together give a fuller description of their exposure to daylight. This highlights the importance of investigating vertical illuminance at different orientations to better understand the daylight potential of a space.

1.3. Daylight performance metrics and occupant well-being parameters

As previously discussed, various atrium configurations impact daylight availability within buildings. This can be measured with instrumental daylight metrics, as often used by the design industry, to assess the building’s performance. The most familiar and widely used photometric unit of measure for light is photopic lux. It quantifies illuminance, the total power of light falling on a detector surface from any direction as perceived by a standard human observer (Serra 1998). What primarily started as a means to assess the daylight conditions needed to provide minimally adequate daylight levels in Europe resulted in the development of one of the earliest metrics for daylight performance. The Daylight Factor (DF) is the ratio of internal illuminance at a point in a building to the unshaded, unobstructed, external horizontal illuminance under standard CIE overcast sky conditions - expressed as a percentage (Moon 1942). An average DF of 2% across a given space is usually required for it to be considered sufficiently daylit. This metric, which was not developed with the intention to accurately assess daylight performance, does not account for different sky conditions and is not sensitive to building orientation, geographic location, or sun position. To address the shortcomings of this overly simplified metric, more complex hourly daylight metrics were developed and adopted. Daylight Autonomy (DA), first defined by Reinhart (2004), is the percentage of occupied times of the year when a minimum work plane illuminance threshold of 500 lux can be maintained by daylight alone. It uses work plane illuminance as an indicator of whether there is sufficient daylight in a space so that an occupant can work by daylight alone. This metric is somewhat problematic as it proposes binary thresholds which might unjustly differentiate spaces based on measurements of light changes that may not be perceived by the human visual system. This was further developed and standardized to what is known as Spatial Daylight Autonomy (sDA) which is a percentage of an analysis area that meets a minimum horizontal daylight illuminance level for a specified fraction of the operating hours of the year (Heschong et al. 2012). A commonly used benchmark is to achieve 300 lux for 50% of the time.
Since the common measurement of illuminance, photopic lux $V(\lambda)$, describes the spectral sensitivity of one aspect of human cone-based vision, these photopic units have limited utility. The spectral sensitivities of the visual and non-visual systems (555 nm and 490 nm, respectively) are different. Thus, illuminance based photopic lux metrics are not appropriate to evaluate non-visual responses. Researchers and professionals in the field have resorted to developing a set of metrics, simulation, field study methods and technological tools for new daylight health effective modes of measurements.

The biological effects of light on humans are usually translated from spectral power distributions and measured in equivalent melanopic lux (EML), a proposed alternate flux density metric that is weighted to the *intrinsically photosensitive retinal ganglion cells* (ipRGCs) luminous efficiency function, which peaks at 490 nanometers and is based on the action spectrum of melanopsin - instead of the cones' photopic luminous efficiency function $V(\lambda)$, which peaks at 555 nanometers and is based on the response of foveal, long and middle-wavelength sensitive cones, which is the case with traditional lux (Enezi et al. 2011). This translation is used to understand how much the spectrum of a light source stimulates ipRGCs and affects the circadian system.

The equivalent melanopic lux metric has been adopted by the WELL Building Standard (Institute 2017) which was launched in October 2014 by The International WELL Building Institute. This standard is commendable as it not only assesses the design and operations of buildings much like the predominant rating systems, but it, more importantly, looks at how they impact and influence human behaviors related to health and well-being. The light category in the WELL standard aims to “minimize disruption to the body’s circadian system, enhance productivity, support good sleep quality and provide appropriate visual acuity”. For work areas, they should meet at least one of two requirements: (1) At 75% or more of workstations, at least 200 equivalent melanopic lux is present for at least the hours between 9:00 AM and 1:00 PM for every day of the year. (2) For all workstations, electric lights provide maintained illuminance on the vertical plane of 150 equivalent melanopic lux or greater. In living environments such as bedrooms, bathrooms, and rooms with windows, one or more fixtures should provide 200 or more equivalent melanopic lux. Lights in workplace breakrooms are required to maintain an average of at least 250 equivalent melanopic lux. They may be dimmed in the presence of daylight but should be able to independently achieve these levels. Learning environments need to meet at least one of two requirements: (1) At least 125 equivalent melanopic lux is present at 75% or more of desks, for at least 4 hours per day for every day of the year. (2) Ambient lights provide maintained illuminance on the vertical plane of equivalent melanopic lux greater than or equal to the lux recommendations in the Vertical (Ev) Targets of the American National Standards Institute and Illuminating Engineering Society IES-ANSI RP-3-13.

The Lighting Research Center at Rensselaer Polytechnic Institute has also proposed a metric, known as “the circadian stimulus” for applying circadian light in the built environment (Mariana Figueiro 2017). It uses irradiance weighted by the spectral sensitivity of every retinal phototransduction mechanism that stimulates the biological clock, as measured by nocturnal melatonin suppression. The metric is derived from a transformation of circadian light into relative units, from 0 to the response saturation of 0.7, and is directly proportional to nocturnal melatonin suppression after one hour of light exposure (0 to 70%). The recommended levels aim for a circadian stimulus greater than 0.3 during the day and less than 0.1 in the evening. A circadian stimulus calculator is also made available online for lighting professionals to enable them to convert the photopic illuminance at the eye provided by any light source and level, into the effectiveness of that light for stimulating the human circadian system (Rea and Figueiro 2016, Rea et al. 2010).

### 2.0. FIELD STUDY SETTINGS

The aim of this study is to compare the daylighting performance of two different atria geometries inside two educational buildings of similar size and spatial typologies yet different atria geometries. Both buildings excel in sustainable design strategies employed, green
technologies and have accomplished LEED certifications. The two buildings selected for this study are: The Lewis Integrative Science Building (LISB) which has achieved LEED Platinum certification and Lillis Business Complex which has achieved LEED Silver certification. Both buildings are located at the University of Oregon Campus, Eugene, Oregon. They both claim to incorporate atriums to enhance daylight availability and encourage social interaction. This study assesses how these two different atria typologies but with similar goals perform differently in terms of daylight availability for visual task needs and occupant well-being.

The Lewis Integrative Science Building (LISB), opened in 2012, is home to research oriented to human brain, molecular biology, nanotechnology and solar energy. The building, with an area of 107,000 gross square feet, consists of four occupied stories, a subterranean level and a fifth floor which contains mechanical equipment. It is comprised of faculty offices as well as office space for graduate and post-doctoral students, collaboration and meeting spaces and more than 30,000 square feet of wet labs, dry labs, an MRI facility, ERPS booths and other instrument labs. It was designed by HDR Inc. and THA Architects with the design intent to achieve LEED Platinum certification by incorporating energy savings including solar shading, daylight harvesting, night flush cooling, immense solar panels, and heat from an adjacent utility tunnel. The research facility uses about 58 percent less energy than conventionally designed buildings of similar size and function. The primary component of interest in this building is the four-story, rectangular atrium elongated in an East-West orientation. This serves as the heart of the building for circulation, to encourage interaction between scientists from different disciplines and allows daylight to penetrate the building from within.

Lillis Business Complex, opened in 2003, houses the University of Oregon’s College of Business. The building, with an area of 196,500 gross square feet, consists of four occupied stories comprised of classrooms, lecture halls, computer labs, conference rooms and offices. It was designed by SRG Partnership with the design intent to achieve LEED Silver certification and incorporates one of the largest solar installations in the Northwest and one of the pioneering uses of photovoltaic solar glass in the world. The building design and configuration helps it achieve maximum energy efficiency, exceeding state energy code requirements by more than 40 percent. Much like LISB’s atrium the atrium in Lillis Business Complex is the heart of social interaction, circulation and daylight penetration. However, rather than being elongated, this typology is more central with flanking zones.
The study was conducted on a typical morning and afternoon day of ASHRAE climate zone 4C, characterized with overcast sky conditions. Illuminance levels and spectral power distribution measurements were taken at several points within the atriums on both the horizontal plane and vertical plane at the North, East, West and South cardinal points. HDRI photographs were also taken to further analyze the space throughout the full day. The results from this luminous environmental analysis were interpreted by computing visual comfort and chronobiological light metrics. Metrics computed included: Daylight Factor (DF), Daylighting Autonomy (DA300), Annual Solar Exposure (ASE), Daylighting Glare Probability (DGP), Circadian Stimulus (CS) and Equivalent Melanopic Lux (EML).

3.0. RESULTS
Findings related to both atria performance are broken down into three analyses: daylight factor and illuminance levels, circadian stimulus, and equivalent melanopic lux metrics. Each location point reports the measurements for both the horizontal plane and vertical plane at the North, East, West and South cardinal points for the morning (9-11am) and afternoon (1-3pm) hours. In the tables, cells that are shaded in gray indicate that measurement did not meet the benchmarks. The daylight factor benchmark was set at 2%, illuminance levels at 300 lux, circadian stimulus at 0.3 and equivalent melanopic lux at 250 EML.

Illuminance levels measurements taken on the horizontal plane tend to be greater than those in the vertical plane facing different directions. This misconception can be misleading to designers as they make assumptions that meeting the 300 lux benchmark for the horizontal plane is sufficient. Some tasks require occupants to look in different vertical directions, this requires designers to different views and planes into consideration. It is also noted that meeting the 300 lux benchmark is not a strong indicator of maintaining the 0.3 circadian stimulus or the 250 EML benchmarks. Both circadian stimulus and equivalent melanopic lux biological benchmarks appear to be more difficult to meet than the visual task illuminance level benchmark requirements. In some cases, the space requirements may require more or less illuminance levels. Designers should anticipate how these changes will be reflected in creating biologically bright or dark spaces.

The elongated atrium in the Lewis Integrative Science Building performed poorly on the lower levels, especially during the morning hours. This critical observation hinders the atrium’s performance since the circadian stimulus benchmarks are not met during the morning hours, when it is most vital. The central atrium in Lillis Business Complex meets the benchmarks at most points during both the morning and afternoon hours. This is due to the South curtain wall which allows more daylight to penetrate the building through side lighting techniques. This is observed in the South vertical plane measurements. Though it aids in increasing daylight, it also increases discomfort glare.

CONCLUSION
This paper has investigated the performance of two different atria typologies from both visual requirements and biological circadian potential standpoints. From the results it can be concluded that daylighting measurements and metrics are multi-faceted and might not be entirely in agreement as to what metrics are suitable for measuring the efficiency of a daylighting strategy on both building performance and occupant’s visual comfort, and well-being. To fully understand the success of these buildings, more investigations are required to map human behavior in these buildings. This requires designers to pay more attention to sensitivity analyses related to occupant’s view sheds and behavior as well as 2D isovists and visibility within the indoor building layout in order to determine if occupants really do receive adequate daylight, or whether they do not, despite meeting building performance benchmarks. Futures studies could take the occupant experience perspective further. This would include sensitivity studies that document behavioral patterns within the atriums. Behavioral mapping, observations, and occupant’s surveys could measure occupants’ patterns that could identify experiential human-centered factors in the indoor environment. These provide insights on how building occupants rate the space themselves. This subjective data could reinforce the
objective daylight parameter data collected. Or, it could prove that a successfully designed daylit building which performs well in terms of providing enough light for visual task needs as well as circadian rhythm regulation does not necessarily translate to positive occupant experience. The findings could demonstrate, the success of the atrium design lies not only in its daylighting parameters but in the opportunity it creates as an intermediate condition between interior and exterior spaces. Fomenting social activity might be more influenced by the space’s furniture, its arrangement, views across space, and proximity to paths. Nonetheless, if the design intent is to create an atrium space to be occupied by building users for extensive periods of time, it is vital for designers to assess the human well-being and biological aspects of daylight in addition to the instrumental metrics. This will help with the considerations for their proper use and pitfalls suggesting that, indeed, atria of one form do not fit all buildings.

Figure 3. Percentage of location points that meet benchmark requirements (Author, 2019)

Figure 4. LISB floorplans with measurement location points (Author, 2019)
### Table 1. LISB daylight factor and illuminance morning and afternoon measurements (Author, 2019)

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### Table 3. LISB equivalent melanopic lux morning and afternoon measurements (Author, 2019)

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Figure 5. Lillis floorplans with measurement location points (Author, 2019)

Table 4. Lillis daylight factor and illuminance morning and afternoon measurements (Author, 2019)
### Table 5. Lillis circadian stimulus morning and afternoon measurements (Author, 2019)

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### Table 6. Lillis equivalent melanopic lux morning and afternoon measurements (Author, 2019)

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REFERENCES


Visual effects of wood on thermal perception of interior environments

Denise Blankenberger¹, Kevin Van Den Wymelenberg¹, Jason Stenson¹

¹University of Oregon, Eugene, OR

ABSTRACT: There is a general consensus, supported by preliminary evidence, that exposed wood improves human perception of thermal comfort, though this idea has yet to be supported by meaningful effect sizes. This study sought to quantify human perception of thermal comfort of wood materials in a controlled laboratory setting. Participants experienced one of two wall treatments: exposed wooden wall panels and white-painted walls in a thermal environment set directly between “neutral” and “slightly warm” (81.5°F, 40%RH, PMV +0.5). We hypothesized that participants exposed to the wood walls would gauge their thermal preference to be closer to neutral than that of participants who experienced the same thermal environment but with the white wall treatment. Wood was found to have a significant and moderate effect on thermal comfort, with the mean response of the participants who received the wood wall treatment being thermally preferable over that of the white wall (wood wall: $M = 0.46$, $SD = 0.56$; white wall: $M = 0.68$, $SD = 0.51$; $p < 0.01$).

KEYWORDS: visual perception, wood, hue-heat hypothesis, biophilia, thermal comfort

INTRODUCTION

Thermal comfort is calculated as a product of six parameters: air temperature, mean radiant temperature, air speed, humidity, metabolic rate, and clothing level (ASHRAE 55). The adaptive model of thermal comfort has expanded on these parameters, including other non-thermal factors that contribute to thermal comfort: namely, the interaction effects among an individual’s physiology, psychology, and behavioral processes (de Dear and Brager, 1997; ASHRAE RP-884). Most research focuses on physiology (primarily temperature acclimation) and behavioral processes (modifying one’s thermal environment), but there is much to be learned about the relationship between psychological and physiological thermal perception, particularly related to visual perception interaction effects. This study is focused primarily on the psychological factor in the adaptive model and the interaction effects between psychology and physiology.

One example of visual perception significance is the notion that color can impact human temperature perception. This theory is referred to as the hue-heat hypothesis (HHH) and suggests that the subjective feeling of the temperature of an object can be altered by the object’s color (Mogensen 1926). In architectural research, this typically takes the form of investigating colored light on temperature perception. A preliminary study on colored light (Fanger 1977) found that participants preferred a slightly lower ambient air temperature ($0.4°C$) when exposed to red-colored light. Chinazzo (2017) reported that colored light was found to have an effect on perception of thermal warmth; when exposed to orange light, subjects reported higher estimated temperatures than neutral (white) and blue light settings in a slightly warm environment.

Humans perceive wood in yellow and red hues (Masuda 1992), so wood materials are thought to be subject to the HHH as well. Rohles and Wells (1977) designed an early experiment of material impact on thermal comfort. Two groups of participants ($n=48$) were exposed to the same thermal environment: one group ($n=24$) in a climate chamber with white enamel walls and the other ($n=24$) in the same space but with the addition of embellishments, including wood paneling, red carpeting, furniture, and décor. The wood décor group reported feeling warmer than the embellished room group. This study is unique in its goal of investigating the
visual impacts of wood on thermal comfort. While many studies have investigated thermal perception of colored materials, few have explored wood materials specifically and fewer yet have utilized full-scale studies.

Wood might be perceived as warm because it is considered a natural material: that is, one that was once living as compared to its manufactured counterparts, such as concrete, glass, and steel, that, though technically also made from elements in nature, tend to be regarded as cold and sterile. Wastiels et al. (2012) found that wood was regarded as visually warmer than plaster, steel, or stone. Rice et al. (2004) investigated the visual impacts of wood finishes using a series of image cards with different images of interior finishes and furnishings, finding that wood was commonly determined as “warm” and “calming” as compared to other interior materials.

Biophilia is defined as the attraction of humans to nature and other forms of life (Wilson, 1984). Wood, therefore, boasts biophilic properties and is thought to both improve productivity and well-being as well as reduce stress and fatigue levels, among other psychological and physiological benefits. Results from Sakuragawa et al. (2005) show that wood wall panels reduced depression scores and reduced systolic blood pressure in respondents as compared to white steel wall panels. Fell (2010) reports psychophysiological impacts of wooden materials, finding that furniture with wood finishes reduced stress levels in an interior environment by measure of skin conductance level. The effect of wood was even greater than the inclusion of plants in the same environment. Tsunetsugu (2007) found that certain ratios of wood to other materials could lead to comfortable and restful qualities in an interior space. Participants (n=15) exposed to a room clad in 90% wooden materials had lower diastolic and systolic blood pressure at the beginning of the test but an increase in pulse rate at the end. The same room with 45% wood coverage resulted in an increase in pulse rate, a significant decrease in diastolic blood pressure, and was subjectively determined to be the most favorable. This suggests that there might be a preferable ratio of wood with other finishes, and in this study, that ratio is certainly less than 100%.

Colored light and colored walls have been studied for thermal properties, and wood has been studied for psychological properties, but, to the authors’ knowledge, wood has not yet been studied in isolation for visual perception of thermal comfort. The goals of this study are (1) to explore the impact of wood materials on perceived thermal comfort in the cooling season (2) to explore the perceived subjective qualities of wood materials and (3) to assess physiological associations of wood materials as indicators of stress response.

1.0. METHODS

1.1. Subjects
The University of Oregon Internal Review Board approved that this study was in compliance with all Human Subject guidelines (Protocol #12012017.001). Participants were recruited from University of Oregon in Portland and Portland State University. Fifty-six participants (20 female, 36 male) completed the experiment (Table 1). No participants reported significant vision impairment, suffered from any heart condition, or were ill at the time of the study.

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Participants were instructed to arrive 15 minutes before the beginning of the session. Participants were permitted to use any mode of transportation so long as they did not arrive “sweaty or out of breath”. Of the 56 participants, 29% arrived by car, 32% by public
transportation, 25% by foot, and 11% by bicycle. Participants were instructed to arrive wearing
or bring typical summer indoor clothing: a short-sleeved cotton T-shirt, long denim pants, and
closed-toe shoes (0.5 clo). Participants were not informed of the purpose of the study, but they
were briefed on the procedure via email before the start of their scheduled session.

1.2. Setting
The human subjects testing occurred weekdays in July-August 2018 at the Energy Studies in
Buildings Laboratory climate chamber located at the University of Oregon’s White Stag
Building in Portland, Oregon. The climate chamber is an 8’x12’x9’ enclosed room with
capability to control radiant temperature, air temperature, humidity, and airflow. The floor is
gray laminate tile, and the ceiling is white-painted aluminum panels. Participants were situated
with their backs to the entrance to the chamber (a sliding glass door), centered in the climate
chamber, to minimize impact from the outside environment and daylight variability. The wall
treatments were floor-to-ceiling reversible panels with unfinished laminated wood on one side
and painted off-white gypsum board (hereby referred to as “white”) on the reverse (Figure 1.2,
1.3). This allowed for both wall treatments to be physically present in the chamber for all
participants, but only one treatment was visible to each participant. A floor-to-ceiling black
fabric curtain covered the wall treatments for the acclimation portion of the experiment (Figure
1.1). The wooden wall panels were intended to mimic that of cross-laminated timber assembly:
laminated Douglas fir (Light reflectance value ~52). The white wall assembly was standard
drywall coated with an off-white matte finish (Benjamin Moore # 2022-70, Light reflectance
value 89.27). Electric lighting was utilized in all conditions (Phillips, F32T8/TL835/ALTO, 3500
Kelvin).

![Figure 1. Wall conditions: 1.1 Black curtain (left), 1.2 White painted drywall (center), and 1.3 Wood (right)](image)

1.3. Thermal environment and equipment
The thermal environment was maintained at +0.5 Predicted Mean Vote (PMV) value
representative of halfway between “neutral” and “slightly warm” on the thermal sensation scale
(ASHRAE 55). Air temperature and mean radiant temperature maintained (81.5°F±1°F).
Relative humidity was 40% RH (±5%), the seasonal average outdoor RH for the Portland
TMY3 file. A data logger (Kestrel 5400 Heat Stress Tracker, accuracy ±0.9°F ambient
temperature and ±2%RH) was positioned at desk height (0.75m) to the participant’s right-hand
side, with continuous monitoring of environmental conditions, logged every minute.
An ambulatory blood pressure monitor (ABPM) was used to record participant blood pressure
readings at 5-minute intervals (Oscar 2, SunTechMedical, accuracy ±5 mmHg). Internal body
temperature was recorded at the start and end of each testing phase with a in-ear clinical
thermometer (Braun ThermoScan Ear thermometer, accuracy ±0.4°F) to check for high
temperatures that might indicate illness.

1.5. Subjective thermal comfort survey
Surveys were conducted at 5-minute intervals with the exception of the first 20-minutes of the
study during which participants acclimated to their environment. Surveys were completed on
a laboratory-provided iPad via a Qualtrics online survey. Thermal sensation (TS) was the standard ASHRAE seven-point scale ranging from cold to hot, with neutral as the middle value. A 5-point scale was used for thermal acceptability (TA), ranging from “clearly unacceptable” to “clearly acceptable”, with three unlabeled options between the two extremes. The three-point McIntyre scale (1978) was used for thermal preference (TP) to determine how subjects would prefer to feel without magnitude: warmer, cooler, or no change. The fourth and final question was temperature estimation (TE), which asked that participants give their best guess for the actual (dry bulb air) temperature of the room, with whichever scale (in °F or °C) participants had previously indicated they felt more familiar. The final question in the thermal comfort survey was open-ended and asked participants to “describe any other issues related to comfort in your space.” Table 2 lists the thermal comfort questions and their respective response options included in the thermal comfort survey.

Table 2. Repeated subjective thermal comfort survey items

<table>
<thead>
<tr>
<th>Thermal sensation (TS)</th>
<th>At this precise moment, how are you feeling? (7-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold (-3)</td>
<td>Cool (-2)</td>
</tr>
<tr>
<td>Slightly cool (-1)</td>
<td>Neutral (0)</td>
</tr>
<tr>
<td>Slightly warm (+1)</td>
<td>Warm (+2)</td>
</tr>
<tr>
<td>Hot (+3)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal acceptability (TA)</th>
<th>How acceptable is your thermal environment? (5-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly unacceptable (1)</td>
<td>(2) (3) (4) Clearly acceptable (5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal preference (TP)</th>
<th>How would you prefer to feel now? (3-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooler (-1)</td>
<td>No change (0)</td>
</tr>
<tr>
<td>Warmer (+1)</td>
<td></td>
</tr>
</tbody>
</table>

| Temperature estimation (TE) | Open-ended (°F or °C) |

1.6. Semantic differential survey

The perceived qualities of each of the wall treatments was assessed by use of a semantic-differential survey of sixteen word pairs judged on a 7-point bipolar scale. The word pairs were selected from existing literature investigating perception of wood materials (Rice 2007, Wastiels 2012). These pairs assess visual qualities (dark-bright, dirty-clean), tactile and thermal qualities (rough-smooth, cold-warm, soft-hard, light-heavy), and affective and preferential qualities (artificial-natural, cheap-expensive, old-new, unpleasant-pleasant, fragile-sturdy, common-unique, dislike-like, calming-exciting, complex-simple, uninteresting-interesting).

1.7. Procedure

In the first 15 minutes, participants’ temperature, height, and weight were collected. A member of the research team would then apply the ABPM cuff. Participants were instructed to leave their arm down to their side and relaxed for each blood pressure reading. The first reading was taken before entering the climate chamber to minimize the effects of white coat syndrome. Participants then entered the climate chamber at minute zero, for the control condition. The first survey included demographic information, the first semantic word pair survey, and the first thermal comfort survey (Q1). After 20 minutes and at subsequent 5-minute intervals, participants were prompted to take the respond to the thermal comfort survey. The participants again completed the semantic word pair survey after the wall treatment was revealed (Q6). At the end of the session, a final survey assessing daily personal thermal comfort was issued (Q9).

1.8. Statistical analysis

The statistical analysis was carried out using RStudio software version 1.1.447. A Shapiro-Wilk normality test resulted in non-normal distribution of all thermal comfort survey data (W=0.44-0.90, p<0.001). For all non-normal data, a non-parametric Spearman correlation regression was used to compare thermal sensation and study variables. A non-paired, two-
A tailed t-test was used to determine statistical significance when $p<0.05$. Hotelling’s $T$-squared statistic was utilized as a multivariate hypothesis test for determining significance of proportional data; which was appropriate for this application because we were testing the difference between the mean responses from distinct populations.

**2.0. RESULTS**

The perceived thermal comfort survey responses were analyzed both independently and as a set. The first survey was regarded as training for the participants and was not included in the data analyses. Because the acclimation time was relatively short, all surveys other than Q5 completed in the control environment are subject to each participant’s thermal adaptation and are therefore unreliable. Comparisons are made between the control and test environments to ensure consistent thermal conditions. The analysis focuses on the difference between the immediate thermal comfort response from control to treatment (Q5 to Q6) and the long-term thermal perception from control to the last survey of the treatment condition (Q5 to Q9) (Table 3).

**Table 3.** Mean perceived thermal comfort results for control (Q5) to first treatment exposure (Q6) and for control to last treatment exposure (Q9). Significance is indicated by “*” when $p<0.05$

<table>
<thead>
<tr>
<th></th>
<th>Wood</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q5</td>
<td>Q6</td>
</tr>
<tr>
<td>TS</td>
<td>0.39* 0.39*</td>
<td>-0.03* -0.36*</td>
</tr>
<tr>
<td>TA</td>
<td>0.21* 0.14*</td>
<td>-0.12* -0.12*</td>
</tr>
<tr>
<td>TP</td>
<td>0.11* 0.18</td>
<td>-0.08* 0.10</td>
</tr>
<tr>
<td>TE (°F)</td>
<td>-0.36 0.79</td>
<td>-0.04 0.50</td>
</tr>
</tbody>
</table>

**2.1. Thermal comfort results**

Thermal comfort results are summarized in Table 3. Thermal sensation responses of participants who received the wood wall treatment was cooler and closer to thermally neutral
(M = +0.54, SD = 0.69), than those exposed to the white wall treatment (M = +0.68, SD = 0.72),
t(56) = 1.67, p = 0.03 (Figure 4). On the 5-point thermal acceptability scale, with 1 being “clearly
acceptable” and 5 being “clearly unacceptable”, at the point at which the wall treatment was
revealed (Q5|Q6), responses of participants who received the wood wall treatment were more
accepting of the thermal environment (M = 2.01, SD = 0.88), than those of the white walls (M
= 2.41, SD = 1.09), p<0.05.

Figure 4. Radar chart of distribution of thermal sensation responses for (A) Q5: the last survey in the
treatment condition (black curtain) for both wood and white groups  (B) Q9: the last survey of the wall
treatment in which groups were exposed to their respective treatment condition

Wall treatment was also found to have a significant effect on perception of thermal preference.
Mean participant response for white wall treatment revealed a desire for a cooler environment
when compared to the control treatment prior (delta_{black:white} = -0.08, SD = 0.39), with the mean
decreasing from the control to the wood wall treatment (delta_{black:wood} = 0.11, SD = 0.57,
p<0.05) (Figure 4).

At the point at which the wall treatment was revealed, perceived thermal preference of
participants who received the wood wall treatment was cooler and closer to thermally neutral
(M = 0.46, SD = 0.56), than those exposed to the white painted drywall wall treatment (M =
0.68, SD = 0.51, p<0.01) (Figure 5). Because thermal preference is a directional scale without
weight, the data are best represented in proportions. Proportioning the responses reveals that
participants were more likely to respond with “no change” in the wood wall condition (54%)
than the control condition prior (36%) and more than the white wall (29%) which decreased
from the control condition prior (31%) (Figure 3).
2.2. Semantic results
The strongest correlation discovered was for the word pair natural-artificial to wall treatment, \( r(56) = 0.77, p < 0.001 \). Wood was considered more “natural” than white walls or the control. Wood was also significantly more “liked” than “disliked” as compared to the white walls, \( r(56) = 0.58, p < 0.01 \). Wood was also found to be significantly more “expensive”, “pleasant”, “sturdy”, “unique”, “interesting”, “new”, and “clean” than the white.

[Figure 6. Semantic-differential word results by wall treatment. Significance is indicated at the top of each word pair; **p < 0.05, ***p < 0.01, ****p < 0.001]

2.3. Physiological results
None of the physiological results varied by function of wall treatment with a meaningful effect size (\( d > 0.2 \)), so the results will not be included in this paper. Possible reasons for this result are included in the discussion.

3 DISCUSSION
This study illustrates the success of PMV for predicting human thermal comfort. For the purpose of understanding perception, we are interested in a small range of responses on the PMV scale: from 0 “neutral” to 1 “slightly warm”; 82% of all thermal sensation responses in this study were one of these two choices.

The results for thermal sensation alone, though minimal, are not negative. The HHH would reason that there may be some concern that exposed wood surfaces may lead to a perceived overheating is the potential for wood materials to lead to an overheating effect in the cooling season because of the HHH. This study supports the alternative. While the cause cannot be identified, we hypothesize it is possibly due to a biophilic effect of wood materials. The perceived qualities of the wood walls might have led participants to feel more at ease, and therefore, more forgiving of the thermal environment.

We posit that we may be able to counteract slight increases in the temperature setpoint in the cooling season by leveraging the visual effects of wood materials on perception of thermal comfort. Based upon the perceived thermal comfort difference from white to wood (+0.2 PMV), with all other variables held constant (MRT, RH, air speed, met, clo), this translates to a potential air temperature difference of 1°F. This effect will likely not go above and beyond the acceptable temperature range of the adaptive model but should be explored in future research. Importantly, even if further studies do not show persistence of this effect, this study lends some confidence that the HHH does not create a new obstacle when trying to reduce heating and cooling demands in exposed wood buildings.

According to Humphreys and Hancock (2007), the use of any particular thermal comfort scale can result in a vote bias. It is for this reason that the thermal comfort responses were treated as a set. This double-inquiry method compares thermal sensation with thermal preference. The data revealed that participants who rated their thermal comfort as “neutral” often selected their thermal preference to be “cooler”. The desired thermal change does not always reflect the responses for thermal sensation. The perceived thermal comfort for individual preferences
is often different from what is desired. In this study, we were interested in determining not only how a person feels, but how they would like to feel. In perception research, this is critical. An individual might determine their environment to be thermally “neutral” but actually would like to feel either cooler or warmer, depending on the context. The thermal sensation and thermal preference scales led to inconsistent feedback from participants; for this reason, in this study, we define perceived thermal comfort as thermal contentedness. Participants were more likely to be thermally “content” in the wood environment than the white walls. The tendency to be more forgiving of the uncomfortable environment might be due to the biophilic properties of wood or its visual interest over that of white walls, but this study cannot articulate cause.

Of particular interest is the first survey after the treatment condition was revealed. The instantaneous effect of wood on thermal sensation appears to be very strong. Over the remaining time in the treatment condition, this effect lessened. This begs the question: Could the effect of wooden materials become negligible over time as the subjects acclimate to their new surroundings? Future research should extend the study time period to determine if there is a duration at which wood no longer affects perceived thermal comfort or if it persists. The inconclusive physiological results are inconsistent with previous research. This study utilized ABPM rather than skin conductance, which could account for some degree of variability. These results could be due to any of the following: (1) there are no parasympathetic effects with respect to exposure to wood, (2) white coat syndrome led to increased blood pressure in any number of the participants and increased variability in HR, (3) the time spent acclimating to the space was not sufficient enough to trigger a parasympathetic response.

The semantic differential word pair results reveal that people found the wood walls to have favorable qualities all-around than the white. These findings are consistent with the literature and support that wood is perceived as a “natural” material. The greater effect size of the semantic results over the thermal comfort subjective results or physiological data suggests that the relationship between humans and biophilic materials such as wood are primarily psychological and rooted in personal preference. Interestingly, in the word pairs, the wood walls were found to be “warmer” than the white, \( r(56) = 0.31, p<0.05 \). Additionally, for all word pairs, there was no significant change between the control condition for the white and the control condition for the wood. This suggests that participants responded to the visual differences between the treatment walls as compared to other factors that might have affected their decisions, including uncontrollable factors such as smell, lighting, daily environmental differences, which seem to have had minimal effect on perceived qualities of the space.

Finally, perception of thermal comfort is important because it can contribute to the adaptive model of thermal comfort. In combining the subjective results with the physiological results, as expected, physiology is the strongest factor for predicting thermal comfort. This study suggests that perception of thermal comfort does not alter the body’s physiology greatly, but visual perception is influential in a person’s assessment of a space that is slightly uncomfortable, at least for over the duration of an hour. By contrast, in an extreme environment (i.e. +2 PMV, “hot”), we would expect most participants to report some degree of discomfort. In this scenario, it is unlikely that the participants would perceive improved thermal comfort regardless of the visual field.

3.1. Limitations
The authors recognize that the sample size was limited. With more time and funding, a repeated-measures study might have more effectively illustrated the individual preference between the two wall treatments and increased the power of the study. In hindsight, we would have liked to also study neural activity at the time the wall treatment was revealed, given the strength of the initial responses. Studying participants’ brain activity in conjunction with the data collected in this study may add a critical perspective useful in interpreting the results.

4.0. CONCLUSION
This study found that wood materials corresponded with thermal preference response indicating “no change” was desired, thus thermal preference was improved with exposure to
wood walls over that of white. Participants associated wood walls with positive qualities for nearly all word pairs. Effect of wood was most strongly correlated with objective (semantic) responses, followed by perception of thermal comfort, then minimally with physiological responses. We conclude that the effect of material perception is highly subjective and, in slightly uncomfortable thermal environments, visually “pleasant” or “warm” surroundings can improve perceived thermal comfort, even when the space may call for cooling.

ACKNOWLEDGEMENTS
This research was funded by the Agricultural Research Station through TallWood Design Institute, Grant #290281. We would like to acknowledge the consultation and assistance from Dr. Stefano Schiavon and colleagues at The Center for the Built Environment at University of California, Berkeley and Dr. Pat Lombardi from the University of Oregon Department of Biology and Dr. Christopher Minson from the University of Oregon Department of Human Physiology.

REFERENCES
Common area allocation, patterns and design in permanent supportive housing

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ABSTRACT: As a response to the growing homelessness crisis in North America, many non-profit housing providers are directing their architects to design housing projects that provide extensive support service spaces on site to support the transition from homelessness for some of the most vulnerable members of our communities. This paper reports on a study of the common spaces of Permanent Supportive Housing projects, which provide chronically homeless individuals with affordable housing, as well as emotional, mental, and physical health resources on-site. The purpose of the paper is to establish the stylized facts of common area allocation in Permanent Supportive Housing (PSH). The data for this research are the common area floor plans for twelve PSH projects. These spaces are analyzed, and typical entry sequences are compared with the intent of understanding the approach to security. The relationships between fundamental rooms are delineated through Space Syntax Analysis. The results from the study reveal high visibility between entry lobbies, offices, and threshold spaces though the space syntax indicated a significant amount of depth between the spaces, indicating difficulty of movement between them. The presence of a vestibule correlated with a greater depth of spaces but also greater visibility for staff and residents. Ultimately, the research serves the health and well-being of the residents and staff of future projects through an evidence-based approach to designing supportive service and resident common spaces. Future research will build on this analysis to investigate the empirical well-being outcomes influenced by design.

KEYWORDS: well-being, chronic homelessness, housing first, space syntax analysis, housing

INTRODUCTION

This paper reports on a research study of the common spaces of Permanent Supportive Housing projects which provide chronically homeless individuals with affordable housing, as well as emotional, mental, and physical health resources on-site. The pairing of housing and supportive services in the same building allows residents to have services tailored to their needs (Rog et al. 2014). The presence of service staff builds trust so the residents can seek assistance when they are ready. Staff in the building will check in with residents frequently even if they are not in treatment. A cornerstone of the Housing First model is that the resident has the right to choose the services they receive with their housing and will receive support in their recovery at their own pace (Tsemberis, Gulcur, and Nakae 2004).

The Housing First approach to Permanent Supportive Housing shows broad positive outcomes such as improved mental, physical, and behavioral health; lower drug and alcohol use; reduced emergency room usage; and fewer crimes of homelessness, such as trespassing and public urination, that result in arrest and jail (Fitzpatrick-Lewis, et al, 2011). A key factor in the success of Housing First is the simple fact that a safe and stable home enables people to remove themselves from survival mode and to work through past trauma in a supportive environment with reliable service providers (Henwood, Matejkowski, Stefancic, and Lukens 2014). Research shows that the Housing First model is effective in achieving residential stability for people who have been homeless for years. One study found that 88 percent of “Housing First” residents remained housed compared to 47 percent in a control group who had entered housing through the traditional, “Treatment First” model (Tsemberis and Eisenberg 2000).
The health and well-being outcomes of Housing First and Permanent Supportive Housing are well documented (Fitzpatrick-Lewis et al. 2011). There is moderate evidence that Housing First results in increased housing tenure and reduced emergency room visits (Rog et al. 2014). There is strong evidence that a sense of security has a demonstrated effect on health and well-being in this environment (Henwood et al. 2018). Residents in Permanent Supportive Housing programs report increased levels of autonomy, choice, and control, and a majority of clients participate in on-site services (Tsemberis and Eisenberg 2000).

Despite the ample literature in psychiatry and public health, there are no known studies that look at the spatial relationships of common areas in PSH. This paper is an examination of supportive housing facilities for homeless individuals in North America, and the results can be used to guide designers of new Permanent Supportive Housing support spaces. By spatializing the relationships of resident common areas, this research contributes an important and missing piece: an empirical understanding of these areas.

1.0. METHODS

The data for this research are the common area floor plans for twelve built, Permanent Supportive Housing projects. In the first stage of the research, the common area spaces are analyzed through inter-building cross-comparison to answer the research questions: What types of common spaces are provided, and how are these spaces allocated. The study places a particular emphasis on the spaces provided to support the well-being of residents. In the second stage, the typical entry sequence of each building is diagrammed for depth using Space Syntax gamma diagrams.

Architecture students chose the initial 40 precedent examples of PSH projects in North America, collecting floor plans from the internet resources or by contacting the architects and project sponsors directly. From this initial group of 40, the researchers winnowed the projects to a group of 12. The primary selection criteria are size (50 or more units), geographic, sponsor and architect diversity, and year built (Table 1). Though Permanent Supportive Housing projects were developed in the 1990s, they are most often rehabilitations of existing Single Room Occupancy (SRO) buildings with limited opportunities for common areas; this research focuses on new construction with a clear Housing First mission.

Table 1. Permanent Supportive Housing Projects Selected as Case Studies

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Location</th>
<th>Sponsor (Owner)</th>
<th>Designer</th>
<th>Built</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingsbridge</td>
<td>Bronx, NY</td>
<td>Jericho Project</td>
<td>OCV Architects</td>
<td>2012</td>
<td>76</td>
</tr>
<tr>
<td>97 Crooke</td>
<td>Brooklyn, NY</td>
<td>CAMBA</td>
<td>Dattner Architects</td>
<td>2011</td>
<td>53</td>
</tr>
<tr>
<td>Connelly House</td>
<td>Philadelphia, PA</td>
<td>Project HOME</td>
<td>BWA Architecture</td>
<td>2011</td>
<td>79</td>
</tr>
<tr>
<td>Sanderson</td>
<td>Denver, CO</td>
<td>Mental Center</td>
<td>Health</td>
<td>2017</td>
<td>60</td>
</tr>
<tr>
<td>Star Apartments</td>
<td>Los Angeles, CA</td>
<td>Skid Row Housing</td>
<td>Michael Maltzan</td>
<td>2014</td>
<td>102</td>
</tr>
<tr>
<td>The Six</td>
<td>Los Angeles, CA</td>
<td>Skid Row Housing</td>
<td>Brooks + Scarpa</td>
<td>2016</td>
<td>52</td>
</tr>
<tr>
<td>Rene Cazenave</td>
<td>San Francisco, CA</td>
<td>BRIDGE</td>
<td>Leddy Stacy Maytum Stacy</td>
<td>2013</td>
<td>120</td>
</tr>
<tr>
<td>Richardson</td>
<td>San Francisco, CA</td>
<td>Community Housing</td>
<td>David Baker</td>
<td>2011</td>
<td>120</td>
</tr>
<tr>
<td>First Hill</td>
<td>Seattle, WA</td>
<td>Plymouth Housing</td>
<td>SMR Architects</td>
<td>2017</td>
<td>77</td>
</tr>
<tr>
<td>Interbay Place</td>
<td>Seattle, WA</td>
<td>DESC</td>
<td>SMR Architects</td>
<td>2015</td>
<td>97</td>
</tr>
<tr>
<td>Dunbar</td>
<td>Vancouver, BC</td>
<td>Coast Mental Health</td>
<td>DYS</td>
<td>2011</td>
<td>51</td>
</tr>
<tr>
<td>First Place</td>
<td>Vancouver, BC</td>
<td>Lookout Society</td>
<td>GBL</td>
<td>2012</td>
<td>129</td>
</tr>
</tbody>
</table>

The first phase of the study uses the case study research method as prescribed by Yin (2017) to understand the common area allocation in the PSH projects. Each building is treated as an

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individual case, and they are then compared to understand the unique combinations of spaces. The common areas are inventoried, measured, named, numbered, and colored. In order to understand their distribution in each project, consistent colors and names are used throughout. The primary categories include office, common area, entry, vertical circulation, horizontal circulation, and accessible outdoor space. Secondary categories are used to differentiate between main, and auxiliary spaces. In order to standardize and make true comparisons, an index—based on common area space per dwelling unit—is created for each.

The second phase of the study uses the space syntax analysis method as prescribed by Hillier and Hanson (1989), Markus (2013), and Bafna (2003). Space syntax analysis has been applied to designed spaces from the scale of the house (Hillier, Hanson and Graham 1984) to the scale of the city (Bhiwapurkar 2018); and across building types from museums (Hillier and Tzortzi 2006), to healthcare (Sadek and Shepley 2016). A more direct precedent in scale and type for this paper is Julia Robinson’s Complex Housing: Designing for Density (2017) for which she conducted space syntax analysis of Dutch apartment buildings.

The space syntax process was not intended to be exhaustive nor explicative of the entire building. Instead, the research questions bounded the scope of the diagrams and analysis. Comparison of entry sequences amongst the buildings was facilitated through depth analysis where the street at the main entry is the root level and each room passed through is an added layer of depth. The calculations for integration and control are used to evaluate safety and security for tenants and staff. After comparison of all twelve projects, common patterns of social and spatial relationships emerge and are expressed through the Space Syntax language.

2.0. FINDINGS
The results of this study show unique combinations of common and office areas in twelve representative Permanent Supportive Housing projects. The key findings from this study are within the following themes: visual and spatial integration of spaces; layering of thresholds; vertical circulation as connective tissue; and hubs of control.

2.1. Allocation of common area and office spaces
In addition to inventorying and calculating the individual spaces, they are also divided into general categories of “Common Area” and “Office Area” (Figure 1). The distribution analysis revealed four programmatic elements in the common area allocation found in all of the projects. These include a multipurpose room, office area, public restrooms associated with resident common area, and laundry room or rooms.

Each of the projects includes secure outdoor space for staff and resident use, either a courtyard on the ground floor or upper level roof terraces, with Kingsbridge including all three types of common outdoor areas. Where courtyards or roof terraces are provided, they are generally found at a depth of 4 or more. Literature in well-being supports access to substantial green space. Kuo and Sullivan (2001) found that aggression levels are significantly lower for residents when nature is present outside of apartments as compared to no nature and Wagenfeld, Roy-Fisher, and Mitchell (2013) found that access to nature improves physiological and psychological health outcomes for veterans with Post-Traumatic Stress Disorder.

While a typical apartment building has an average net-to-gross ratio of 70 to 75 percent (Meeks 2005), the PSH projects studied here range from 43 to 64 percent with a mean of 54 percent. As noted previously, PSH is distinguished from typical market-rate apartment buildings, or even typical affordable housing for families, by the inclusion of extensive common area spaces and supportive service office spaces, as well as smaller than average dwellings. This allocation at Sanderson is intentional, according to the Mental Health Center of Denver, “to create a sense of community, the building is equally divided between engagement spaces and apartment living.” Because of this unique condition, this study proposes a “PSH-adjusted” net-
to-gross calculation in which the common areas and office areas are added to the net unit areas. With this calculation, the metric ranges from 49 to 73 percent, with a mean of 61 percent.

Figure 1. Common and office area per unit by project

2.1.1. Supportive service offices

Essential to the Housing First philosophy is the inclusion of on-site supportive services paired with housing. Each of the case study projects has at least four designated supportive service offices on site. The arrangement of the supportive service spaces in these projects follow two distinct patterns. First, the “office tree” occurs when there is a room off the lobby or corridor that functions as an anteroom and the offices are arranged immediately off this area. A modified version of this has the “office tree” with a front check-in office within the space. Second, the offices are located immediately off the main corridor. This results in a plan with less depth than the office tree and, as a result, less spatial security for the staff and tenants.

While eleven of the projects allowed tenants to remain within the enclosure of the building to access services, a recommendation of Housing First principles, the Los Angeles project, The Six, deviated from this pattern: the supportive service offices that directly serve the tenants of the building are accessed off the street, through a separate entry. This is likely to result in more privacy for residents, while still ensuring convenience.

2.1.2. Common areas

The primary recreation space for residents, found in all projects, is the multipurpose room. The multipurpose rooms do not vary significantly in size from project to project, regardless of unit count. The average multipurpose room is 985 square feet. However, the depth of the multipurpose room varies significantly according to the space syntax analysis. At First Place, the multipurpose room has a depth of 2, while Kingsbridge’s multipurpose room has a depth of 7. The space syntax analysis also showed that the multipurpose room frequently has an attached room of another depth, usually a kitchen or laundry room, and often a direct relationship at the same or similar depth to a common outdoor space.

All twelve projects in the study have a significant quantity of resident common area with an average common area per dwelling unit throughout the twelve projects at 32 SF per dwelling unit. This area ranges from 16 SF per unit at Rene Cazenave and Richardson to 62 SF at Dunbar, with Sanderson also representing the top end with 58 SF. In eight of the 12 study
projects, common area is distributed throughout the building; four of the projects have common area on the ground floor only. It is of note that the two projects with the lowest common area to unit count are examples of projects with common area on the ground floor only, while the two projects representing the top end have common area on multiple floors.

While all of the projects have at least one multipurpose room, as discussed above, some have small specialty rooms in addition to the multipurpose room. The proliferation of many, specifically programmed common areas aligns with principles of Trauma Informed Care. According to Hopper, Bassuk, and Olivet (2010), access to choice is key, “because control is often taken away in traumatic situations, and because homelessness itself is disempowering; trauma informed homeless services emphasize the importance of choice for consumers” (p. 82). Dunbar and Sanderson, found to have the greatest common area per dwelling unit, follow this approach of many, activity-specific spaces. The studied projects include art rooms (Sanderson and Star), libraries (Sanderson, Star and First Place), and wellness/exercise rooms (Sanderson, Star, First Place and Kingsbridge). Half of the projects include a common room labelled, lounge. There is a computer room in six of the projects and a specific television room at three of the projects (Sanderson, Interbay, and Dunbar).

2.2. Visual and spatial integration
Space syntax analysis does not typically explicate the visual links between spaces. The method is modified for this study and a dashed line indicates the visual connection when a spatial one does not exist. Several of the projects have designed visual connections, typically using interior windows, presumably to enhance safety, security, and social interactions. Some of these visual connections are between adjacent spaces at the same depth, but often a visual connection bridges a spatial divide of many layers.

Visual connections are especially common near reception areas. Of the twelve projects studied, all but one have distinct reception areas and half of the projects have reception desks within lobbies near the entrances to the buildings. These desks provide a physical connection to the lobby space with most, but not all, being physically accessed from the lobbies themselves. The exception to this can be found at Rene Cazenave in Los Angeles where the element of staff security is heightened with a door leading from the reception area to a secure corridor beyond the entry lobby. The reception area can also provide a strong visual connection to an entry area, when placing front desk staff within a secured room. In three of these examples, the reception room has a visual connection to an entry vestibule with access from the building lobby, adding an additional layer of depth. The visual connections between the office and entry court at Kingsbridge spans three layers of depth (Figure 2). Double-height spaces also create opportunities for visual connection across both spatial depth and floor level. In First Place, people in the double-height lobby and multipurpose areas can look up at the exercise room, and at Kingsbridge, a central stair connects the lobby with the supportive service spaces on the basement level.

2.3. Layering of threshold spaces
In the case study projects, combinations of four typical components make up the entry sequences: the entry court, the vestibule, the lobby, and reception (Figure 3). The space analysis reveals high visibility between entry lobbies, offices, and threshold spaces—but also a significant amount of depth between the spaces, indicating difficulty of movement between them. The presence of a vestibule correlates with a greater depth of spaces—but also greater visibility for staff and residents.

Three of the buildings provide access right off the street into the building lobby. In other projects, an outdoor entry court, set off from the street, is the first element of the project's entry sequence. This outdoor green space is most often isolated from other common outdoor areas of the project but results in a greater setback from the street frontage for the entrance to these urban buildings. In three of the projects that utilize an entry court, two of those enter directly into a lobby, one into a vestibule, and the fourth directly accesses the residential vertical circulation in the lone project without a residential lobby or reception desk.
The entry vestibule has recognizable security implications for the six projects that have included it as a programmatic element. In these projects, the space syntax diagrams show a visual connection between the vestibule and a reception area with access between the two through the building lobby. The remaining three projects utilizing a vestibule have a reception desk inside of the building lobby. It is possible that the vestibule provides a point of control for visitors and that future observational studies could confirm this hypothesis.

2.3.1. Depth to dwelling unit
The scope of this research is the common areas of Permanent Supportive Housing, but study of the entry sequence requires a short discussion of the relationship of the dwellings themselves to the front doors of the buildings. Of the twelve projects studied, seven of the projects provide common areas serving staff and residents on the same floors as the dwelling units. The space syntax analysis reveals that the unit depth ranges from four to seven layers of depth from the outside of the building to the units. For the three projects with units on the ground floor, the unit depth ranges from 4 for Sanderson to 6 for Interbay where residents pass through common areas and office waiting areas to reach their dwelling units.

2.4. Vertical circulation as connective tissue
It was not unexpected to find that all of the projects in the study were elevator served, given the number of units and stories in the building projects. In half of the projects the elevator has a lower depth than the stairs, meaning residents and staff encounter the elevator before the stairs, indicating residents, staff, and visitors are likely to use the elevators for vertical circulation more frequently. The other six projects have a stairwell accessed from the same area as the building elevator. At Connelly, the space syntax analysis shows the stair is at the same depth as the elevator, but the floor plan analysis shows that the stair access is not as visible from the reception and mail area. Surprisingly, Dunbar and First Hill provide no stair access from the first floor of the building to the residential floors, as the stairwells serving the residential floors exit directly to the exterior at the ground floor. This requires visitors and staff to use an elevator to access the residential units on the upper floors, and anyone seeking to utilize the ground floor common areas featured in these projects are reliant on the building elevators.

In contrast to the two projects with no stair access at all from the common areas, four of the projects have a third, non-required, stair. In each, the openness and visual connection to the rest of the building likely encourages its use over the elevator for vertical circulation and provides a place for resident social interaction. In essence, the stair becomes additional
common area as opposed to circulation only. At three projects, the feature stair is located in the building lobby with a strong visual and physical connection to the entry area. The space syntax analyses for these three projects reveal the stair and the elevator at the same depth. The feature stair at Sanderson is enclosed in glass to control for smoke in a fire while not reducing the visual connection. At Richardson Apartments, the third stair is accessed from the secure exterior courtyard. A visitor or resident enters the building at the lobby, transitions from the lobby into the corridor, and exits the building into a courtyard to use this exterior open stair. The other two stairwells are not easily accessible from the main building entry. While the elevator and the stair are at the same depth for this project, the stair in the courtyard lacks a clear visual connection to invite use from a building visitor but rather serves as a social space and vertical circulation primarily for the building tenants.

2.5. Hubs of control
In addition to the paradigm of the “office tree,” where multiple supportive service spaces are served off a single office space, several projects had spaces that serve as “hubs” to multiple common areas. Hubs have the effect of “flattening” the space syntax diagram and increase spatial integration. To determine whether a space functioned as a hub, the control value of potential hubs and lobbies were calculated and compared (Table 2). According to Hillier and Hanson, spaces with higher values have greater potential for control.

Most hubs in the case study projects are two or three depth steps away from the street; Kingsbridge’s is the farthest, at six depth steps away. At Kingsbridge, the basement level of the double-height space (the landing of the third stair) serves six other spaces. Like Kingsbridge, the hub at First Place is not on the main entry level; it connects 8 second-level offices and common spaces. Dunbar’s lobby connects nine spaces, and opens directly onto the large multipurpose room. Sanderson’s lobby also functions as a common area hub, connecting eight spaces in addition to the vertical circulation and vestibules (Figure 4). Like Sanderson, Interbay’s lobby functions as a hub with vertical circulation. A pair of parallel and ringed corridors one level deeper connect nine spaces between them.

The central circulation spaces at Cazenave and Richardson each connect eleven distinct spaces, including the multipurpose rooms, courtyards, and office trunks, though neither connects directly to vertical circulation. The Star Apartments has two common area hubs, the first-floor lobby connecting five spaces, and the central circulation space on the second floor connecting seven. At Star, as well as Kingsbridge and Sanderson, the hubs are directly connected to the more open third stairs, further increasing the potential for social interaction. According to Space Syntax theory, distributed systems lead to diffusion of spatial control, while more symmetrical systems lead to integration (Hillier and Hanson 1984). The integration of the common area systems for these buildings ranged from .1561 for Star Apartments to .4080 for Crooke (Table 3). Mean depth had no correlation with number of common area spaces and very small correlation with overall depth.

3.0. DISCUSSION
The anticipated outcome of this research is a greater understanding of the importance of socially connected and secure spaces for the residents of Permanent Supportive Housing. Studying multiple buildings at a time rather than visiting one precedent helps to create patterns that architects can replicate instead of an idea they can copy. This is especially important for first time designers of such projects or for designers in new markets.

Connecting diverse uses creates space for potential social interactions between tenants, and between tenants and staff. space syntax analysis of existing spaces allows for an understanding of typological patterns. Space syntax as a design process tool reveals the hub-like nature of certain corridors, spaces which may then be augmented with increased chances for social interaction such as seating areas. However, the distillation of complex psycho-social and spatial elements of architecture down to two-dimensional diagrams is a limitation of the method. Future research will triangulate these results through primary narrative data such as interviews and other qualitative data collection methods.
Table 2. Space Syntax Empirical Value for Control
Figure 4. Sanderson Gamma Diagram

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Hub</th>
<th>Lobby</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingsbridge</td>
<td>2.95</td>
<td>1.00</td>
</tr>
<tr>
<td>97 Crooke</td>
<td>N/A</td>
<td>3.83</td>
</tr>
<tr>
<td>Connelly House</td>
<td>N/A</td>
<td>3.15</td>
</tr>
<tr>
<td>Sanderson Apartments</td>
<td>4.58</td>
<td>4.58</td>
</tr>
<tr>
<td>Star Apartments</td>
<td>3.87</td>
<td>1.86</td>
</tr>
<tr>
<td>The Six</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Rene Cazenave</td>
<td>6.15</td>
<td>1.08</td>
</tr>
<tr>
<td>Richardson Apartments</td>
<td>5.68</td>
<td>2.09</td>
</tr>
<tr>
<td>First Hill</td>
<td>7.20</td>
<td>2.63</td>
</tr>
<tr>
<td>Interbay Place</td>
<td>4.65</td>
<td>1.93</td>
</tr>
<tr>
<td>Dunbar</td>
<td>6.85</td>
<td>6.85</td>
</tr>
<tr>
<td>First Place</td>
<td>8.00</td>
<td>2.97</td>
</tr>
</tbody>
</table>

There is mixed evidence of social integration in the Permanent Supportive Housing literature. On one hand, Nelson et al (2016) found that, “housing enabled people to move from a mode of survival to a place of security and future orientation, and the intensive support services that were provided with housing helped participants to gain greater control over their social relationships, mental health, and ability to maintain housing” (p. 595). Tsai, Mares and Rosenheck, on the other hand, found no increase in social integration after moving into Permanent Supportive Housing (2012). Further research will explore the design implications of social integration to understand how the spaces and their connections may influence relationships between residents.

CONCLUSION
This paper is a space syntax, empirical evidence-based examination of supportive housing facilities for homeless individuals in North America. It contributes a necessary spatialization to the existing research on Permanent Supportive Housing. It also establishes the stylized facts for this building type, through an inventory and analysis of the common areas and office spaces found in existing projects. While each case study project has a unique combination of

Table 3. Space syntax analysis results for depth and integration

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Entry Court</th>
<th>Vestibule</th>
<th>Common Areas</th>
<th>Total Depth</th>
<th>Mean Depth</th>
<th>Relative Asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingsbridge</td>
<td>Y</td>
<td>Y</td>
<td>33</td>
<td>8</td>
<td>6.45</td>
<td>0.3516</td>
</tr>
<tr>
<td>97 Crooke</td>
<td>N</td>
<td>Y</td>
<td>17</td>
<td>5</td>
<td>4.06</td>
<td>0.4080</td>
</tr>
<tr>
<td>Connelly House</td>
<td>N</td>
<td>Y</td>
<td>37</td>
<td>6</td>
<td>4.86</td>
<td>0.2206</td>
</tr>
<tr>
<td>Sanderson</td>
<td>N</td>
<td>Y</td>
<td>34</td>
<td>6</td>
<td>3.76</td>
<td>0.1725</td>
</tr>
<tr>
<td>Star Apartments</td>
<td>N</td>
<td>N</td>
<td>33</td>
<td>5</td>
<td>3.42</td>
<td>0.1561</td>
</tr>
<tr>
<td>The Six</td>
<td>Y</td>
<td>N</td>
<td>17</td>
<td>6</td>
<td>3.05</td>
<td>0.2733</td>
</tr>
<tr>
<td>Rene Cazenave</td>
<td>N</td>
<td>Y</td>
<td>30</td>
<td>5</td>
<td>4.10</td>
<td>0.2214</td>
</tr>
<tr>
<td>Richardson</td>
<td>N</td>
<td>N</td>
<td>23</td>
<td>4</td>
<td>3.08</td>
<td>0.1981</td>
</tr>
<tr>
<td>First Hill</td>
<td>N</td>
<td>Y</td>
<td>19</td>
<td>5</td>
<td>3.84</td>
<td>0.3341</td>
</tr>
<tr>
<td>Interbay Place</td>
<td>Y</td>
<td>N</td>
<td>31</td>
<td>6</td>
<td>4.22</td>
<td>0.2225</td>
</tr>
<tr>
<td>Dunbar</td>
<td>Y</td>
<td>N</td>
<td>24</td>
<td>6</td>
<td>3.71</td>
<td>0.2464</td>
</tr>
<tr>
<td>First Place</td>
<td>N</td>
<td>N</td>
<td>25</td>
<td>5</td>
<td>3.44</td>
<td>0.2122</td>
</tr>
</tbody>
</table>
programmed spaces and demonstrates a particular set of priorities, similarities can be seen across projects regardless of building size, geographic location, architect or project sponsor.

The results of this study can be used to guide designers of new Permanent Supportive Housing supportive spaces. The key patterns found by the researchers that are relevant for designers are: 1) augmented spatial separation with visual connection; 2) supportive service office arrangement with security and accessibility; 3) enhanced vertical circulation as a social integration strategy. Future studies will use these findings as hypotheses to be tested with field observations and interviews with staff.

REFERENCES


Hillier, Bill, Julienne Hanson, and Heather Graham. "Ideas are in things: an application of the space syntax method to discovering house genotypes." Environment and Planning B: planning and design 14, no. 4 (1987): 363-385.


Well-being in memory care facilities: identifying the role of spatial design for social interaction in empirical literature

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ABSTRACT: From the last 40 years, the design of the physical environment in supporting dementia residents has been frequently mentioned in the research literature. The environmental design research literature has outlined the importance of social interaction and social network as one of the therapeutic goals to maintain the quality of life (QoL) for people experiencing dementia. Although several previous studies have conducted the empirical literature review to understand the physical environment and associated QoL in long-term care facilities (LTCF), no single study concentrated on the role of spatial design in social interaction. For elderly people with dementia, changes in their social or physical environment, or manifestations of dementia may have an influence on their social interaction and therefore, it is imperative to understand the factors associated with the physical environment, social interaction and thereby the improved quality of life (QoL). This study aimed to fill this gap and contribute to a better understanding of how ‘social interaction’, the most important determinants to measure QoL for people experiencing dementia could be influenced under different spatial design and environmental characteristics. This study provides a comprehensive understanding of the published evidence from diversified sectors such as medical and health literature, environmental psychology, architecture, interior design, and evidence-based design literature. By reviewing relevant literature and discussing environmental design factors associated with social interaction as a determinant of QoL, this paper outlines several critical spatial design characteristics and a comprehensive set of spatial design overview for LTCF that shown to affect positive social interaction and QoL of the residents, staff and their caregivers. The summary of this review could influence the future design of care facilities and provide designers the effectiveness or the weaknesses of their design decisions. As an expected outcome, this applied research could enhance the value and professional practice knowledge of memory care design that have a positive ripple effect in the healthcare design industry.

KEYWORDS: Spatial Layout, Social Network, Quality of Life, Physical Environment, Long-Term Care Facility

INTRODUCTION
Dementia is surrounded by stigma associated with memory loss particularly in older adults which results in social isolation. It is also associated with long-term care placement, high health care costs, functional dependency, serious behavioral problems, mortality, and reduced quality of life (QoL). Globally, the number of person with dementia (PwD) is expected to rise to 65.7 million in 2030 and 115.4 million in 2050, and over 90% of all cases are diagnosed over the age of 65 (Carrillo, Thies, & Bain, 2012). Improving QoL has become the focus of dementia care outlined by the Alzheimer’s Association (Fazio, Pace, Maslow, Zimmerman, & Kallmyer, 2018) so identifying factors associated with QoL is essential. For elderly PwD, changes in their social or physical environment, or manifestations of dementia may influence their QoL, and it is therefore imperative to understand the relationships between physical environment and social interaction.

A growing number of studies are examining the relationship between the different physical characteristics of spatial design and social interaction, confirming the importance of these factors in memory care facilities for PwD. The environmental design research literature has
established the importance of social interaction and social network as one of the therapeutic goals to maintain QoL in PwD. The objective of this systematic review is to comprehensively outline a set of factors related to the spatial design of LTCF that may influence social interaction and subsequently QoL in PwD. Therefore, this review aimed to fill this gap and contribute to a better understanding of how ‘social interaction,’ one of the most important determinants of QoL for PwD, could be influenced by different spatial designs and environmental characteristics.

1.0. METHODS
In order to identify spatial design factors potentially influencing social interaction for elderly (i.e. over 65 years of age) PwD, the author conducted a systematic keyword search within major research databases to identify the relevant studies. Seven databases from two distinct disciplines, medical or health literature and evidence-based architecture or design literature, were included in the search strategy. The keywords used to search for relevant articles were categorized into three different domains: spatial design, social interaction, and spatial settings (i.e. care facility). Each search included one keyword from each domain so that results reflected all relevant aspects for the review. A total of 988 articles were initially identified from the database search and a total of 51 full-text items were identified for inclusion in the systematic review (Figure 1).

All studies included in this review explored factors potentially influencing social interaction in elderly PwD living in LTCF. An Excel spreadsheet was created to evaluate the quality and record key information extracted from each study, including the location of research, research design, study setting, sample age and size, design intervention, inclusion criteria, outcome measures including use of scale or tool, and major findings and results of the study (Supplementary Table 1). This checklist is based on critical appraisal tools from Zaza et al., which also follow the PRISMA 2009 checklist and flow diagram (Zaza, 2000). The articles are also globally distributed and have study settings in many regions including Australia, United States (US), United Kingdom (UK), Scandinavia, Europe, Canada, and different countries of East Asia.

RESULTS
After careful examination of the 51 studies included in this systematic review and synthesis (Supplementary Table 1), four major spatial design features that could directly or indirectly influence social interaction in PwD were identified and are outlined below. The results from
this synthesis have been categorized into those four features, although there is understandably substantial overlap between many of these factors.

1. The Physical Environment/Setting of the Facility
When considering the physical environment of care facilities, unit size, scale, and other environmental characteristics are considered principal design elements. Although residents of care facilities value the care services most (Digby & Bloomer, 2012), the importance of the physical environment is simultaneously identified as a leading factor in potentially influencing social interaction. Spatial design features such as ambience in the environment, the use of familiar objects, furniture type and arrangement, inclusion of kitchen and residential scaled dining room, white noise, connection to nature, access to outdoor areas, privacy, use of bright light, color, temperature, wayfinding, use of smaller spaces or landmarks with simple decision making points, and, above all, homeliness can significantly impact a patient’s mood and behavior which can further influence social interaction and QoL (Barnes, 2002; Calkins, 2009; Digby & Bloomer, 2012; Fleming & Purandare, 2010; Mitchell et al., 2003; Werezak & Morgan, 2003).

Almost every study focusing on the physical environment and design guidelines for dementia care settings recommended more home-like character, which includes furniture, family pictures, a cozy living room with a sofa or armchair, and a small-scale dining layout next to the kitchen (Barnes, 2002; Boer et al., 2015; Calkins, 2009; S. Lee, Chaudhury, & Hung, 2016a, 2016b; Smit, Willemsen, Lange, & Pot, 2014). In a longitudinal study conducted in Canada, Lee et al. concluded that residents in small-scale, home-like facilities experience more positive effects on mental health and behavior compared to residents living in a traditional large-scale unit (i.e. LCTF). Small-scale green care farm or home-like care environments can provide an added benefit for residents due to the close proximity to nature. Residents living at green care farms are significantly more active, more often participating in domestic activities and outdoor/nature-related activities, and significantly less often engaged in passive or purposeless activities than the residents of a traditional nursing home.

Physical environment of dining room as mealtime intervention is another significant factor in improving behavioral and psychological symptoms of dementia and several studies considered music, food service, dining environment, and group conversation as the most important determinants of improving social interaction during mealtime (Chaudhury, Hung, & Badger, 2013; Whear et al., 2014). A supportive dining environment can foster functional ability, maximize orientation, provide a sense of safety and security, create familiarity, homeliness, provide optimal sensory stimulation, provide opportunities for social interaction, support privacy and personal control (Chaudhury et al., 2013; Chaudhury, Hung, Rust, & Wu, 2017).

Dementia-friendly outdoor design features more specifically garden is also important aspect in designing care facilities. Views of the garden and large windows allowing natural daylight allowed residents to complete activities of daily living efficiently (Nordin et al., 2017). Environmental factors such as outdoor public space may moderate the relationship between education level and sense of coherence. More educated residents who stay in LTCF with outdoor public space may have a stronger sense of coherence than those who stay in LTCF without outdoor public space (Jueng, Tsai, & Chen, 2016). When designing the outdoor environment, bright colors such as yellow can be disruptive or agitating to the homeliness of the environment; instead, landmarks could be used as wayfinding cues, and street lighting that illuminates the pavement edge without creating glare or changes in texture or identifiable color of paving can be used to avoid potential hazards (Mitchell et al., 2003).

2. Accessibility, Legibility, and Layout
Accessibility, legibility and layout are strong determinants of social interaction that can enhance residents’ well-being and independence and are highly influenced by both organizational factors and environmental design aspects (Moyle, Fetherstonhaugh, Greben, Beattie, & AusQo, 2015; Nordin et al., 2017). Design of both the indoor and outdoor environment influence the residents’ activities and interactions. An architecturally legible
environment, or an environment where the function of each room is evident through the size, proportion, materiality, and furnishings is important for designing any LTCF (Marquardt & Schmieg, 2009). The floor plan design of a nursing home, in particular, has a significant influence on residents’ spatial orientation and wayfinding (Calkins, 2009; Marquardt, 2011). Architectural design guidelines suggest various strategies to enhance orientation, including improvements for wayfinding by using signage and by choosing a supportive organization of the building (Hoof, Kort, Waarde, & Blom, 2010; Marquardt, 2011).

Privacy, sense of belonging, and furniture layout to initiate communication are important determinants of social interaction (Barnes, 2002; Marquardt & Schmieg, 2009; Torrington, 2006). The strongest evidence supports the positive benefits of private bedrooms on outcomes such as the satisfaction of families and staff, residents’ QoL, and reduced neuro-disability (Calkins, 2009). Ideally, bedrooms should be located close to the community space to allow for social interaction but with substantial privacy for the resident. Although economically reasonable and to some extent beneficial for social interaction, shared bedrooms are not popular in care facilities due to noise, spread of diseases, and lack of privacy. Design recommendations also include home-like decorations, adequate lighting, and furniture should be arranged in a conversational pattern to stimulate social interaction between the physical and social environments.

3. Social Environment and Network
Frequent social interaction is associated with higher QoL, and research clearly describes the importance of social interaction and positive mood in promoting QoL. In one study, dementia residents with higher QoL were more engaged in active and expressive social activities and less engaged in passive/purposeless activities compared to PwD with lower QoL (Beerens et al., 2016). By looking at 1704 interactions over the course of 143 hours, Abbott et al. highlighted five factors to characterize interaction: 1) location of interaction, 2) context of interaction (e.g. social, care-related, or re-direction), 3) type of interaction (verbal or non-verbal and with whom), 4) frequency and duration of the interaction, and 5) quality of interaction (Abbott et al., 2017). The results found that interactions were brief, verbal, and social in nature and occurred in public areas. Casual living and activity areas in close proximity to bedrooms or kitchens enhanced the social environment and integration through both design and staff involvement. The socio-human environment was perceived to be more important than the physical environment. Specialized physical design features can be useful for maintaining the QoL to reduce disruptive behaviors. In 2012, Garcia developed a mnemonic – C.A.R.E.F.U.L. (Consistency, Approach, Ratio of staff to residents, Environmental Design, Flexibility, Understanding, Level of Noise) – as a design recommendation tool for the social environment, identifying design elements from the physical and social environment that hinder or improve the disruptive behaviors and QoL of residents in LTCF (Garcia et al., 2012).

It is evident that frequent social interaction is associated with higher QoL, reminiscence, leisure, expression, and vocational occupational had the greatest potential to enhance well-being. A 20-year prospective cohort study on social activity, cognitive decline, and dementia risk identified that people who engage in solitary activities, such as travelling, gardening, doing odd jobs, word finds, knitting and sewing, watching movies also have increased engagement in social, physical, or intellectual pursuits that result in decreased risk of dementia (Marioni et al., 2015). Social environment factors such as staff roles, resident group size, and physical factors such as a non-institutional character of the environment, nursing station location, adequate seating, and informal social interaction in care facilities are important determinants (Campo & Chaudhury, 2011). One meta-analysis shows that people with less social participation, less frequent social contact, and more feelings of loneliness have an increased risk of developing dementia. Although the results were not statistically significant, low satisfaction with social network seems to be associated with incidence of dementia (Kuiper et al., 2015).
4. Staff-Resident Ratio, Empowerment and Care Philosophy

A supportive work environment is very important for staff interaction, and quality staff interaction plays an important role in promoting the psychological well-being of PwD in any psycho-geriatric setting (K. H. Lee, Boltz, Lee, & Algase, 2017). Evidence from the literature review supports that appropriately designed physical settings play an important role in creating a PCC approach for the residents. PCC focuses on independence, selfhood or having an individual identity, well-being, and abilities of residents to feel supported, valued, and socially confident within their surrounding environment. Dementia and Alzheimer’s disease changes a person’s ability to think, act and interact with the surrounding social environments, and a PCC approach may reinstate the confidence of the residents. Sociability is an embodied dimension of selfhood (the state of having an individual identity) in person-centered dementia care, and both sociability and selfhood in dementia are equally important in comparison to other factors. In a qualitative descriptive study using in-depth semi-structured interviews, participants described that the care received was more important than the physical environment, but participants also valued homeliness and privacy (Digby & Bloomer, 2012). Chaudhury et al. identified the role of the physical environment in supporting person-centered dining, and the evidence indicates that well-designed physical settings can play an important role in creating a person-centered dining environment to support the best possible mealtime experience (Chaudhury et al., 2013).

Across all studies, continuous and spontaneous staff collaborations were key activities in supporting quality care. Staff interaction during the older adults’ transitions were influenced by three main themes: i) the significance of formal and informal organizational activities and interactions, ii) interpersonal relationships and cultures of care, and iii) professional hierarchy and different scopes of practice (Eika, Dale, Espnes, & Hvalvik, 2015). Low ratio of staff to residents and disturbing noise were identified as two of the most important factors influencing behavior and QoL of residents (Garcia et al., 2012). Staff were catalysts for the psychosocial climate, and when present or engaged, they could create a climate interpreted by the residents as homely, which supported patient well-being. When staff were absent, the climate quickly became anxious, and this was associated with patient ill-being (Edvardsson, Sandman, & Rasmussen, 2012). Empowerment and collective decision making enhances social interaction, QoL, and well-being among older adults (Knight, Haslam, & Haslam, 2010). Empowered residents feel more engaged with their environment and the people around them, and they are generally happier and have better health. In an observational longitudinal study of 176 residents in a nursing care home, the study findings suggest the provision of autonomy for residents, letting them make their own choices and encouraging social interaction and participation in activities (Boer et al., 2015). By creating a more home-like dining atmosphere, one study of pre- and post-renovation of physical environment of the dining room has suggested five notable themes from the renovations: (a) autonomy and personal control, (b) comfort from a home-like environment, (c) conducive to social interaction, (d) increased personal support, and (e) effective teamwork among residents (Chaudhury et al., 2017).

DISCUSSION AND CONCLUSIONS

It is evident that one in eight baby boomers will be diagnosed with dementia of the Alzheimer’s type once they are 65 years old. In 2016, the first baby boomers turned 70, and it is projected that by 2031 nearly one in two baby boomers over age 80 will be diagnosed (Bredfeldt, 2015). Dementia of the Alzheimer’s type is a disease that does not have any cure or prevention, so the focus of care should be to improve social interaction and thereby QoL, and this may be done through environmental design. The objective of this literature review was to provide guidelines for designing better memory care facilities by highlighting the spatial design features for better QoL. The study identified that both physical and social environment are equally important aspects in maintaining positive social interaction between peers and caregivers. The design recommendation to create opportunity for social interaction includes spatial configuration of the physical layout such as visually legible and physically interactive spaces, small-scale home like setting, physical environment of the dining room, ambient features of the indoor environment, therapeutic garden or outdoor environment, exposure to natural settings, home-like décor with personalized features, spatial orientation, navigation and
wayfinding, furniture layout and seating arrangements, approach to care philosophy to empower the residents through autonomy, privacy, and increased staff-resident ratio to initiate positive social network.

One important objective of this review was to identify gaps in knowledge in the existing research literature to give directions for future research. There is a strong need for evidence-based design solutions to accommodate the personal, social and psychological needs of the residents, staff, caregivers, and family members. There was very little research addressing the importance and key design features of the spatial configuration and ambient environment as they are proportionately related to the physiological and psychological health and well-being of the immediate users. Effective layout of the facility, clean air, cross ventilation, reduced glare, indirect natural light, soothing sound, white noise, aromatherapy, visual paintings are a few areas of concern that need further research specifically in long-term care settings for cognitively impaired people. Among the reviewed literature, many studies had small sample sizes, without describing the quality assessment, cross verification or triangulation in study design, insufficient inclusion criteria and control of the environment or settings, these all are considered as limitations in this synthesis study. Moreover, this article only addressed “people with dementia” in long-term memory care settings as opposed to healthy older adults or other forms of cognitive impairment for older adults in different settings such as a home or residential care, end of life, hospice care; thus, generalizability is limited. By highlighting the design intervention guidelines, this systematic review could be used as a resource for all LTCF administrators and healthcare design professionals and researchers to understand the gaps and opportunities in designing future care facilities to provide a positive social environment for PwD.

REFERENCES


Fazio, S., Pace, D., Maslow, K., Zimmerman, S., & Kallmyer, B. (2018). Alzheimer’s Association Dementia Care Practice Recommendations. THE GERONTOLOGIST, 58(S1), S1–S9. doi:10.1093/geront/gnx182


<table>
<thead>
<tr>
<th>Research Design</th>
<th>Location of the Research</th>
<th>Year</th>
<th>Research Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quasi-experimental design with a longitudinal comparative study</td>
<td>Belgium and Netherlands</td>
<td>2015</td>
<td>Borrero, Zeegers, &amp; Sijbesma-Peters</td>
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<tr>
<td>Descriptive longitudinal study with 178 residents</td>
<td>Norway</td>
<td>2016</td>
<td>Eika, Dale, Espevik, &amp; Høvding</td>
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<tr>
<td>Observational study of 12 residents in dementia care home environments</td>
<td>Belgium</td>
<td>2015</td>
<td>Wille, Defossez, &amp; De Bleecker</td>
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<tr>
<td>Qualitative research with 120 residents and interviews with 10 caregivers</td>
<td>Australia</td>
<td>2015</td>
<td>Coughlan, King, Iversen, &amp; Brimacombe</td>
</tr>
<tr>
<td>Longitudinal cohort study and systematic review of PRISMA guidelines</td>
<td>Norway</td>
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<td>Oberg, Låg, &amp; Sandvik</td>
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<td>Cluster randomised controlled trial involving 15 care homes</td>
<td>Austria</td>
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<td>Scherzer, Kogler, &amp; Köhler</td>
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<tr>
<td>Cluster randomised controlled trial with 209 residents</td>
<td>USA (Seattle)</td>
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<td>Keller, Kupper, &amp; Zeegers</td>
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<tr>
<td>Cluster randomised controlled trial with 303 dementia residents</td>
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<td>2016</td>
<td>Liesen, Korff, &amp; Schneider</td>
</tr>
<tr>
<td>6 participatory articles</td>
<td>Belgium</td>
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<td>De Bleecker, Zeegers, &amp; Sijbesma-Peters</td>
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<tr>
<td>Systematic review of 35 articles</td>
<td>Belgium</td>
<td>2015</td>
<td>Van den Bergh, Van den Bergh, &amp; Van Den Bergh</td>
</tr>
<tr>
<td>17 systematic review articles, 3 qualitative articles, and 1 mixed-method study</td>
<td>Belgium</td>
<td>2015</td>
<td>Van den Bergh, Van den Bergh, &amp; Van Den Bergh</td>
</tr>
<tr>
<td>Literature review with 52 articles</td>
<td>China</td>
<td>2016</td>
<td>Jing, Cui, Y., &amp; Wang, X.</td>
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<td>Study Design</td>
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<td>Barnes (2002); UK</td>
<td>Literature Review</td>
<td>Cross-sectional, multiple - method design: 36 residents ages 63 to 94</td>
<td>Residents’ positive and negative relationship networks in the nursing home</td>
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<tr>
<td>Casey, Low, Jain &amp; Brodaty (2016); Australia (Sydney)</td>
<td>Cross-sectional, multiple - method design: 36 residents ages 63 to 94</td>
<td>Residents’ positive and negative relationship networks in the nursing home</td>
<td>Findings highlight Nursing Home residents’ isolation and lack of engagement.</td>
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<tr>
<td>Fleming &amp; Punsandrum (2013); UK (Manchester)</td>
<td>A Literature review of 57 articles</td>
<td>Size of the care home, an optimum level of stimulation, unobtrusive safety features, social environment</td>
<td>Design features: safety and security of the residents, a variety of spaces with differing ambiance, size and function, single, personalize room for each resident.</td>
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<tr>
<td>Gebov (2009); USA</td>
<td>Systematic review of design principles</td>
<td>Design principles are general “rules of thumb” within a PCC context</td>
<td>The paper zeroes on ten design principles for elders and dementia care staff.</td>
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<tr>
<td>Hoof, Kort, Waanz &amp; Biehn (2010); Netherlands</td>
<td>Literature review and supplementary focus group sessions</td>
<td>Environmental interventions (1) safety and security at home (2) perception, orientation, and memory.</td>
<td>Falls and carpet design, signage, wayfinding, easy access, lighting, grab bars, guard rails, non-slip floor covering as design intervention.</td>
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<tr>
<td>Hoof, Kort, Duijnse, Rutten et al. (2010); Netherlands</td>
<td>A Literature review of the integrated design of the indoor environment</td>
<td>An overview of the indoor environmental parameters, integrated design and implementation of relevant building systems.</td>
<td>Results are presented as indicators of the basic value, functional value and economic value, as well as a synthesis of building-related solutions.</td>
</tr>
<tr>
<td>Magilton, Rivera &amp; Dawson (2003); Canada (Ontario)</td>
<td>Randomized controlled trial. Four nursing home units in a geriatric center, 32 residents (mean age of 86 years)</td>
<td>The effect of the intervention on the residents’ spatial orientation and agitation.</td>
<td>The residents demonstrated increased ability to find their way to the dining room one week after the intervention and showed a decline in level of agitation.</td>
</tr>
<tr>
<td>Michell, Burton, Renman, Blackman &amp; Williams (2003); UK</td>
<td>Literature review</td>
<td>Design guidelines for the outdoor environment familiar, legible, distinctive, accessible, comfortable safe.</td>
<td>Small-scale street blocks with Architectural facades, open spaces, short streets with good visual access, a variety of materials, colors and street furniture.</td>
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<td>Marquardt (2011); Germany</td>
<td>Literature review</td>
<td>Therapeutic Physical Environment: Legibility, Familiarity, Autonomy, Sensory Stimulation, and Social Interaction</td>
<td>The floor plan design, decorating with personal items, corridors, natural light, natural views has a significant influence on residents’ spatial orientation and wayfinding.</td>
</tr>
<tr>
<td>Parker, Barnes, McKee, Morgan et al. (2004); UK (Sheffield, Yorkshire)</td>
<td>Cross-sectional, multiple - method design: 38 Care Homes (11 small, 14 medium, 13 large)</td>
<td>Access to the indoor/outdoor environment, privacy, personalization, choice, safety, comfort to measure building domains.</td>
<td>QoL is a multi-dimensional construct that includes social relationships. A positive association between the physical environment and QoL.</td>
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<tr>
<td>Torrington (2006); UK (Sheffield)</td>
<td>Cross-sectional, multiple - method design: 38 Care Homes</td>
<td>To identify the effects of building design on residents’ well-being.</td>
<td>Overall well-being score was larger in small homes. Physical environment should be designed to support activity by providing good physical support.</td>
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<tr>
<td>Chauthary, Hang &amp; Badger (2013); Canada (Vancouver)</td>
<td>Literature review; 22 journal articles including 12 intervention studies</td>
<td>Incursion criteria: (1) empirical research, (2) the physical environment of the dining rooms (3) published in English from 1993 or later.</td>
<td>Supportive dining environment can foster (1) functional ability, (2) orientation, (3) a sense of safety/security, (4) familiarity, (5) sensory stimulation, (6) social interaction, and (7) privacy, personal control.</td>
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<tr>
<td>Chauthary, Hung, Roi &amp; Wu (2017); Canada (Vancouver)</td>
<td>Pre-post renovation ethnographic observations. Two care units of a large long-term care facility</td>
<td>Physical environmental interventions, adding an open kitchenette and creating a home-like dining atmosphere.</td>
<td>Five themes are notable: (a) autonomy, (b) comfort of a home-like environment, (c) social interaction, (d) personal support, (e) effective teamwork.</td>
</tr>
<tr>
<td>Juang, Tsai &amp; Chen (2015); Taiwan</td>
<td>104 LTCF residents Face-to-face interviews and cross-sectional analysis using sense of coherence (SOC) scale (Chinese version)</td>
<td>Room type, natural windows, outdoor public space</td>
<td>Long-term care facilities in Taiwan had a relatively low sense of coherence scores compared to their counterparts in Western countries.</td>
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<tr>
<td>Author(s)</td>
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<td>Chaudhury, Cooke, Cough, &amp; Razagh (2017); Canada</td>
<td></td>
<td>Literature Review; 103 full-text, 94 empirical studies, 9 reviews, published after 2009.</td>
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<tr>
<td>Young Lee, Chaudhury &amp; Hung (2015); Canada</td>
<td></td>
<td>Longitudinal study, traditional large-scale setting and small-scale, home-like setting</td>
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<td>Forsund &amp; Ytethus (2016); Norway</td>
<td></td>
<td>Qualitative study with interview and observation in Specialized care units (SCU)</td>
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<tr>
<td>Collins (2009); USA (Ohio)</td>
<td></td>
<td>Literature review</td>
<td>Household, Building configuration, Non-institutional design, Wayfinding, Safety, Outdoor areas, Dining rooms, Bedroom</td>
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<tr>
<td>Smidt, Willemse, Lange &amp; Pot (2014); Netherlands</td>
<td></td>
<td>Exploratory Study; 57 residents in 10 dementia care facilities</td>
<td>Home-like door and furniture arrangement</td>
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<tr>
<td>Nordin, McKee, Wallinder, Koch, et al. (2017); Sweden</td>
<td></td>
<td>Comparative Case Study with mixed-method, convergent analysis. 54 residents, 25 staff members, 4 relatives.</td>
<td>Open plans, automatic doors, smooth flooring, safety devices, and elevators in buildings</td>
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<td>Warzek &amp; Morgan (2003)</td>
<td></td>
<td>Literature Review</td>
<td>Social, physical and psychological environment</td>
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<tr>
<td>Ricci, Luijje, Schaafsma, et al. (2012); Netherlands</td>
<td></td>
<td>Quasi-experimental longitudinal research design, 175 residents with dementia.</td>
<td>Traditional versus small-scale long-term care institutions</td>
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<td>Bananen, Boer, Zwartkolk, Tan, et al. (2016); Netherlands</td>
<td></td>
<td>An observational study with 115 participants. Mean age was 84 years old</td>
<td>Social interaction to promote good QoL</td>
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<td>Kontos (2011); Canada (Southern Ontario)</td>
<td></td>
<td>Ethnographic study. 79 residents (11 men and 68 women) in Oriodox Jewish LTGF</td>
<td>Induction criteria, cognitive impairment, and two times more women than men.</td>
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<td>Abbott, Sellisk, Halsma, et al. (2017); USA</td>
<td></td>
<td>Observation Study including 39 residents with medical charts and visitor logs</td>
<td>Interaction: 1) Location, 2) context, 3) type 4) quantity and 5) quality of interaction</td>
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<td>Boer, Harries, Zwartkolk, et al. (2017); Netherlands</td>
<td></td>
<td>Longitudinal observation study, 115 nursing home residents. Mean age of 82 years.</td>
<td>To investigate whether residents of green care farms are more engaged in physical activities and social interaction than are residents of other nursing homes.</td>
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<td>Edwardsen, Sandman, Rasmussen (2011); Sweden</td>
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<td>Grounded theory design. Interviews &amp; Observation in a psycho-geriatric hospital unit with 24 residents.</td>
<td>Sharing space and moment, ‘sharing peace but not moment’ and ‘sharing place but not moment’</td>
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<td>Smidt, Willemse, Lange, Pot (2014); Netherlands</td>
<td></td>
<td>The exploratory study using 8th edition of Dementia Care Mapping (DCM) with 57 residents in 10 dementia care facilities</td>
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<tr>
<td>Liao, B., et al. (2017)</td>
<td>USA (Michigan and Pennsylvania)</td>
<td>113 persons in 17 nursing homes and 3 assisted living facilities</td>
<td>Multi-site descriptive study</td>
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<td>Digby, R. and Bloomer M. (2012)</td>
<td>Australia</td>
<td>Qualitative descriptive study, in-depth semi-structured interviews</td>
<td>Care environments that promote non-institutional design features</td>
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<td>Nordin, M., et al. (2012)</td>
<td>Sweden</td>
<td>A road-method, convergent analysis in two residential care facilities</td>
<td>Relationships between the physical environment and activities</td>
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<td>Campo, T. and Chaudhury, A. (2011)</td>
<td>Canada (Vancouver, B.C.)</td>
<td>The ethnographic study, observations &amp; interviews</td>
<td>Informal social interaction (1) physical (2) organizational (3) individuals and (4) social norms</td>
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<td>Mercier, P. and Le, V. (2016)</td>
<td>Europe (France)</td>
<td>A longitudinal study in 2-year follow-up prospective school study</td>
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<td>Lee, T., et al. (2016)</td>
<td>Canada (Vancouver, B.C.)</td>
<td>Mixed-method research that includes environmental assessments, comparisons, qualitative fieldwork &amp; group interviews</td>
<td>Staff perceptions on the role of the physical environment</td>
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<td>Knight, C. and Haslam, B. (2010)</td>
<td>UK (Southeast England)</td>
<td>The longitudinal experiment involves a case study and observational measures</td>
<td>Residents’ behavior, QoL and use of social space</td>
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<td>Mercier, E. and Johnston, et al. (2011)</td>
<td>Cross-sectional data for a large randomized controlled study</td>
<td>Spatial layout of the home and space syntax varies in legibility and connectivity</td>
<td>Higher connectivity was associated with the worse performance of social activities of daily living (ADLs), intel legibility was not associated with ADLs.</td>
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<td>Anderson, P., et al. (2015)</td>
<td>Sweden (Göteborg)</td>
<td>Exploratory observation study in dementia wards</td>
<td>The common spaces contain multi-purpose common spaces with integrated activities, dining rooms, and sitting rooms.</td>
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</table>

**Notes:**

- **Physical environment and Resident care**
- **Design of the physical environment, Residents' activities, Interaction**
Light-diffusing insulation: existing solutions and new prototypes for glazing interlayers

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ABSTRACT: Daylighting is an important strategy for low energy buildings today, yet glass compromises the overall thermal resistance of building envelops: even expensive triple-glazed windows conduct heat at over twice the rate of opaque exterior walls, insulated to energy code minimums. Triple glazed windows are also heavy, expensive, and energy intensive in their manufacturing. Today, lighting consumes 1/3 of electricity in commercial buildings, and daylighting may potentially reduce building energy use by 28% or more (Williams 2012). As the energy code continues to constrain the prescriptive window-to-wall ratios of commercial buildings, it is important to develop envelope systems that admit energy-saving daylight while better managing heat gains and losses. A series of graduate courses at Kansas State University examined the performance of several existing glazing-integrated insulation solutions, using this research to propose a variety of innovative alternatives that can increase the thermal performance of transparent assemblies in building facades. With both computer analysis and instrumented testing of small prototypes, the research seeks to better understand the physics of fenestration interlayers, while also identifying new strategies for improving the performance of basic double glazed insulated glass units and double wall construction. Test results in the paper present the thermal performance, light transmission, and light diffusion of existing light-diffusing and translucent products and student-developed prototypes. Following a discussion of the research work, a generalized model attempts to better explain the physics at work in interlayers, and propose how such systems can be optimized to maximize light diffusion while improving the thermal performance of glazing units.

KEYWORDS: Daylight, Prototyping, Thermal Testing, Simulation,

INTRODUCTION

Fenestration remains a contentious issue in the architectural field today. On one hand, architects and many building owners value transparency in buildings for a variety of legitimate reasons – among them the broad benefits of daylight, visual connection to outdoor spaces, and introduction of beneficial solar radiation into passive buildings. On the other hand, energy codes and energy efficiency experts abhor the overuse of fenestration in buildings, and the architectural field has come to accept increasingly strict limits (typically in the form of window-to-wall ratios) on the amount of glazing that can be used in buildings. For today’s high-performing buildings, fenestration has to deliver ever-higher levels of performance in order to balance thermal resistance with the benefits of transparency – specifically daylight. While incoming solar radiation is also an important performance factor in transparent assemblies, this research focuses on the transmission and diffusion of daylight.

Conventionally wisdom tells us that highest-performing thermal barriers are opaque. Transparent assemblies allow light to pass through them, at the expense of transmitting heat more quickly than opaque assemblies. While the thermal resistance of transparent assemblies can be improved with invisible measures like coatings, additional layers of glass, and special gasses in the fenestration cavity, even the best-performing transparent fenestration falls short of the thermal resistance of opaque assemblies, leaving the impression that thermal resistance, light transmission, and light diffusion are opposing criteria.
Interlayers – materials added between fenestration layers – can greatly improve the thermal performance of fenestration, while still preserving transparency. Among the variety of interlayers available are matrices that tend towards openness, versus fibrous with increasing density that reduces transparency. This paper proposes a new perspective on how insulating interlayers may perform in order to admit and diffuse light more effectively, while providing a high level of thermal resistance.

1.0 BACKGROUND

1.1. The need for better-performing fenestration

Daylighting alone may potentially reduce building energy use by 28% or more (Williams 2012), though adding glass area to buildings can create new efficiency problems unless the thermal resistance of glazing is improved. Triple glazing (and experimental quadruple glazing), deliver such improved fenestration thermal resistance, but pose new critical issues. For example, a third layer of glass adds 50% more glazing cost, weight, and embodied energy to an insulated glass unit (IGU), versus a conventional double glazed IGU. Like insulation in opaque assemblies, adding layers to windows has diminishing returns: each layer produces less performance improvement than the layer before. In addition, the long-term performance of the highest-performance IGUs depends on gas infill such as Argon, which can escape the IGU over time (or even during manufacturing and construction) to reduce performance.

In many building types, the potential energy savings from glass is further hampered by comfort issues caused by the failure to control direct sunlight or very bright daylight. Such conditions cause occupants to leave window shades and blinds in a closed position indefinitely, actually increasing the reliance on electricity for lighting. As such, a building with a large amount of glass may rely on triple glazing to manage heat transfer, only to fail in realizing efficiency due to lack of daylight control. The latter problem, in part, can be solved by ‘daylight fenestration’: a sector of materials, products, and systems that makes incoming daylight (or sunlight) useful by diffusing it, rather than simply transmitting it. Thus a better performing fenestration should address both heat transfer but also light transmission and diffusion.

1.2. Fuzz vs. physics: misconceptions from biomimicry and opaque assemblies

Insulating opaque cavity walls was one of modern building science’s first innovations, combating convective heat transfer in open cavity spaces by filling them up with insulating material. Creating thermal resistance with fibrous, foamed, granular, and spongy materials is an insulating strategy that we see around us everywhere: incorporated in ubiquitous fiberglass batting but also in jackets, quilts, and mittens. We are assured of the reliability of this strategy because we see it frequently in nature.

‘Fuzz’ is only one way to combat heat transfer, however. The impetus of this paper began in an earlier research project where a group of students created a multilayered façade system where multiwall polycarbonate created a deep envelope cavity (Gibson 2015, Figure 1). As the students rushed to prototype their concept, the question was asked: what goes in the cavity, and can this insulation still allow some transmission of light through the façade? The team decided to solve the problem with fuzz: a dozen or so bags loose polyester fiber (aka ‘teddy bear fill’) from the nearest big-box craft store. The fuzz method worked, but the resultant assembly wasn’t very translucent anymore.

The challenge in fenestration interlayers, stated earlier, is that you want the interlayer to resist heat transfer while also allowing light to pass through. While fibrous insulation is known to work well as an insulator, the physics of fibrous insulation is somewhat fuzzy (pun intentional). Textbooks lump fibrous insulation together with a range of other insulating methods (such as foams) that ‘trap air’ in order to take advantage of its great insulating properties when free convection is prevented. While the trapped air method certainly prevents convection, this doesn’t fully explain what’s happening inside of the fibers. Studies to improve fibrous
insulation’s thermal resistance have shown that increasing fiber diameter and density can actually decrease thermal resistance; the same study proposed adding thin layers of radiant barrier between fiber layers in order to boost thermal resistance (Wan & Fan 2012). In summary, the problem of reducing heat transfer through a fenestration cavity isn’t just about shutting down convection; a significant amount of heat transfer is also occurring from radiation as well.

Recent studies comparing the performance of double, triple, and quadruple glazing configurations show that radiation (rather than just convection) plays a primary role in heat transfer in glazing cavities, accounting for 45 to 75% of heat transfer (Arici, Karaby, & Kan 2015). As glass planes are added, radiation is reduced between planes and surface temperature differentials fall as well, controlling convection. In the same study, the gap width between glazing didn’t make as much impact as adding additional layers, supporting the argument against simply thickening the IGU assembly itself.

These studies suggest that an interlayer should not just address convection, as is the case with fibrous insulation, but also should address radiation. Thus a better optimized interlayer could trade density for transparency as it balances its counteraction of both convection and radiation.

1.3. Heat transfer physics of translucent insulation materials – theoretical model
Few studies have attempted to characterize the physics taking place in fenestration interlayers. While architects have been ‘sold’ on the possible benefits of plastics and metals inside glazing systems, some recent research has jumped to propose exotic interlayers. For example, a recent study demonstrated a nearly 40% reduction in heat transfer using a phase change material (PCM) as an interlayer (Li, Zhong, Zhou & Zhang 2014), while multiple projects are evaluating the thermal benefits of electrochromic ‘switchable’ glazing.

In contrast to exotic technology, it actually takes very little to disrupt the heat flows affecting a glazing unit. Insect screens have been shown to increase thermal resistance considerably, yielding a 7% reduction in U-Value when placed on the exterior of windows and 14% when placed on the interior of windows (Brunger, Dubrous, & Harrison 1999). The presence of even a very porous material near the glazing extends the convective ‘film’ present at the window, decreasing the heat transfer coefficients of convection and radiation. Another study examining
cellular shades indicates a 14.4% reduction in heating energy and 14.8% reduction in cooling energy with cellular shades operated according to a standardized protocol, and 10.5% and 16.6% (respectively) when shades were down all the time (Petersen, Merzouk, Sullivan, Metzger & Cort 2016), along with a 33% average reduction in U-factor during the experiment. If window screens or inexpensive cellular shades can almost match the performance of an exotic PCM interlayer, one might ask: why not just introduce these materials to the inside of IGUs as interlayers? Would they not serve the same thermal functions inside the IGU as they would on the interior side?

This paper does not attempt to propose mathematical models, but rather intends to reference an exercise in prototyping and testing to propose an improved theory for glazing interlayers. Reiterating earlier discussion, a great interlayer must reduce both radiation and convection – while taking advantage of the air gap in the fenestration assembly that also prevents conduction. That said, potential sources of conduction across the layers should be avoided; thus interlayers should have a low thermal conductivity, avoid density that would multiply conduction pathways, and minimize contact with either glass layer. Importantly, disrupting both convection or radiation does not require continuity, as the insect screen and cellular shade examples suggest. For natural convection, it is generally known that air will resist convection through gaps less than about 1/4” (6.4 mm); when air is moving slowly, visually porous materials can create nearly the same barrier to convection as a continuous surface. Similarly, most thermal radiation is transferred across vectors normal to the glazing surface, following the cosine law. Thus an interlayer that blocks normal radiation can be an effective barrier to thermal radiation, even if it allows angled or diffused visible light to pass through open voids. In summary, the interlayer can use geometry and layering, rather the microscopic redundancy of fiber batting, to reduce heat transfer – and by doing so, both admit and diffuse light.

2.0. TESTING METHODS

2.1. Overview of experiments

Over the course of two years, students in a research seminar developed interlayer solutions for fenestration, testing them against a variety of existing products, which they tested along with their prototypes. In the first seminar, teams examined solutions for glazed IGUs while in the second seminar, teams explored solutions for a double layer wall with multiwall polycarbonate on each side and a 3 ½” (88.9mm). Test results presented hereafter present the assemblies’ U-factor including the respective glass or polycarbonate layers; though it may be noted that these strategies are interchangeable between glass or polycarbonate assemblies.

Two primary testing methods were engaged by research teams and presented here: computer analysis and the live testing of instrumented prototypes. The value of instrumented prototypes to this research project should not be understated, particularly because convection is difficult to predict with the empirically-derived and interdependent equations for convective heat transfer that serve as the underpinnings for computer software.

2.2. Computer analysis

The software THERM was used by research teams to analyse combined two-dimensional heat transfer through their proposed interlayer systems in early development. THERM uses finite element analysis with detailed, 2-dimensional geometry inputs along with the ability to input custom material properties. While the accuracy of THERM versus live testing methods has been independently validated, THERM simplifies certain aspects of convective and radiative heat transfer. Interested readers can look at this in greater detail in THERM literature available on the web. For the research presented in this paper, the actual prototype tests are considered to be the most accurate results.

2.3. Prototype testing for thermal performance
As teams developed concepts with greater detail, they constructed small prototypes measuring approximately 14 inches by 14 inches (35.6 cm by 35.6 cm). Thermal testing was conducted to determine thermal resistance of the prototypes, following parts of the standard testing methods ASTM C-1046 and C-1155 (see References) for determining thermal resistance of assemblies in-situ. The prototypes were installed on the face of a compact freezer with its temperature maintained by a micro-controlled thermostat to simulate a cold exterior environment. The interior room in which tests were conducted served as the interior boundary condition. Data was collected from thermocouples and a heat flux sensor¹, together which were used to determine thermal resistance² using the summation method from ASTM C-1155. While the duration of tests was shorter than that dictated by ASTM testing, tests achieved 10% convergence as described in ASTM C-1155.

2.4. Prototype testing for light diffusion and transmission

Testing for visible light transmission (VLT) was carried out using handheld light meters and a single projection LED light source at a fixed distance. Values for VLT are shown in Table X. Readings were taken normal to the specimen surface and normal to incoming light.

Regarding light diffusion, the physical property of interest is diffuse hemispherical transmittance: the shape at which light is spread as it passes through a material. Perfect hemispherical diffusion is considered to be ideal for daylighting materials as it distributes light energy evenly to the building interior, specifically tempering direct sunlight. As diffusion becomes more specular, light energy passing through the material retains its directional and intensity. Measuring diffuse hemispherical transmittance is normally accomplished with a goniophotometer: a large, expensive, specialized apparatus not available to the research project. Instead, the research team used an improvised method³ to measure transmitted light at fixed intervals (15°, 30°, 45°, 60°, 75°, and 90°) across two planes (vertical and horizontal) using 3-dimensional masks. The masks consisted of angled tubes and flanges, coated in light-absorbent paint, that mated to a light meter. An LED light source was focused on the specimen while the light meter measured incident light from a specific angle through each mask, maintaining a consistent distance to the surface of specimens. Readings were then used to construct a hemispherical diffusion curve for the specimen. Comparing these curves to a perfect hemisphere demonstrated the system’s effectiveness in diffusing light (see Fig. 3).

3.0. SYSTEMS TESTED AND RESULTS

3.1. Existing systems

Select alternatives to conventional glazing were tested by research teams prior to the development of prototype systems. A summary description of each system along is shown in Table 1 with results from computer analysis and live testing are summarized in Tables 2. Note that all of the values presented in this paper are for ‘center of glass’ thermal resistance; in other words, contributing impact of fenestration frames is not included in the results, although this has been a subject of previous student research conducted with the author (Gibson 2015). U-Factors for double- and triple-glazing are included in the tables for comparison, though these systems weren’t evaluated with live testing.

Panelite was one of the first systems examined in the research. This proprietary product consists of a polymer creating an array of tubes perpendicular to the glass. Panelite is marketed for its daylighting and solar control benefits only; though one may suspect that the honeycomb sandwiched between the glass serves some thermal purpose in preventing free convection in the IGU. Testing revealed that, in fact, Panelite is about 8% less thermally resistant than the tested double pane IGU, attributed to unobstructed radiation transmission and conduction across the air gap via the plastic matrix.

Kalwall, another proprietary system, was tested by the teams. The specimen tested was a standard 4" wall panel with crystal FRP on each side, non-thermally broken edges, and air in the cavity. While Kalwall markets translucent fiberglass batting and nanogel infill options for their products, neither were available for testing in this study. The Kalwall specimen performed
slightly better (10%) than the tested double-glazed IGU, and somewhat better than product brochures report.

Multiwall polycarbonate is a common, inexpensive substitute for curtain wall systems and Kalwall. A cavity-wall-type application of this system was tested, using triple-wall 16mm polycarbonate for an inner and outer skin, and leaving 3.5” of air gap in between. These two layers of polycarbonate, before adding any interlayers, yielded a 46% improvement over the double glazing. Student researchers also tested the results of adding a single layer of cellular shades within the polycarbonate assembly, which yielded an assembly with a 29% better U-Factor than the best triple glazing while retaining a remarkable VLT of 19.1% when closed.

Lastly, research teams were also interested in ‘switchable’ interlayers. An off-campus university affiliate had a 37-year-old installation of ‘Beadwall’ – a now-defunct system in which loose polystyrene beads were alternately blown and vacuumed from fenestration cavities to provide insulation in solar buildings. While there is no room to discuss the details of the collaboration within this paper, the Beadwall’s purported R-22 (U-0.045) performance claims inspired the research team to mock up a small prototype of Beadwall for testing. When filled, the Beadwall assembly delivered about half the performance it promised – yet was still over 5 times more thermally resistant than double glazing and 3 times more thermally resistant that two layers of multiwall polycarbonate. In order to be switched, Beadwall required many valves, motors, and pipe connections to work properly; something that couldn’t be sustained in the local installation over time. Eventually the Styrofoam beads ended up ‘stuck’ in the cavities, either partially filled or empty. Observing the Beadwall’s fate underscores the importance of fixed – or at least greatly simplified – interlayers for fenestration.

3.2. Glazed IGU interlayer prototypes

While developing interlayer designs, research teams intended to create systems that would improve upon the performance of double glazing systems, while striving to approach the performance of triple glazing systems and diffuse incoming light.

Three systems were tested as part of a 1” IGU assembly. The first employed various sizes and configurations of polyethylene bubblewrap, before settling on a final solution where two layers of bubblewrap were affixed to the inner glazing surfaces of the IGU. Remarkably, the bubble wrap yielded a U-Factor that was 50% better than double glazing, and even exceeded triple glazing. The second system used 3 layers of 3-D printed honeycomb offset within the glazing gap. While the honeycomb produces a more modest performance outcome than the bubblewrap, it improved the U-factor by 13% despite an open structure. Another team
experimented with layering 6mm multiwall polycarbonate within glass layers; their best performing prototype IGU had a 23% improved U-factor over high-performance triple glazing.

Table 1. Source: (Author 2019)

<table>
<thead>
<tr>
<th>Total System Width</th>
<th>Interlayer Config.</th>
<th>Int. and Ext. Faces</th>
<th>Fill</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Glazed IGU</td>
<td>1&quot; (25.4mm)</td>
<td>None</td>
<td>¼&quot; Clear Glass air</td>
</tr>
<tr>
<td>High-Performance (HP) Double Glazed IGU</td>
<td>1&quot; (25.4mm)</td>
<td>None</td>
<td>¼&quot; Glass, Low-E on #2 surface argon, no interlayer</td>
</tr>
<tr>
<td>Triple Glazed IGU</td>
<td>1.25&quot; (31.8mm)</td>
<td>None</td>
<td>¼&quot; Glass air</td>
</tr>
<tr>
<td>High-Performance (HP) Triple Glazed IGU</td>
<td>1.25&quot; (31.8mm)</td>
<td>None</td>
<td>¼&quot; Glass, Low-E on #2 and #5 surface argon, no interlayer</td>
</tr>
<tr>
<td>Panelite IGU</td>
<td>1&quot; (25.4mm)</td>
<td>Fixed</td>
<td>¼&quot; glass polymer honeycomb infill, air</td>
</tr>
<tr>
<td>Kalwall</td>
<td>4&quot; (102mm)</td>
<td>None</td>
<td>FRP air</td>
</tr>
<tr>
<td>Dbl 16mm Polycarb</td>
<td>4.1&quot; (104mm)</td>
<td>None</td>
<td>16mm 3-wall polycarb. 3.5&quot; air</td>
</tr>
<tr>
<td>Dbl 16mm Polycarb w/ Cellular Shades</td>
<td>4.1&quot; (104.mm)</td>
<td>Movable</td>
<td>16mm 3-wall polycarb. Single Layer Cellular Shade</td>
</tr>
<tr>
<td>Beadwall</td>
<td>3.6&quot; (91.4mm)</td>
<td>Movable</td>
<td>FRP 3.5&quot; loose polystyrene beads, air</td>
</tr>
<tr>
<td><strong>Prototype Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bubblewrap IGU</td>
<td>1&quot; (25.4mm)</td>
<td>Fixed</td>
<td>¼&quot; glass 2 layers of bubblewrap laminated to inner glazing faces, air fill</td>
</tr>
<tr>
<td>Layered Honeycomb IGU</td>
<td>1&quot; (25.4mm)</td>
<td>Fixed</td>
<td>¼&quot; glass 3 layers 0.17&quot; offset 3D-printed interlayers, air fill</td>
</tr>
<tr>
<td>Layered Polycarbonate IGU</td>
<td>2.5&quot; (63.5mm)</td>
<td>Fixed</td>
<td>¼&quot; glass 3 layers 6mm multiwall (2-wall) polycarbonate, ¼&quot; spacing with air fill</td>
</tr>
<tr>
<td>Foam Strips</td>
<td>4.1&quot; (104mm)</td>
<td>Movable</td>
<td>16mm 3-wall polycarb. Single layer vert. 1/8&quot; polyisocyanurate foam strips wrapped in nylon, interior side reflective.</td>
</tr>
<tr>
<td>Foam Louvers, 45° Open</td>
<td>4.1&quot; (104mm)</td>
<td>Movable</td>
<td>16mm 3-wall polycarb. 1&quot; polyisocyanurate horz. louvers wrapped in aluminum</td>
</tr>
<tr>
<td>Quilted Tessellation</td>
<td>4.1&quot; (104mm)</td>
<td>Movable</td>
<td>16mm 3-wall polycarb. 2 layers cotton with 1/16&quot; polyester batting</td>
</tr>
</tbody>
</table>

3.3. Polycarbonate interlayer prototypes

Research teams later developed three movable interlayer systems that were incorporated inside 16mm multiwall polycarbonate skins. It should be considered that these systems could work within glass units as well. Though the systems were designed to be movable, this paper considers them as potential fixed systems.

The first system used polyethylene foam strips configured vertically, and wrapped with synthetic fabrics – the inside facing layer with a reflective covering. These thin foam strips did not form a complete ‘seal’ and presented a number of ways in which they could be opened, closed, or positioned to allow light transmission. Yet the foam strips yielded a U-factor that was 45% of the base polycarbonate configuration, with an estimated U-factor contribution on their own that was similar to basic triple-glazing. Another system used horizontal 1" polyisocyanurate foam louvers with a reflective coating, producing a U-factor that was 53% of its U-factor even when open at 45 degrees – creating openings that almost 2" wide in the cavity. A third system used a quilting of cotton of polyester batting in a folding configuration,
producing similar improvements over the base polycarbonate assembly from a very thin but translucent interlayer.

Figure 3. Various results from diffuse hemispherical transmission testing. While the Crystal FRP is not the most diffusing skin available from Kalwall, it is still considered to have excellent light distribution properties. Off-the-shelf cellular shades offer almost the same diffusion performance. Most of the prototypes diffused light more effectively than the Panelite specimen, which shows nearly complete specular transmission. Source: (Author 2019)

Table 2. Source: (Author 2019)

<table>
<thead>
<tr>
<th>System</th>
<th>Simulated U-factor, THERM [1] (Btu/ft²<em>h</em>F)</th>
<th>Tested Prototype U-factor [2] (Btu/ft²<em>h</em>F)</th>
<th>Est. Contribution of Interlayer, U-factor (Btu/ft²<em>h</em>F)</th>
<th>Visible Light Transmission (VLT) %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing Systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Glazed IGU</td>
<td>0.476 [4]</td>
<td>0.408</td>
<td>0.081</td>
<td>63.3%</td>
</tr>
<tr>
<td>HP Double Glazed IGU</td>
<td>0.247 [4]</td>
<td>0.195</td>
<td>0.052</td>
<td>59.8%</td>
</tr>
<tr>
<td>Triple Glazed IGU</td>
<td>0.307 [4]</td>
<td>[3]</td>
<td>0.177</td>
<td>57.8%</td>
</tr>
<tr>
<td>HP Triple Glazed IGU</td>
<td>0.123 [4]</td>
<td>[3]</td>
<td>-</td>
<td>47%</td>
</tr>
<tr>
<td>Panelite</td>
<td>0.26</td>
<td>0.439</td>
<td>-5.882</td>
<td>63.3%</td>
</tr>
<tr>
<td>Kalwall</td>
<td>0.49</td>
<td>0.366</td>
<td>-</td>
<td>47%</td>
</tr>
<tr>
<td>16mm Polycarb</td>
<td>0.425</td>
<td>[3]</td>
<td>0.176</td>
<td>50%</td>
</tr>
<tr>
<td>Dbl 16mm Polycarb</td>
<td>0.200</td>
<td>0.220</td>
<td>0.176</td>
<td>43%</td>
</tr>
<tr>
<td>Dbl 16mm Polycarb w/ Cellular Shadesc</td>
<td>0.114</td>
<td>0.235</td>
<td>0.176</td>
<td>2.7%</td>
</tr>
<tr>
<td>Beadwall (beads in place)</td>
<td>0.074</td>
<td>0.075</td>
<td>0.092</td>
<td>&lt;0%</td>
</tr>
<tr>
<td><strong>Prototype Systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bubblewrap</td>
<td>0.26</td>
<td>0.204</td>
<td>0.176</td>
<td>50%</td>
</tr>
<tr>
<td>Layered Honeycomb</td>
<td>0.14</td>
<td>0.356</td>
<td>2.778</td>
<td>50%</td>
</tr>
<tr>
<td>Layered Multiwall Polycarb</td>
<td>0.17</td>
<td>0.124</td>
<td>0.178</td>
<td>50%</td>
</tr>
<tr>
<td>Foam Strips, Vertical</td>
<td>[5]</td>
<td>0.120</td>
<td>0.263</td>
<td>12.6%</td>
</tr>
<tr>
<td>Polyiso Foam Louvers at 45°</td>
<td>[5]</td>
<td>0.116</td>
<td>0.246</td>
<td>2.1%</td>
</tr>
<tr>
<td>Quilted Tesselation</td>
<td>0.124</td>
<td>0.111</td>
<td>0.226</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

[1] U-Factor presented is total U-Factor with air films, as outputted by THERM software and following National Fenestration Ratings Council practice. Divergence between 2D THERM analysis and live tests seem to increase with both large air gaps and small geometry.

[2] ASHRAE Handbook air film thermal resistances of R-0.68 for interior and R-0.17 for exterior have been added to the surface-to-surface U-Factors observed from testing, in order to be appropriately compared to published values and THERM results.

[3] Units were not available for live testing.

[4] U-Factor shown is center-of-glass value from the analysis software WINDOW and standard for NFRC ratings.

[5] Simulation results not shown due to limitations in modeling continuous air volumes in THERM; this reinforces the importance of testing prototypes when complex heat transfer is at play.

4.0. A REVISED THEORETICAL MODEL FOR FENESTRATION INTERLAYERS

The array of solutions investigated illustrate several important points about glazing interlayers and how these assemblies can increase thermal resistance, while conducting and diffusing light. Of the prototypes tested, none employed dense, fibrous insulation to fill the air gap. In
fact, some of the better performing prototypes consisted of rather thin interlayers and others were even discontinuous: gaps and openings resulting from their materiality and construction didn’t seem that detrimental to their performance as insulating systems. Certainly convection occurred in the gaps and openings in the prototypes’ interlayers, yet the net flow of heat from combined convection and radiation was greatly reduced compared to double glazing. Estimations of the U-factor improvements contributed by the prototypes systems suggests that a properly designed, discontinuous interlayer can transmit significant quantities of natural light while interrupting significant amounts of detrimental radiation. As discussed earlier in this paper, radiation plays a major role in transferring heat within insulated fenestration units. An optimized interlayer shouldn’t treat fenestration like opaque walls, stuffing the air cavity with fibers; an optimized interlayer should instead interrupt thermal convection and convection just enough to slow heat transfer, while let natural light diffuse through it.

**Figure 4.** Heat flows within fenestration are at left. Convection in the air gap transfers heat, but so does radiation. At right is a proposed high performance interlayer that works without fibrous batting. Using the right materials and geometry, an interlayer can greatly slow down convection while blocking significant radiation, increasing the thermal resistance of the fenestration while letting light through. Source: (Author 2019)
CONCLUSION
Rather than attempt to engineer fibrous batting into translucency (the ‘fuzzy’ solution), this research argues for an approach to fenestration interlayers where the right material properties, with respect to conduction and radiation, are combined in an optimized geometry that slows convection rather than attempts to completely eradicate. Such an assembly can still transmit critical daylight, and while doing so provide a functional, affordable, and sustainable option to process-energy-intensive, heavy, and expensive triple glazing. Presently, this research is investigating geometric and material solutions that can be inexpensively manufactured, while meeting objectives of the theoretical model described herein. The next steps for this research will be to conduct a new round of computer analysis and prototype testing for an updated interlayer system, emphasizing the lessons learned thus far.

Among many possible concluding observations, the author emphasizes that continuation with the testing of physical prototypes is essential in understanding the performance outcomes of fenestration concepts. Virtual testing, like that afforded by THERM and similar analysis software, does not fully capture the complexity of the invisible physics taking place within fenestration cavities.

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- Foam Strips: Nica Delarosa, Eddie Garcia, Dipen Patel, Zach Rostetter
- Polyiso Foam Louvers: Mahima Suress, Paul Karr, Austin Ungerbehler, Brandon Heide
- Quilted Tessellation: Dominic White, Megan Cantu, Nataani Garnenez, Katelyn Guengerich.

REFERENCES


**ENDNOTES**

1 Instrumentation used in the thermal resistance tests are explained as followed. Surface and air temperature was measured using standard K-type thermocouples and a model OMB-DAQ-2416 data acquisition unit. Tests sites were verified to be representative of typical specimen surface temperature using thermography, and thermocouple junctions were masked according to ASTM 1046 recommendations. Heat flux was measured via an HFS-4 calibrated heat flux sensor and DP-41E meter using an analog output board for logging.

2 Uncertainty for thermal resistance calculations is 5.03% of R-value or U-factor for a representative measured U-factor of 0.20 ft²*°F/Btu from observed ∆T of 50°F and heat flux (q) of 10 Btu/h*ft². Absolute measurement error for the DP-41E meter is ±0.005% of range or ±0.38 Btu/h*ft². Absolute measurement error for the OMB-DAQ-2416 is ±0.825°F for a total of ±1.65°F for ∆T.

3 The importance of measuring diffusive hemispherical transmittance is increasingly relevant as translucent materials are evaluated with the widely-used lighting simulation program Radiance. While not strictly a part of this research, it should be noted that all translucent materials in Radiance are simulated with perfect hemispherical diffusion. This is problematic for designers who rely on the results of simulations to understand the performance of a light-diffusing material; the result in real life may be quite different if the material isn’t a perfect hemispherical diffuser.
Evaluating the in-situ effectiveness of indoor environment guidelines on occupant satisfaction

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¹Ryerson University, Toronto, Ontario
²National Research Council Canada, Ottawa, Ontario

ABSTRACT: Post occupancy evaluation (POE) studies typically use a combination of occupant questionnaires and physical measurements of various aspects of the indoor environment to assess building performance. These physical measurements are often compared against published reference limits to evaluate compliance and satisfactory performance. This study investigates whether indoor environment conditions compatible with published indoor environment quality (IEQ) standards and guidelines are predictive of occupant satisfaction. Data used in this study were collected as part of two large building evaluation field studies conducted in the past eight years. Occupant questionnaire and physical measurement data from 11 office buildings across North America were used (N=194). Inputs for the analyses were demographic factors and workstation characteristics, as well as aspects of the measured physical indoor environment. Outcome variables were various measures of environmental satisfaction (i.e. lighting, acoustics/privacy, and ventilation/temperature). The results of this study suggest that occupants had higher satisfaction with lighting when measured desktop illuminance levels were within IESNA RP-1-12 (2012) recommendations. Measured sound levels and thermal conditions within reference limits did not correlate to higher occupant satisfaction in their respective categories.

KEYWORDS: Indoor environment quality, post occupancy evaluation, lighting, acoustics, thermal comfort

INTRODUCTION

People in developed economies typically spend 90% of their lives indoors (Klepeis et al. 2001; Leech et al. 2002), and rising concern for occupant well-being mean that indoor environment quality (IEQ) and occupant comfort are receiving increasing attention in both research and industry. It has been well established in literature that aspects of the physical workspace have an effect on job satisfaction, stress levels, and health (Klitzman and Stellman 1989; Pejtersen et al. 2006). A well-conditioned indoor space plays a crucial role in achieving higher levels of organizational productivity and well-being (World Green Building Council 2014). In terms of economic importance, studies have demonstrated the significant financial benefits of improved IEQ (Fisk, Black, and Brunner 2011).

A commonly applied method of evaluating in-situ performance of a building is through post-occupant evaluations (POEs). POEs are a process that involves evaluating buildings in a systematic manner after they have been built and occupied for some time (Preiser and Vischer 2005). There are many existing POE field studies evaluating aspects of the physical workspace and occupant satisfaction using questionnaires or physical measurements, or both. Numerous studies have shown the importance of various demographic factors and physical aspects of the workspace on occupant satisfaction. Previous studies have consistently shown significant differences in terms of environmental satisfaction across sexes and age groups (e.g. Kim, de Dear, Cândido, Zhang, & Arens, 2013; Leder, Newsham, Veitch, Mancini, & Charles, 2016; Newsham, Veitch, & Charles, 2008). Others have found significant relationships between workstation enclosure (i.e. private versus open-plan workstations) and occupant satisfaction (Kim and de Dear 2013; Leder et al. 2016). The beneficial effects of windows in the workstation enclosure are also well documented.
are also well established in literature (Frontczak et al. 2012; Galasiu and Veitch 2006; Yildirim, Akalin-Baskaya, and Celebi 2007).

With regards to physical IEQ, many field studies have measured indoor environment conditions and compared them to recommendations in various published standards and guidelines (e.g. ASHRAE 55). For instance, in a POE study of 52 office buildings, Pei et al. (2015) compared thermal and lighting measurements against prevailing standards but performed no further validation of their effects on satisfaction. Other researchers (e.g. Ali, Chua, and Lim 2015; Kwon, Chun, and Kwak 2011; Liang et al. 2014) used similar comparisons of indoor environment measurements against relevant standards as an indication of acceptable performance. Although these published standards and their recommended IEQ thresholds are based on consensus derived from studies of human response to physical conditions, the studies were primarily conducted in controlled laboratory conditions and each study focused on a single aspect of the indoor environment. The analysis in this paper examines some of these published physical IEQ guidelines and recommendations for their effectiveness in achieving occupant satisfaction in a commercial office setting. The results will provide additional insight on the validity of these recommendations, and the potential for future revision of recommendations, and of POE protocols.

2.0 METHODOLOGY

2.1 Data Source
The analysis in this paper uses existing field data from two studies that gathered data from occupied offices in combination with questionnaire responses from the occupants of these workspaces. The research protocols were approved by the NRC Research Ethics Board. The first study involved data collected from public and private sector employees in 12 conventional buildings and 12 green buildings across Canada and the northern United States. The questionnaires were distributed electronically online to the participants, while a representative sample of the workspaces were measured using portable equipment that provided a detailed snapshot of the indoor environment in an individual office space over a 10 to 15-minute period. Physical indoor environmental factors such as sound level, temperature, air speed, relative humidity, concentrations of various air pollutants, and desktop illuminance were measured. The occupant questionnaire covered items relating to environmental and job satisfaction and various organizational productivity indices. The questionnaire items were generally rated on a 7-point Likert type scale, ranging from very unsatisfied to very satisfied. The data were collected between May 2010 and October 2011. Physical data were collected at a total of 977 workstations, and questionnaire responses were received from 2,545 occupants. A subsample of 230 physical measurement locations were matched to occupant responses. For more details regarding the data collection methodology, refer to Newsham et al. (2013).

The second, more recent, field study involved data collected from a large, conventional public-sector building located in the National Capital Region in Canada. Data were collected from occupants and representative workspaces in the building between October and November 2017. The data collection methodology in the second study was almost identical to that of the first field study. Physical measurements were conducted at a total of 265 workstations in the building. A total of 1,953 questionnaire responses were received from the occupants in this study. A subsample of 80 physical measurement locations were matched to occupant responses.

Previous researchers (e.g. Leder et al. 2016; MacNaughton et al. 2017; Holmgren, Kabanshi, and Sörvqvist 2017) have consistently demonstrated differences in environmental satisfaction between conventional buildings and green buildings. As such, only data from conventional buildings in the first study was combined with the data from the second study to avoid potential confounding effects. This resulted in a total sample of 194 cases from 11 buildings in which physical data and occupant questionnaire data referred to the same workstation across the
two studies. Sample sizes may differ between individual analyses as missing cases vary across questionnaire items. That is, the number of responses for any given questionnaire item may not total 194. Table 1 below shows the demographics of the participants in this sample.

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Education</th>
<th>Job Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-29</td>
<td>(N=15)</td>
<td>High School (N=23)</td>
<td>Administrative (N=54)</td>
</tr>
<tr>
<td>20-39</td>
<td>(N=42)</td>
<td>Community College (N=31)</td>
<td>Technical (N=13)</td>
</tr>
<tr>
<td>40-49</td>
<td>(N=55)</td>
<td>University Courses (N=17)</td>
<td>Professional (N=89)</td>
</tr>
<tr>
<td>50-59</td>
<td>(N=67)</td>
<td>Undergraduate Degree (N=66)</td>
<td>Managerial (N=34)</td>
</tr>
<tr>
<td>&gt;60</td>
<td>(N=12)</td>
<td>Graduate Degree (N=52)</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Data Analysis

North American standards and guidelines, to which these buildings would be expected to conform, were examined to evaluate their correlations with occupant environmental satisfaction. The ANSI/IESNA RP-1-12 American National Standard Practice for Office Lighting was used to examine satisfaction with lighting. The ANSI/ASA S12.2 American National Standard Criteria for Evaluating Room Noise standard was used to examine satisfaction with acoustics. The ANSI/ASHRAE 55 Thermal Environmental Conditions for Human Occupancy standard was used to examine thermal comfort. A summary of the recommended range of values for illuminance, sound, and thermal comfort in the standards is presented below in Table 2.

<table>
<thead>
<tr>
<th>Standard/Guideline</th>
<th>Recommended range</th>
<th>Aspect of IEQ</th>
</tr>
</thead>
</table>

The lighting and acoustics reference values are self-explanatory in their interpretation. However, for the calculation of thermal comfort some assumptions were made. For clothing insulation (clo), a value of 0.5 (average) was assumed for data collected in the summer months, 0.7 (average) for data collected in the fall or spring, and 1.0 (average) for data collected in the winter. A metabolic equivalent (MET) value of 1.1 was assumed throughout. These are common assumptions for office conditions and sedentary office work in North America (ASHRAE 2017).

For the purposes of this study, specific items and parameters relating to environmental satisfaction were selected from the original questionnaires. This included three composite variables created by averaging the responses of multiple questions relevant to that aspect of the indoor environment: satisfaction with lighting, satisfaction with ventilation and temperature, and satisfaction with acoustics and privacy. For more detailed information on the contents of the subscale composite measures of indoor environment and their formulation, refer to Veitch et al. (2007).

The data were analyzed using multiple hierarchical regression. This procedure was selected because many predictor variables can be analyzed simultaneously. It allows for a predefined sequence of steps where the effects of individual predictors can be examined independently while their shared variance is considered. This approach has been used in similar published studies (Leder et al. 2016; Charles et al. 2006; Veitch et al. 2005). In general, hierarchical regression is an accepted practice as the researcher can select the predictors and their order...
of entry based on subject knowledge and the specific hypotheses of interest. All statistical analyses were performed using the IBM SPSS 24 Statistical software.

The predictor (independent) variables were input as three separate blocks to isolate the effects of each block on the outcome (dependent) variables. The first block of inputs consisted of demographic variables that have been shown in literature to have impacts on environmental satisfaction. The second block of inputs consisted of various workstation characteristics for similar reasons. The last block contained variables reflecting adherence to guideline values in the measured environmental variable of interest (e.g. whether desktop illuminance measurements were between 300-500 lux etc.).

3.0 RESULTS

3.1 Descriptive statistics

Table 3 summarizes the predictor variables used in this study. Window location is divided into workstations with and without windows. The windows in the sampled buildings were not operable. Workstation enclosure is separated into private workstations (full height walls and a door) and open workstations (all other configurations). Other workstation characteristics such as workstation size and wall partition were originally included as predictor variables in the analysis but were subsequently removed because of excessive multicollinearity (i.e. intercorrelation between predictor variables). In this sample, very few cases had sound levels greater than 44 dBA, and a separate category for such values was not large enough for statistical validity. As such, the acoustics limits were set to whether measured background noise levels were below recommendations. Table 4 provides the descriptive statistics of the recorded physical IEQ measurements used as inputs to the reference value variables in Table 3. Dependent (outcome) variables used in this study are summarized in Table 5. As previously stated, composite variables made up of averaged values across multiple questionnaire items were used.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>18-29 (N=15)</td>
</tr>
<tr>
<td></td>
<td>20-39 (N=42)</td>
</tr>
<tr>
<td></td>
<td>40-49 (N=55)</td>
</tr>
<tr>
<td></td>
<td>50-59 (N=67)</td>
</tr>
<tr>
<td></td>
<td>&gt;60 (N=12)</td>
</tr>
<tr>
<td>Sex</td>
<td>0 = Female (N=126)</td>
</tr>
<tr>
<td></td>
<td>1 = Male (N=65)</td>
</tr>
<tr>
<td>Window Location</td>
<td>0 = No window in workstation (N=108)</td>
</tr>
<tr>
<td></td>
<td>1 = Window in workstation (N=84)</td>
</tr>
<tr>
<td>Workstation Enclosure</td>
<td>0 = Open workstation (N=138)</td>
</tr>
<tr>
<td></td>
<td>1 = Private workstation (N=56)</td>
</tr>
<tr>
<td>Illum_Ref</td>
<td>0 = Outside of 300-500 lux (N=109)</td>
</tr>
<tr>
<td></td>
<td>1 = Within 300-500 lux (N=85)</td>
</tr>
<tr>
<td>SoundRef_Below</td>
<td>0 = Less than 44 dBA (N=135)</td>
</tr>
<tr>
<td></td>
<td>1 = Greater than or equal to 44 dBA (N=59)</td>
</tr>
<tr>
<td>Therm_Ref</td>
<td>0 = Outside of thermal comfort zone (N=111)</td>
</tr>
<tr>
<td></td>
<td>1 = Within thermal comfort zone (N=83)</td>
</tr>
</tbody>
</table>

3.2 Hierarchical Regression

The multiple linear regression results can be interpreted as follows. The columns under each $\beta$ heading show the standardized regression coefficient (or slope coefficient) for a predictor variable. For every standard deviation increase in the predictor variable, $x$, there will be $\beta^*x$ standard deviation increase in the outcome variable; larger regression coefficients represent larger correlations between the predictor variable and the outcome within that analysis. The asterisks present in the tables represent $p$-values (significance levels), with thresholds at 0.05,
P-values less than the significance level thresholds represent a statistically significant result. Tolerance represents the redundancy of a predictor variable in the overall analysis; the smaller the value, the more redundant its contribution to the regression (values <0.1 are typically used as a criterion for predictor exclusion). Effect sizes ($R^2$) are interpreted using the small (1%), medium (9%), and large (25%) effect size criteria from Cohen (1988).

Table 6 below shows the analysis results for satisfaction with lighting. The results show that occupants in offices with windows had greater lighting satisfaction. Data from this table also show that occupants had higher satisfaction with lighting in workstations where the measured desktop illuminance values were within the recommended range of 300-500 lux.

Table 4. Descriptive statistics of physical IEQ measurements

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop Illuminance (lux)</td>
<td>487</td>
<td>276</td>
<td>58</td>
<td>1631</td>
<td>194</td>
</tr>
<tr>
<td>Sound Level (dBA)</td>
<td>42.1</td>
<td>3.8</td>
<td>33.4</td>
<td>52.7</td>
<td>194</td>
</tr>
<tr>
<td>Air Velocity (m/s)</td>
<td>0.12</td>
<td>0.05</td>
<td>0.02</td>
<td>0.37</td>
<td>194</td>
</tr>
<tr>
<td>Radiant Temperature (°C)</td>
<td>22.9</td>
<td>1.2</td>
<td>19.1</td>
<td>27.6</td>
<td>194</td>
</tr>
<tr>
<td>Air Temperature (°C)</td>
<td>22.9</td>
<td>1.0</td>
<td>18.9</td>
<td>27.4</td>
<td>194</td>
</tr>
<tr>
<td>Relative Humidity (%)</td>
<td>28</td>
<td>8</td>
<td>15</td>
<td>54</td>
<td>194</td>
</tr>
</tbody>
</table>

Table 5. Descriptive statistics of outcome variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction with lighting (average of 5 questions)</td>
<td>4.9</td>
<td>1.1</td>
<td>1</td>
<td>7</td>
<td>191</td>
</tr>
<tr>
<td>Satisfaction with acoustics and privacy (average of 10 questions)</td>
<td>4.2</td>
<td>1.3</td>
<td>1</td>
<td>7</td>
<td>194</td>
</tr>
<tr>
<td>Satisfaction with ventilation and temperature (average of 3 questions)</td>
<td>3.9</td>
<td>1.5</td>
<td>1</td>
<td>7</td>
<td>194</td>
</tr>
</tbody>
</table>

Table 6. Satisfaction with lighting regression results

<table>
<thead>
<tr>
<th></th>
<th>$\beta$</th>
<th>$\beta$</th>
<th>$\beta$</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.00</td>
<td>-0.04</td>
<td>-0.02</td>
<td>0.95</td>
</tr>
<tr>
<td>Sex</td>
<td>0.12</td>
<td>0.12</td>
<td>0.10</td>
<td>0.98</td>
</tr>
<tr>
<td>Window</td>
<td>0.29***</td>
<td>0.32***</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td>Workstation Enclosure</td>
<td>-0.03</td>
<td>-0.04</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Illum_Ref</td>
<td></td>
<td>0.16*</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>$R^2$ Change</td>
<td>0.01</td>
<td>0.08***</td>
<td>0.02*</td>
<td></td>
</tr>
<tr>
<td>Total $R^2$</td>
<td>0.01</td>
<td>0.10***</td>
<td>0.12***</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.00</td>
<td>0.06***</td>
<td>0.10***</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Tolerance values are shown for variables at the final step. N = 190, *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

Table 7 below shows the analysis results for satisfaction with acoustics and privacy. In the first step of the analysis females were found to be less satisfied with acoustics & privacy than their male counterparts. However, this effect was not sustained through the rest of the hierarchical regression. A positive correlation was found between workstation enclosure and satisfaction with acoustics and privacy; occupants in private workstations reported higher levels of satisfaction than those in open workstations. No statistically significant differences in acoustic satisfaction were observed between workstations with measured background noise levels less than 44 dBA and workstations above 44 dBA.

Table 8 below shows the analysis results for satisfaction with ventilation and temperature. Sex was significantly correlated with satisfaction with ventilation & temperature. Male occupants were typically more satisfied with their thermal environment than females. The results also show a correlation between workstation enclosure and satisfaction. Occupants in private workstations were less satisfied with ventilation and temperature than their open workstation
counterparts. No statistically significant differences in satisfaction were observed between measured thermal conditions within, and outside of, the thermal comfort zone suggested in the ASHRAE Standard 55.

Table 7. Satisfaction with acoustics and privacy regression results

<table>
<thead>
<tr>
<th></th>
<th>( \beta )</th>
<th>( \beta )</th>
<th>( \beta )</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.08</td>
<td>-0.13</td>
<td>-0.13</td>
<td>0.96</td>
</tr>
<tr>
<td>Sex</td>
<td>0.15*</td>
<td>0.13</td>
<td>0.13</td>
<td>0.98</td>
</tr>
<tr>
<td>Window</td>
<td>0.04</td>
<td>0.04</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>Workstation Enclosure</td>
<td>0.35***</td>
<td>0.35***</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>SoundRef_Below</td>
<td></td>
<td>0.05</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>

R\(^2\) Change 0.03 0.12*** 0.00
Total R\(^2\) 0.03 0.15*** 0.15***
Adjusted R\(^2\) 0.02 0.13*** 0.13***

Notes: Tolerance values are shown for variables at the final step. N = 191, \( *p \leq 0.05, **p \leq 0.01, ***p \leq 0.001 \).  

Table 8. Satisfaction with ventilation and temperature regression results

<table>
<thead>
<tr>
<th></th>
<th>( \beta )</th>
<th>( \beta )</th>
<th>( \beta )</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.03</td>
<td>0.95</td>
</tr>
<tr>
<td>Sex</td>
<td>0.19**</td>
<td>0.20**</td>
<td>0.22**</td>
<td>0.96</td>
</tr>
<tr>
<td>Window</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>Workstation Enclosure</td>
<td>-0.18*</td>
<td>-0.17*</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>Therm_Ref</td>
<td></td>
<td>-0.09</td>
<td>0.96</td>
<td></td>
</tr>
</tbody>
</table>

R\(^2\) Change 0.04* 0.03* 0.01
Total R\(^2\) 0.04* 0.07** 0.08*
Adjusted R\(^2\) 0.03* 0.05** 0.05*

Notes: Tolerance values are shown for variables at the final step. N = 191, \( *p \leq 0.05, **p \leq 0.01, ***p \leq 0.001 \).  

4.0 DISCUSSION

The results of the lighting regressions were largely in agreement with expectations. The positive effects of natural daylighting and windows on occupant satisfaction have been shown across many studies (Galasiu and Veitch 2006; Veitch et al. 2005; Yildirim et al. 2007). The results also showed that occupants were significantly less satisfied with lighting when the measured desktop illuminance levels were not within recommended thresholds as specified in IESNA RP-1-12 (2012). Newsham et al. (2008) reported similar findings in a study of conventional open plan offices. This result reinforces the validity of the limit thresholds outlined in the IESNA document.

The most obvious finding from the results of the acoustics regression was the correlation between more enclosed workstations and higher satisfaction with acoustics and privacy. This effect was consistently observed across every step of the hierarchical regression. These results corroborate the findings of prior work (Leder et al. 2016; Frontczak et al. 2012; Kim and de Dear 2013). Nevertheless, industry trends continue to move practice away from private to more open workstations. The desire to have more open workstations is driven by cost-savings on real-estate and the belief that more open workspaces support more communication amongst coworkers and foster innovation (Waber, Magnolfi, and Lindsay 2014). However, this belief is largely unsupported by recent objective research (e.g. Bernstein and Turban 2018; Kim and de Dear 2013). Contrary to expectations, this study did not find any significant differences in satisfaction between measured sound levels within, and outside of, ASA S12.2 (2008) recommended thresholds. One possible explanation is that the range of the measured sound levels within this study was limited, and only a small number of workstations had high levels of measured background noise (refer to Table 4). In a study using different noise level
intervals, Newsham et al. (2008) also found background noise to not significantly influence acoustic satisfaction.

Consistent with literature, the regression analysis of thermal satisfaction found that male occupants were more satisfied. Other researchers have reported similar findings in their studies (Kim et al. 2013; Leder et al. 2016; Newsham et al. 2008). This observed result may be related due to several season such as biological differences between the sexes, or differences in clothing attire (i.e. insulation), particularly during the cooling season when the A/C is in operation. The effects of workstation enclosure observed in this study support the results of Kim and de Dear (2013), where occupants of private workstations were less satisfied with their thermal environment. This is also in agreement with the findings of Charles et al. (2006), where partition height in open-plan offices was negatively correlated with satisfaction with ventilation and temperature. A possible explanation is that full height walls could prevent good air mixing and thermal conditioning throughout the spaces from the mechanical systems.

No differences in satisfaction were found between indoor environment measurements that were within and outside of ASHRAE Standard 55 (2017) comfort criteria. While unexpected, these results are consistent with Cheung et al. (2019), who found PMV-PPD to be a poor indicator of thermal sensation and satisfaction. The results of our study may be further explained by the fact that approximately half of the data samples used in this study were obtained from a single building, measured across a three-week period. This could reduce the range of measured thermal conditions, diminishing possible correlations in the data. Furthermore, unlike ASHRAE Standard 55 (2017) which focuses purely on thermal comfort, the composite measure of satisfaction with ventilation and temperature used in this analysis refers not only to the thermal environment, but also air quality. While ventilation systems in large North American office buildings typically regulate both air quality and the thermal environment, it is possible that the impressions of air quality separate from thermal issues may have diluted any observed effects. Assumptions of clothing and activity levels also may not have been entirely reflective of actual conditions, potentially resulting in inaccurate PMV and PPD calculations.

It is unexpected that no significant differences in satisfaction were observed by staying within the reference criteria for acoustics and thermal comfort, and it prompts a discussion on some of the possible reasons why this occurred. It is possible that the sample size wasn’t large enough to establish consistent results in the data. Prior research using a larger dataset with similar data collection methodologies did find significance in various physical indoor environmental predictors (Newsham et al. 2008; Charles et al. 2006; Veitch et al. 2005). Observing the effect size of these prior studies, the lighting regression in this study had marginally more explained variance. This study had an adjusted R² of 0.095 compared to an adjusted R² of 0.092 found by Veitch et al. (2005). The thermal comfort regression in this study had less explained variance, an adjusted R² of 0.051, compared to an adjusted R² of 0.111 found in Charles et al. (2006). This can likely be attributed to the smaller number of predictor variables used in this study.

Moreover, physical measurements were performed over a 10-15 minute interval. This method is used consistently in research as a necessary trade-off in order to capture reasonable sample sizes. However, it does assume that the short sampling period is representative of the environment over longer periods. The conditions in some workstations may vary significantly both on a daily cycle (for example east or west facing) and over different seasons. It is likely that the survey responses in this sample were framed with respect to longer-term conditions. Therefore, if the 10-15 minute sample was not representative of longer-term conditions this would introduce a source of error into the data.

Furthermore, people adapt to make themselves more comfortable. There could potentially be such adaptations that were not measured as part of this methodology. In terms of office acoustics, occupants could wear headphones or change their position within a workstation to avoid loud spots. Similar considerations could apply to thermal comfort. While the assumptions of clothing values and metabolic rates are typical for indoor office work conditions, they might
not be entirely representative of reality. Occupants can modify their thermal sensations by wearing additional or fewer layers of clothing to make themselves more comfortable. Lighting levels may also be easily adjustable by occupants with the use of individual task lights or shading devices, or occupants might find specific locations within a workstation to avoid glare.

Given the improved availability of relatively cheap sensors in recent years, perhaps adjustments to the data collection methodology could be made to provide more insights in future POE studies. For example, the use of more longitudinal sensors could alleviate some of the issues regarding the changing indoor environment conditions over time. Wearable sensors could provide more accurate data on local indoor environmental conditions, help provide more realistic metabolic rate estimates based on heart rate, and provide more detailed information on individual behaviour and characteristics.

CONCLUSIONS
This study originally set out to evaluate the relationship between various IEQ guideline thresholds on occupant satisfaction. The analyses suggest that adherence to the illuminance recommendations of 300-500 lux by the IESNA RP-1-12 (2012) standard correlated with higher levels of occupant satisfaction with lighting. In terms of sound level and thermal comfort, the results of this study did not show any significant increases in occupant satisfaction when the measured physical parameters were within recommended ranges (ASA S12.2, ASHRAE 55). Whilst this study did not confirm the field validity of acoustics and thermal comfort reference criteria, it did confirm the expected effects of sex, window proximity, and workstation enclosure. Females had lower levels of satisfaction with ventilation and temperature, offices with windows were correlated with increased lighting satisfaction, and more enclosed workstations were associated with increased satisfaction with acoustics and privacy, but decreased satisfaction with ventilation and temperature.

ACKNOWLEDGEMENTS
The authors would like to acknowledge and thank the following individuals at NRC for their contributions: Chantal Arsenault, Anca Galasu, Sandra Mancini, and Alexandra Thompson. We would also like to thank the managers and employees who took time out of their day to participate in the studies.

REFERENCES


The Alzheimer’s patients’ experience of the built environment: A Phenomenological approach

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¹North Carolina State University, Raleigh, NC

ABSTRACT: Healthcare regularly uses phenomenology as a research perspective to improve medical care. This paper explores the opportunities for applying phenomenology to better understand how the built environment might impact the behavioral symptoms of patients with Alzheimer’s disease. Alzheimer’s disease is expected to be a major public health problem in the U.S. for the aging population. It is projected that by 2050, the number of patients diagnosed with Alzheimer’s will triple. This projection raises the question of how we are prepared to provide care for this growing population who, in some stages of the disease, are no longer able to meaningfully communicate. This paper outlines a review of phenomenology as a tool for that planning. From its inception to modern applications, possibilities for applying phenomenology to the intersection of the built environment and Alzheimer’s are reviewed. The ontology of phenomenology, including Husserl and others, is assessed, and standard methodologies are discussed. With this foundation, possibilities for the application of a phenomenological approach to better understand the built environment’s role in the of the lived experience of Alzheimer’s disease are explored, including discussions of quality standards. Rooted in interpretivism and seeking an in-depth understanding of contexts and personal interpretations, phenomenological studies typically gather data through surveys, interviews and observations, which may cause problems with patients that often have issue retaining their memories. As such, this paper walks through the development of phenomenology with an eye to its potential application to Alzheimer’s. This is followed by suggestions for applying the phenomenological research paradigm towards the support - and potentially future cure process of Alzheimer’s with a focus on the built environment.

KEYWORDS: phenomenology; Alzheimer’s disease; aging; health; built environment

INTRODUCTION
Alzheimer’s disease (AD) is expected to become a major public health problem in the U.S. for the aging population. It is projected that by 2050, about 65% of the aging population will die of Alzheimer’s (Hebert et al. 2013). To put it differently, in about twenty-five years, the number of people diagnosed with AD in the United States will be three times larger than the current number of 5 million. This projection represents the fastest growing health risk for the elderly population. Since the definite cause of AD is not yet fully identified, medical researchers work toward solutions based only upon the hypotheses that speculate about causes. Because there is no identified cause, or cure, most current healthcare efforts to provide hope and support for this disease are directed at providing care solutions that alleviate the symptoms for patients.

The medical costs for supporting Alzheimer’s patients is the largest segment of healthcare cost in the U.S., higher than heart diseases and cancers (Medicaid 2018). This suggests that there will be an associated increase in cost to provide care for the growing number of AD patients, many of whom will not be able to live alone or care for themselves. These projections raise the question of if - and how - we can establish an infrastructure to provide care for this growing population with such specific needs. Alzheimer’s patients specific condition requires particular support in different stages of the disease progress. This condition is different in different person with different health background, age of involvement, and diagnosis, and therefore requires addressing a range of environmental design issues including, but not limited to, safety and security, special lighting design and exposure, night time care and supervision. The patients
would also need to be reminded and taught their daily routines and other specific tasks. With the ability to influence how patients are able to maneuver through their daily lives, and provide support for daily functioning, the built environment can play a crucial role in promoting both the care, and potentially the cure process, for the disease.

Given the projected increase in AD patients over the next decades, it follows that there will also be a high demand for patient care environments ranging in scale from individual units, family homes, and both public and private care facilities. This impending demand underscores the need for research to inform designers and policy makers about the built environment needs of AD patients in “care-oriented” settings. Research in this domain must develop a new understanding of how the built environment can - and must - better address and accommodate the needs of the patients in this growing population beyond doing no harm. Supporting AD patients through the built environment is particularly important because patients living with AD, as well as others showing signs of Mild Cognitive Impairment (MCI - a precursor to AD) spend most of their time in care facilities and homes (Constantine G. Lyketsos* 1999). Therefore, the built environment can be seen as both a factor to impact their symptoms and quality of care, but also as a potential support for future inventions in the cure process of AD.

Alzheimer’s is a cognitive functioning disorder that may impact the attention, concentration, language skills, memory, visual perception, perceptual ability, idea management, reasoning and intelligence of afflicted individuals (Boland 2015). Alzheimer’s disease symptoms are categorized in four different types: cognitive, behavioral, mood, and psychological (Boland 2015). Each type has its own subcategories of symptoms. For example, cognitive symptoms may consist of confusion in the evening hours, delusion, and disorientation. Behavioral symptoms might include aggression, agitation, difficulty with selfcare, and sleeping disturbances. Mood symptoms may appear as loneliness and mood swings. Psychological symptoms could be seen as depression, hallucinations, or paranoia. These complex symptoms become more complicated when overlaid with the variability of environmental factors in care facilities. As such, one important question becomes: how can researchers effectively design rigorous inquiries about environmental design considerations for AD patients? While the medical field is monitoring more in-depth physiological changes of AD patients and pathological signs of the disease, other disciplines such as design research should be rigorously investigating symptoms to suggest built environment scenarios not only for AD care, but also as a potential supplier of cure stimulus environments. The common point of these two disparate disciplines is that they both consider the experiences, even though they seem to have different agendas. Because of its emphasis on understanding the essence of the lived experience (Vagle 2014), the authors pose phenomenology as both a theoretical perspective and methodological approach that can provide valuable insight to inform design researchers about the experience of AD patients in care facilities. While a few studies have been done on phenomenology and symptoms of AD, such as depression (S.E. Starkstein 2008, Starkstein 2015), there is still much work that can be done in this arena. These types of studies would be helpful in informing researchers on medical care processes, continuing care providers, and design strategy selection and implementation.

1.0. BASICS OF PHENOMENOLOGY
Phenomenology is difficult to define since it can be viewed as both a theoretical perspective and a methodology (Creswell 2007); like similar general terms, phenomenology is routinely understood from widely different perspectives. Yet all observers agree that phenomenology concerns phenomena (Martyn Hammersley 2007).

The term “Phenomenology” was used in scientific context by Newton. In General Scholium, an essay added to his book of Philosophic Naturalis Principia Mathematica, Newton clearly claims that his understanding of his experimental philosophy in exploiting the laws of nature comes directly from the experience of the phenomena itself (T. Rockmore 2011). Here, Newton helps to define the role of phenomenology by testing experimental reasoning through the individual experience of the phenomena. This is very important that he defines phenomenology as trying
to know an experimental reasoning (theory) by exploring the experience of individuals on that theory.

Philosophers Kant and Hegel began using the term in the early 19th century, allowing it to gain popularity. Both were constructivists who desired to explain what it means to “construct” the “cognitive object” (Rockmore 2016). The strength of Hegel’s position on phenomenology lies in his ability to provide a logical explanation of what it means to “construct what one knows,” which leads to the construction and understanding of the phenomena. Hegel’s point of view, which describes phenomenology as constructing knowledge on what one knows about a phenomenon, presents a population who are involved in the phenomenon and/or have experienced it and can talk to a researcher about their experience. (Given 2008). Hegel differentiates between what is and what we experience in defining a pathway, addressing how we can reliably claim to know what is gained through experience (Redding 2017). His phenomenological approach bounds cognitive claims within the contents of awareness understood as phenomena, which do not refer beyond themselves to noumena (the properties of perception), to the thing (by itself or things by themselves), or to the external world independent from mind. Kant, following Hegel, evaluates the preconditions of consciousness. Kant makes no claim to know what is outlined beyond the plane of consciousness (Redding 2017). This emphasis on the experience of the conscious condition shows how the Kantian phenomenology acquires information out of experience of people in a conscious condition; this does not necessarily happen in medical cases applying phenomenology. Particularly, because Alzheimer’s patients often have issues with clarity of thought, this approach could be a limitation towards applying phenomenology in the AD population.

2.0. HUSSERL’S PHENOMENOLOGY

Husserl became the father of the school of Phenomenology around the turn of the 20th century with the publication of his work Logical Investigations; (Given 2008). His books are the major references in most phenomenological studies. Husserl claims that “a phenomenological study describes the meaning for several individuals of their lived experiences of a concept or a phenomenon” (Creswell 2007). Phenomenologists focus on describing what all participants have “in common” as they experience a certain phenomenon. For instance, we can look at grief as a phenomenon. Grief is experienced universally. The same could be said for pregnancy, and - it is likely - for Alzheimer’s disease. The main objective in phenomenology is to scale down individual experiences with a phenomenon to a more universal definition. The researcher then collects data from individuals who have experienced the phenomenon and outlines a composite description of the character of the experience for all of the persons. This description consists of “what” they experienced and “how” they experienced it (Creswell 2007). A deeper understanding of this type for those functioning daily with Alzheimer’s would be extremely helpful in designing built environments for their care.

2.1 Knowing

For analytical purposes, Husserl separated phenomena into two parts: the noesis and the noema. The noesis consists of the acts of consciousness, the noema is the properties of the perception. If there is, for instance, a bird in the garden, then it can be observed and be seen clearly. But if it is glimpsed, the perception of the bird remains vague and blurred. Different levels of attention constitute a different phenomenon every time the bird is seen – always a bird, but once with clarity and once with only vague contours. The noema in this case consists in the properties of the perceived. The bird is not a giraffe, and if it has an orange belly it does not have a blue belly, and if it is an old bird it is not a young bird. Whether any of these noematic characteristics are noticed depends on noetic attention. Therefore, both aspects, the noesis and the noema, creates the phenomenon. A phenomenon is always a noetic-noematic unity and includes “acts of consciousness as well as properties of their object” (J.Creswell 2018). We propose that with this noetic-noematic unity, different characteristics of disorders with similar symptoms can be distinguished and assessed. This type of approach could be helpful
in working toward a thorough understanding of the individual experience of an Alzheimer’s patient by breaking down the conscious experiences and the perceived experiences.

3.0. THE OBJECT OF HUMAN EXPERIENCE

Phenomenological researchers identify a phenomenon as an "object" of human experience (Linda Groat 2013). Van Mannen defines phenomenology as “a grasp of the very nature of the thing” and phenomena as: an “object of human Experience” (J.Creswell 2018). Human experiences may be phenomena such as insomnia, blindness, being left out, anger, grief, pregnancy, or undergoing coronary artery bypass surgery. As noted, it is very possible that an experience as “object” could also be a diagnosis of Alzheimer’s or being a caregiver for a loved one with Alzheimer’s. Because Husserl had studied in fields such as philosophy, mathematics, physics and astronomy, his long experience working quantitatively with definitions and logic allowed him to outline the idea that philosophical analysis should change to “the things themselves”. This was the birth of phenomenology, the ‘science’ of understanding phenomena. In this context, the question becomes: What are ‘the things themselves’ as it relates to the experience of Alzheimer’s? How do humans perceive and conceive of this identified phenomenon?

Given this scientific shift in the field, what are “human experiences”? In this perspective, Descartes had seen the human’s mind as a “subjective consciousness” that creates ideas corresponding to what was in the real world (Johnson 2016). As a general definition, phenomenology can be described as a theory perspective that focuses majorly on phenomena (defined as what we perceive) more than on the reality of things, such as what is directly observable. The approach and concentration of phenomenology is on the experiences of thinking and knowing: how phenomena was presented and occurred to consciousness (Havi 2011).

4.0. APPLYING PHENOMENOLOGY TO ALZHEIMER’S DISEASE

Alzheimer’s disease is arguably one of the most serious challenges today, impacting millions of people around the world. Despite this, there is little research investigating what it is truly like to live with Alzheimer’s from the patients’ own perspectives; the essence of this experience is elusive. This gap in research may be somehow due to the shared idea, that people with dementia do not have clear understanding about their disease condition and are not able to describe their experiences precisely. Johnson, in her paper about exploring the lived experiences of AD patients, articulates that such beliefs are inaccurate and invalid in most cases, and shows a great opportunity in investigating AD patient’s experiences in order to have better understanding of their particular situation (Johnson 2016).

No cure is found for Alzheimer’s disease to this date. Also, the common treatment also is not noticeably impacting the disease progression (Johnson 2016). For treatment, the medical field is largely prescribing anti-psychotic drugs in an attempt to control symptoms (Johnson 2016, Eduardo Marques da Silva 2011); medical research has been very slow in finding any contributions to a cure for Alzheimer’s disease. Specifically, some symptoms of the disease such as depression, anxiety and even simply sleeping disturbances are independently known and, in some cases, treatable. However, the holistic complexity of Alzheimer’s is difficult to pin down. According to Brentano (as cited in Varela, E, and Rosch 1993), all states of mind (perception, memory, etc.) are of or about something; in his concept, mental states necessarily have "reference to a content" or "direction toward an object", which is not necessarily a thing in the real world. The clear use of the lived experiences or how Brentano named it intentionality, is the defining characteristic of the mind.

4.1. Addressing symptoms

One possibility is that major symptoms of AD, including depression, anxiety or sleeping disturbances and agitation, could be the result of external factors - including the built environment (Steenwinkel, Audenhove, and Heylighen 2017). Alzheimer’s patients are left alone more frequently due to the significant difficulty communicating with others. Depressed
patients, on the other hand, who are not diagnosed with Alzheimer’s are able to communicate more, which decreases loneliness, which can help the depression to be more treatable (Thorpe 2009).

There is little evidence to inform researchers and caregivers about the true experience. The above statements about Alzheimer’s and its symptoms are from the generally accepted perspectives about patients living with Alzheimer’s, which often results in increased alone time, impacting levels of loneliness. But is this situation truly the reality of their experience, or a perspective constructed by outsiders? One of the ways to illuminate understanding can be through the use of phenomenology in the field of Alzheimer’s.

Medical diagnosis investigations cannot make us understand what the priority of the issues to Alzheimer’s patients are and what are the constant challenges they are encountering in their daily routine. Understanding these factors which requires the researcher to seek an understanding of the experience of Alzheimer’s patients of their everyday life difficulties, will enable her/him to enhance the AD patients living experiences. Therefore, Phenomenological approach in studying AD patients, brings valuable direction to the research and researchers and reduces inaccuracy (Johnson 2016).

4.2. Healthcare precedents

Phenomenology is a helpful and common methodology for investigating and expressing experiences. When phenomenology is applied in healthcare research, it seeks information about the experience of the disease, from the patient diagnosed with the disease to have a clearer understanding of the targeted experience. However, currently in medical research and practice the phenomenological approach is applied based on a predefined set of variables. Then, the experience of patients on these variables is investigated (Havi 2011).

In applied phenomenology, in an experiment conducted on patients who suffer from a disease, healthcare researchers try to carefully regenerate the process of how the patients experience the disease (Boland 2015). For example, in a cerebral hemorrhage case, researchers acquire precise explanations of each step of the trauma, beginning from the specific incident to the regained “sense-connections” after awakening from an artificial coma lasted 2–3 weeks (Flick 2014). Through this phenomenological approach, the lived-experience of patients was gathered through interviews, recorded and analyzed in order to reach an insight and understanding of the disease as the phenomenon of interest. In the cerebral hemorrhage case, the recovered patients could recall their experience and were able to share it with the phenomenological investigator. However, in Alzheimer’s disease, particularly in progressed stages, patients have almost no mental or emotional connection to the surrounding environment and people. In this case, other individuals who share part of the phenomena’s experience, such as caregivers or family, are asked for participation to express their experience of closely supporting people living with Alzheimer’s disease.

Most research projects in the field of medicine are evidence-based. This approach focuses on the outcome which is carried out of the patients’ experience of the health system including treatment approaches and the influences of them on the disease. Evidence-based approach is been applied in similar fields related to humans such as environmental design. Evidence-based design is an approach, design decisions are made based on the most reliable research evidence aiming for success in improving human’s health condition and quality of living and monitoring the proceeding pathway of design outcomes (Malkin 2008).

4.3. Understanding alzheimer’s

While phenomenology considers the distilled experiences of individuals and populations with the same experiences, it might be difficult with this depth of insight in mind to engage people who are not able to express themselves and their experiences in detail, such as Alzheimer’s patients. However, Alzheimer’s disease is a disease for a family, not just the individuals. This is because of the very unknown condition that involves the patient that needs special care and support as well as huge emotional load of these alterations due to the disease such as difficulty
in communication, speaking and hearing, fast pace progress of memory loss and orientation problem (Bergman et al. 2016). While this may be the case for the affected, the close family, friends, and caregivers would be able to share both their experiences as well as the experiences as communicated by the patient. For Alzheimer’s and dementia, many different organizations are involved in trying to discover the causal factors to lead toward a cure. In a shift from this historical experimental approach, applying phenomenology as a research perspective focused on the lived experiences of AD patients would allow the focus to be on the patients’ daily functioning in light of the disease. The resulting in-depth understanding might make a phenomenological approach one of the more useful frameworks implemented in medical research, working more toward patient-centered care than strictly the alleviation of symptoms without understanding experiences (R.M.Epstein and L.Street 2011).

The key element here is the patient’s experience with the disease and their personal interpretations of these experiences, which would be recorded, interpreted and distilled by the researcher. For those living in progressive stages of Alzheimer’s, the patient’s experiences during the disease progress may seem unknowable yet may be the most important. When the subject has difficulty in describing his/her experiences, the researcher’s interpretation of their journey may diminish the credibility of the phenomenological exploration of this disorder.

A study done by Rosenberg and Nygård (2016) explored the process of learning new technology as experienced by AD patients. The phenomenological approach investigated the way a new technology such as smart mobile phone or computer is learned by Alzheimer’s patients in a daily routine, based on their individual experiences during the day and night. Few AD patients which were diagnosed of Alzheimer’s were interviewed. The value in this type of information seeking is trying to understand such experiences not only to shed light on medical research but also to illuminate the way built environment designers research on designing supportive environment and product for this population.

5.0. CONNECTION TO THE BUILT ENVIRONMENT

The phenomenon of living with Alzheimer’s disease can be broken down into micro phenomena that may be directly connected with design factors in the built environment. Medical teams still do not have a clear understanding of Alzheimer’s patient experiences with their disease, daily living difficulties, and communication issues; it may be even more difficult for built environment teams to have a clear understanding of this population’s needs to design meaningfully responsive environments. However, by taking a phenomenological approach to understanding the disease, some known symptoms are more likely to be treatable including, sleeping disturbances, agitation, depression and daily alertness. These may be addressed through design factors in the built environment (Aarts 2016).

While these symptoms are known as medical symptoms, they have connections to build environment factors. Research shows that some built environment factors, such as lighting design, can directly impact Alzheimer’s neuro-biological and neuro-psychological symptoms (J. van Hoof 2009, konis 2018, White, Ancoli-Israel, and Wilson 2013). Van hoof research indicates that exposure to lighting with specific characteristics including intensity, wavelength, color temperature and exposure in a particular time of the day has shown significant impact on alleviating the symptoms of AD patients such as agitation, sleeping disturbances, and lack of alertness. These symptoms, and by association the lighting characteristics, have a direct impact on an AD patient’s daily activity, and their family and caregivers as well.

Some research has focused on alleviating the symptoms of Alzheimer’s disease. In the instance of lighting, the experienced phenomena of sleeping disturbances, daily naps and night-time agitation and hallucination for AD patients could easily be related to the lighting exposure, a direct impact of the design of the built environment. The lighting experiments conducted on the effect of light-therapy and bright light exposure on AD patients, although are yet to be investigated, show enhancement in resetting circadian rhythm and sleeping disturbances which can be applied as design retrofit plan for housing of seniors with memory disorders. Similarly, social engagement is linked to the design of social spaces in the physical
environment (Campbell 2014, Passini et al. 1998). Other literature indicates that certain wayfinding strategies may be able to work against memory and cognitive deficiencies in Alzheimer's disease patients (Passini et al. 1998), while design guidelines can address this issue to support wayfinding in memory care facilities (Passini et al. 2000). In addition to the aspects of Alzheimer's disease patients that is impacted by the design of the built environment, aesthetics and view is important as a factor of healing environment. In severe cases of AD patients who are not able to move easily during the day, the surrounding environment could change their experience in terms of light, color, pattern and view. According to the list of the symptoms of Alzheimer’s disease, safety has higher value and priority. Many other factors can impact safety for Alzheimer’s patients including their entrance and exit from the building. This opens up a vast chapter of AD patients’ routine issues starting from wayfinding and orientation problem leading to the night wandering and agitation which is a serious threat for patients (McQuilkin 2016).

Sleeping disturbances and agitation have shown a connection to the light exposure by research. Phenomenology enables design researcher to investigate the different experiences of Alzheimer’s patients in care facilities with various lighting design to reach a better understanding of this phenomena (Seamon 2000). Different care facility designs with admitted patients of different age and stage of the disease shape numerous scenarios with different lighting experiences to be studied. Similar approach applies on the differences we as designers need to consider in designing a care facility for patients with depression and Alzheimer’s patients who have depression as a part of their disease symptoms. The way these two different groups experience daily living and function should be studied from a phenomenological perspective.

While evidence-based design is commenced as a medical research approach in the built environment design research in order to rely design decisions on humans’ living experience in terms of different aspects of quality of life, it is still not covering the entire issue of humans’ experience during life-time. Alzheimer’s disease as discussed above, is one them which is increasing rapidly in number of people involved and not fully investigated and understood. One reason behind this delay is that evidence-based design is a general approach, which considers a series of variables for design research studies that are connected to humans’ health and care support. In contrast, Alzheimer’s is a partly unknown disease and consequently has different and undiscovered variables. The effect of environmental variables could vary not only among the patients of different diseases but also among the patients of the same disease with different stages (e.g., Alzheimer’s has 4 stages with different symptoms and experiences). In summary, the conventional approaches to studying the impact of built environment on patient's well-being focus on a set of pre-defined well-being characteristics. We argue that, in addition to these general characteristics, each class of diseases (as specific phenomena) might need a set of characteristics that pertain to the differences in experiences of the patients. Phenomenology as both a research method and theory perspective can focus on specific population’s experiences and derive and set the variables based on the experiences. Applying Phenomenology in investigating Alzheimer’s patients’ experiences which are influenced by the built environment, unites design researchers with AD caregivers for a more clear and purposeful support for patients.

6.0. DISCUSSION AND CONCLUSION

This study proposed phenomenology as a theoretical perspective and methodological approach that provides valuable insight to inform design researchers about the experience of AD patients in care facilities. The authors introduced the fundamental concepts of phenomenology by reviewing the definitions offered by the pioneers. The authors then discussed some precedents of applying phenomenology in healthcare research. In it’s focus on AD, this paper reviewed the characteristics of this disease and its symptoms with a focus on environmental factors that can influence the experience of patients in their built environment. For instance, wayfinding, lighting design for AD patients, light-therapy, and safety assurance design.
Despite the advantages of phenomenology in understanding AD patients' experience in building and facilities, the authors acknowledge that phenomenology may have some limitation in certain cases, discussed as follows:

- Phenomenology may have limitations in explaining the experience of Alzheimer’s patients in advanced stages because, in advanced stages, a loss of memory and disability in verbal communication may emerge. To mitigate this challenge, researchers must consider that a phenomenology of Alzheimer’s patients experience in their care environment is not independent of their care giver’s experience in the built environment. The care givers, families, and those who work in such environments can also provide relevant information that helps improve the experience of all occupants in such facilities.

- As relevant to the concerns about the memory of patients, the timeframe between the occurrence/emergence of certain phenomena and data collection may influence what the participants remember of the phenomena and their experience of it.

- Since Alzheimer has a range of stages and progressions, and patients even in the same stage may show different symptoms among the many possible symptoms, the lived experience of patients may vary greatly and therefore the attempts to validate an experience across all patients may be more challenging. Phenomenology gives the researchers some flexibility in addressing the variety of experiences the patients may have in care facilities.

REFERENCES

Bergman, Mette, Caroline Graff, Maria Eriksdotter, S. Fugl-Meyer Kerstin, and Marja Schuster. 2016. "The meaning of living close to a person with Alzheimer disease." Medicine, Health Care and Philosophy.


Flick, Uwe. 2014. The Sage Handbook of qualitative data analysis: Sage.


McQuilkin, Jennifer. 2016. "WANDERING-FRIENDLY ENVIRONMENTS FOR RESIDENTS WITH ALZHEIMER'S DISEASE IN MEMORY CARE FACILITIES." *Alzheimer's and Dementia*.


Acoustic design of reconstructed Banff Pavilion of Frank Lloyd Wright

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ABSTRACT: The late Frank Lloyd Wright designed and through an Alberta architect installed a pavilion in Banff, Alberta within the Parks Canada’s land. The pavilion was built in the prairie style with a gathering space, washrooms and minimal food services. Built in 1916, it was used only in the summer. However, it was demolished in 1933 due to damage from two major floods. A group of Wright aficionados is very keen to get the pavilion rebuilt with the aim of preserving the original design. The group retained seven Ryerson University academics to study the feasibility of recreating the pavilion with the stipulation that the space can be used all through the year. One of the envisaged uses of the space is a small concert hall in the main meeting space. The original and reconstructed pavilion space uses materials such as glass, stones and concrete. The envelope materials are highly reflective. The acoustical response of the space was simulated in ODEON for different scenarios. One short jazz piece, Autumn Leaves, was used to generate wave files by conducting auralization through ODEON. Based on the responses movable acoustic panels were designed to produce acceptable concert hall from an acoustic perspective. The results of the acoustic simulations will be presented in this paper.

KEYWORDS: Wright Pavilion, Banff, Acoustic simulation, auralization, absorptive panels

INTRODUCTION
Frank Lloyd Wright, as per reliable sources, designed only two buildings in Canada. One of them, in Banff, Alberta, was built in 1916 and was used as a summer pavilion with typical Prairie design of Wright. However, after a number of floods, two major ones in 1920 and 1933, the pavilion was demolished in 1933. An archival image of the front view of the, now defunct, pavilion is shown in Figure 1 below.

Figure 1. Front View of Banff Pavilion. Source: (www.archivesalberta.org)

Recently, there was a concerted effort to rebuild the pavilion and a group of academics from the Department of Architectural Science was tasked with the feasibility of heritage reconstruction of the pavilion. One of the main objective of the study was to investigate the
possibility of accessing the new pavilion for the entire year with various usages envisaged for
the pavilion. One of the main aspect of Wright’s designs is its adherence to impact of the
surrounding environment and the natural forces. The proposed pavilion would investigate the
possibility of having a concert hall within the central portion of the building. The proposed
concert space was modelled in acoustic simulation software, ODEON, and the acoustic
performance of the central hall was determined for different scenarios [ODEON]. Design
details and the performance results are discussed in this paper.

1.0. BACKGROUND
An axonometric view of the pavilion reconstruction is shown in Figure 2. The footprint of the
original pavilion is kept the same. However, current building code requirements of the Province
of Alberta will be applied to the proposed development. Even the orientation of the pavilion
will be kept identical to the original layout to take advantage of the daylighting potential. Only
the location will be slightly modified to fit within the current use of the park site. Since the park
will be used all through the year, heating and cooling system will be provided and insulation to
reduce the heat loss will be added to the envelope of the building. All of the necessary
modifications will, strictly, follow the heritage preservation regulations of the Frank Lloyd Wright
designs.

Figure 2. Axonometric View of the Proposed Banff Pavilion. Source: (Yew-Thong Leong, Ryerson
University)

The main focus of the current exercise is the evaluation of the acoustic performance and
acoustic design of the performance space envisaged for the central area, shown in Figure 2
above. One is immediately faced with many questions such as the impact of the performance
space on the original design as well as the acoustical aspects of the performance spaces
designed by Wright. It must be pointed out that Wright’s performance space designs such as
the multi-purpose auditorium, Grady Gammage Memorial Auditorium in Tempe, Arizona and
Kalita Humphreys Theater in Dallas, Texas applied conventional acoustical techniques
prevalent in the 1950s. Finally, to be financially viable, the City of Banff, Alberta would like the
pavilion to be used for different purposes such as concerts and banquets etc. And hence, the
current acoustical design is a part of the exercise. To alleviate any concerns that the original
Wright’s design may be sullied, the performance space is a temporary installation. The interior
look of the pavilion will retain its original look on days without any concerts or plays. The
results of the acoustic evaluation are presented in the next section.

3.0. ACOUSTICAL PERFORMANCE OF PERFORMANCE SPACE
A general layout of the performance space is shown in Figure 3. The location of the stage and
audience area are also highlighted in Figure 3.

Acoustical evaluation of the performance was investigated using the acoustic simulation
software, ODEON [ODEON]. Simulations included many different layouts of the performance
space: a) no acoustic panels with two different seating plans; b) a single panel behind the
audience seating and in front of the main glass doors; and c) three acoustic panels enclosing
the performance space around the audience seating. **NOTE:** It must be pointed out that the
proposed reconstruction will retain the original interior design of Wright. It will not be possible
to treat the ceiling area or the two fireplace areas with acoustical materials. The only possibilities are to add necessary amount of movable acoustical panels as shown in Figure 4.

Figure 3. Schematic Details of the Performance Space
The stage is a movable platform set near the back wall of the pavilion. The audience area can be horizontal seating or ramped seating as shown in Figures 3 and 4.

Figure 4. Acoustical Details of the Performance Space

Computer simulations to evaluate the acoustical performance in rooms have become well established practice during the design process. Four simple articles by Johnston-Iafelice and Ramakrishnan, Ramakrishnan and Johnston Ia-Felice, Ramakrishnan and Dumoulin, and Vorlander are cited to show the successful application of computer simulations.

The simulations involved two calculation procedures. The first set evaluated different acoustic metrics at one or two locations within the audience seating with a source placed on the stage. Four of the acoustic metrics will be assessed in this paper and are described below. The acoustic results will be presented in the next section.

3.1. Acoustical metrics [Gade, Long]

3.1.1. Reverberation Time, $RT_{60}$
Reverberance is the best known metric of subjective room acoustic aspect. When a room creates too much reverberance, speech loses intelligibility. For music, reverberance can add an attractive fullness to the sound. The reverberation time, $RT_{60}$, is the traditional objective
measure of reverberance and is the time taken for the sound to decay by 60 dB after the source is turned off.

The volume of the central portion of the pavilion is around 3500 cu.m. The acceptable reverberation time for such a space is given in Table 1 below.

**Table 1.** Optimal Reverberation Time, sec [Source: Doelle, Mehta]

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Octave Band Centre Frequency, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Empty Room, Floor Seating</td>
<td>2.3</td>
</tr>
</tbody>
</table>

It must be noted that the performance area seating is in the middle of the central portion and hence, the acceptable reverberation time needs to be smaller than the values given in Table 1.

### 3.1.2. Clarity, C₈₀
Clarity describes the degree to which every detail of the performance can be perceived as opposed to everything being blurred together by late-arriving reverberant sound components. It is evaluated by giving importance to the sound that arrives within the first 80 msec (0.080 sec). The metric is represented as dB and the usual range of acceptable C₈₀ values are -5 dB to +10 dB. Positive values show a strong aspect of clarity.

### 3.1.3. Centre Time, Tₛ, msec
Center time is used to describe the balance between early and late sound and low values of Tₛ corresponds to a clear sound. The maximum limit of Tₛ is 110 msec (0.110 sec).

### 3.1.4. Echo Potential
One of the metrics evaluated is the echo potential between the source and the receiver. Echo values vary between 0 and 1. Any value below 0.75 is considered good and the chance of the echo at the source will be minimal.

As discussed earlier, the acoustical results for the above metrics will be presented in Section 4.

### 3.2 Auralization
The second simulation was performed to evaluate auralization results. Auralization is a procedure designed to model and simulate the experience of acoustic phenomena rendered as a soundfield in a virtualized space [Auralization]. This is useful in configuring the sound scape of architectural structures, concert venues, public-spaces and in making coherent sound environments within virtual immersion systems. Auralizations are experienced through systems rendering virtual acoustic models made by convolving or mixing acoustic events recorded ‘dry’ (or in an anechoic chamber) projected within a virtual model of an acoustic space, the characteristics of which are determined by means of sampling its impulse response (IR). Once this has been determined, the simulation of the resulting sound field in the target environment is obtained by convolution and the resulting sound is heard as it would if emitted in that acoustic space.

A short (51 seconds) piano piece, *Autumn Leaves*, was used for auralization. One could have used any short musical piece such as an opera aria, Moon Light sonata, solo cello piece etc. The main idea is to listen to the convolved result, assess its subjective quality and modify the acoustical requirements until the results are satisfactory. The auralization results are generated as audio files and hence will be demonstrated only during the conference presentation.

### 4.0. ACOUSTICAL RESULTS
The first set of simulation results were evaluated for two locations within the audience seating area. The results for a location near the stage, Location 1, are discussed in this section. The results are evaluated for five different scenarios: a) Empty room (no people) and floor seating; b) Full room (with people) and floor seating; c) Full room (with people), back acoustic panel and floor seating; d) Full room (with people), no acoustic panels and ramped seating; e) Full room (with people), back acoustic panel and ramped seating; and e) Full room (with people), three acoustic panel and ramped seating. **NOTE:** The main focus of the exercise is to create a space for natural sound from the musicians without any artificial amplification.

Reverberation Time results are presented in Figure 1 below. The main observation from the RT$_{60}$ results are:

a) Most of the interior surfaces of the central space of the pavilion are glass and wood, and they have more absorption in the low frequencies compared with mid-to-high frequencies. The reverberation time in the high frequency is more due to the high volume of the central area. The performance area is smaller and hence the reverberation time needs to be lower.

b) The reverberation does reduce with the room filled with audience, but not satisfactorily.

c) For floor seating, it can be seen that the reverberation time reduces adequately with an acoustic panel in front of the main glass doors.

d) Similar results can be inferred for ramped seating also, except a single acoustic panel in front of the main doors had minimal impact since the ramped seating shielded the panel.

e) The same perception can be obtained from the audio files resulting from auralization calculations.

f) Finally, if microphone-speaker systems are required for pop music and Jazz ensembles, the reverberation time needs to be reduced substantially. Such a result can be realised (Scenario f) by adding two more acoustic panels to envelop the seating area.

The results for Clarity, Centre time and Echo Potential are listed in shown in Figures 6, 7, and 8 respectively. The clarity results clearly show that clarity, C$_{80}$, gets better and satisfactory as one introduces acoustic panels into the room. Centre time, T$_S$, is seen to be well below the acceptable range of 110 msec. The results imply that there is a good balance between the early sound and later reflections for all the six options of the performance space. The results show that echo is a major issue for the empty space without acoustics panels (Scenario a). Such a result is obvious since the large glass doors are immediately behind the seating area and all the room surfaces are highly reflective. Once the room is occupied with people the echo potential is seen to become minimal for the remaining five scenarios.

4.0. AURALIZATION RESULTS

Audio files were created for each of the six scenarios by using a short 51 second piano piece, *Autumn Leaves*, as the source on the stage. Two receiver locations, one near the stage and the other at the back of the seating area, were used to generate the audio files.

The generated results were in the form of audio wave files and hence, will be played back during the actual presentation of the paper at the conference. However, a brief subjective perception will be described for the three scenarios of floor seating.

The original recording from ODEON’s database, when played back, sounded very dry without any reverberant embellishment. One of the subjective requirements for a listening space is that listener should be enveloped by the music and/or speech from multitude of reflections from all bounding surfaces within the first 80 msec. The first convolved result at location near the stage is from empty room with floor seating. The piano piece sounded very muddled due to large amount of reflections from all hard surfaces of the space such as, stone, wood and glass, with strong echoes from the main glass doors. When the room is occupied with people, the only acoustic absorption is provided by audience seating on wooden chairs. The Reverberation Time results of Table 2 showed that the absorption by audience was not sufficient and is reflected in the audio file. The auralized result sounded muddy still. Finally, when the single panel was installed in front the main doors, the result was influenced by two factors – more absorption was created in the room as well as removed the strong reflections.
from the glass doors in mid-to-high frequencies. And hence, the audio file sounded to be satisfactory.

Figure 5. Reverberation Time Results for different scenarios at Location 1, sec.

Figure 6. Clarity Results for different scenarios at Location 1, dB.
CONCLUSIONS
The potential of incorporating a performance space within the central area of a reconstruction proposal of Banff Pavilion designed by Frank Lloyd Wright in 1916 was investigated in this paper. The performance area must be considered as a temporary installation with movable stage, seating area, and acoustic panels. The temporary nature of the performance space was to keep the original interior design intact on days without any performances.
Acoustic evaluations were conducted through simulation to predict values of RT$_{60}$, C$_{80}$, T$_{60}$, and Echo potential. In addition, audio files at two audience locations were generated through auralization and by using a short piano piece. The results clearly show that a performance space is possible for both mic-less concerts as well as for concerts with artificial amplification.

Finally, the current investigation shows, as well as from past acoustic design of occupied spaces for sound listening, that acoustic simulation studies must become de rigueur. Architects as front line designers of new spaces must become aware of the need for acoustical studies in any future praxis.

ACKNOWLEDGEMENTS
Contributions by graduate students Eyad Hachemi and Mitchell Cairns-Spicer in preparing the necessary sketchup files for acoustic simulations are duly acknowledged.

REFERENCES

Exploring developers’ understanding of health strategies in multifamily development

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ABSTRACT: Discussions around health are increasingly seen in design. Stakeholders across different built environments are beginning to break apart the meaning of “health”. Despite multifamily housing being forecasted to add an additional 4.4 million units by 2025 (Freddie Mac 2016), market-rate multifamily developers are largely latecomers to health conversations. This paper outlines the structure, methodology, and findings of a multi-year project supported by the Robert Wood Johnson Foundation addressing how multifamily developers understand, talk about, and execute health strategies. Using an exploratory case study methodology to address how and why (Yin 2017), three multifamily developers situated as early adopters of health strategies were recruited to better understand how they conceptualized, executed, and evaluated health strategies. In-depth interviews were held in the developers’ home offices in the southeast United States, using a semi-structured interview protocol to explore standard processes, partnerships, designs, and strategies specifically related to health. Cyclic memoing, data collection, transcription, and analysis allowed for reflexivity and protocol modification as new issues emerged. Site visits, web site analysis, and clicks through national online real estate databases also contributed to triangulation and a holistic perspective of this complex problem. Results suggest that private multifamily developers focus on commonly accepted and easily marketable strategies with little application of evaluative metrics (Rider et al. 2018). When directly questioned about health strategies, participants focused on place making, community building, and social and mental well-being, as well as designated fitness spaces. Participants were uncomfortable discussing health strategies in terms of health outcomes through a public health lens. This research aims to suggest a shift in interdisciplinary conversations around health in multifamily real estate, ultimately supporting a more diligent adoption of health strategies in this difficult building type. These results can support stakeholders in design, development, private investment, property management, public health, community design, and policy.

KEYWORDS: health, built environment, multifamily development, case study, real estate

INTRODUCTION

Private developers in the multifamily market are late to discussions about health and well-being strategies in their projects. With the establishment of building rating systems such as the WELL Building Standard and Fitwel, discussions of health are gaining more exposure with professionals in the design and construction industries, as well as with end users. However, these discussions primarily address office spaces, followed by built environments for special populations such as K-12 schools and environments for the aging; multifamily housing has largely been absent from both national discussions and notable implementation. With the increase in urban living and a growing population, multifamily projects are anticipated to add an additional 4.4 million units nationally by 2025 (Freddie Mac 2016). Given this projected boost combined with increased time at home due flexible work hours, homeschooling, and retirement, the importance of supporting health and wellness in home environments cannot be overlooked. Urban Land Institute’s (ULI) Building Healthy Places Initiative supports this idea by emphasizing the creation of communities through development, at the hands of the developer. Funded by the Robert Wood Johnson Foundation (RWJF) and Academy Health under RWJF’s Culture of Health Initiative, this paper explores how a select group of leading
multifamily developers in the southeast United States perceive, understand, discuss, and implement health strategies in their projects.

1.0. BACKGROUND
The adoption of different movements in the building industry, like the green building movement, have a curve of engagement that takes time to foster. LEED was officially established in the late 1990s but took years to hit its stride and become popular practice, changing both conversations and the market around green building. Because of the journey with, and adoption of, green building rating systems, the industry is slightly quicker overall to welcome rating systems addressing a topic related closely to sustainability: health. As illustrated in Figure 1, the green building movement serves as a precedent to the healthy building movement, with important parallels including market transformation and purpose. This research has a focus on understanding the multifamily real estate perspective, which is considerably different from other project types addressing health such as workplace, schools, or design for aging. In those program types, the argument for working toward a healthier population is not difficult. Multifamily real estate, on the other hand, has such a diverse population inhabiting the spaces for widely different timeframes, making developers more unwilling to take innovative risks in their decision-making around health. Despite health outcomes being linked to home environments, as reviewed below, health strategies for multifamily projects are difficult to identify.

![Figure 1. Area of interest](image)

This research study explores the unique business approach to multifamily residential projects overlaid with considerations of outcome-driven health strategies. The aims for the research include increasing awareness of outcome-based health concepts and strategies, while helping to shift the direction of multifamily development to think of health as an investable attribute. Long term, the findings can contribute to policy standards, either at the company or jurisdiction level, as well as connect health outcomes with multifamily design strategies.

2.0. FRAMEWORKS AND RESEARCH QUESTIONS
Rooted in the built environment, this research borrows the Robert Wood Johnson Foundation's (RWJF) Culture of Health Action Framework to provide structure for the inquiries and to begin to reach toward a new understanding of knowledge around health in the built environment.

2.1. Public health approach
The American Public Health Association (APHA) defines public health as “promot(ing) and protect(ing) the health of people and the communities where they live, learn, work and play. …those…working in public health try to prevent people from getting sick or injured in the first place. We also promote wellness by encouraging healthy behaviors.” (APHA 2018) Achieving this requires an understanding of the critical health outcomes linked to built environments. Much of the research in this area focuses on access to public green spaces - such as parks, sporting fields, greenways, trails, community gardens, and nature conservation areas (Wolch et al. 2014), as well as transportation systems - such as infrastructure that supports bicycling, walking, and use of public transportation. Evidence shows that children and adults with more access to parks and recreational facilities are more active than those with less access (Roux et al. 2007). Additionally, attractiveness and size of public open space encourages more physical activity, especially if perceived as aesthetically pleasing with minor traffic, sidewalks, trees, and nearby retail shops (Wolch et al. 2014). Proximity and use of public green spaces have also been inversely related to weight gain. Children, for example, who lived in greener neighborhoods experienced less excess weight gain than children in neighborhoods with less green space (Bell et al. 2008). Transportation related research has found that walking- and cycling-friendly cities are associated with more walking (Owen et al. 2007; Salis et al. 2015), less obesity (Creatore et al. 2016), and less sedentary time in cars (Frank et al. 2004). Additionally, transit-associated walking links to increased physical activity, with one study revealing that transit walking contributed to meeting daily levels of physical activity (Freeland et al. 2013).

Additionally, studies have shown that some environments have salutatory effects on mental health and well-being. These salutatory settings can include: legible places; attractive, well-maintained, safe places; places with appropriate contact with other people, and contact to green space (Sullivan & Chang 2011). Day (2008) reported that places that provide views, or direct exposure to, trees and other forms of vegetation are associated with an increased sense of well-being, higher levels of self-reported peace and quiet, and greater satisfaction with home and neighborhood environments. Similarly, exposure to open green spaces and tree canopied areas are associated with reduced levels of stress (Grahn & Stigsdotter 2003).

Where and how populations achieve recommended healthy lifestyle behaviors are increasingly reliant on immediate home environments. For example, research indicates that during an average week - including weekends and weekdays - people are spending more time within their home domain. Not only is this true for all ages, but the research indicates that home environments are a primary venue for healthy behaviors, especially physical activity. A study of 6 to 11 year olds found that youth spend 47.2% of their day at home, accounting for 43.6% of their moderate and vigorous physical activity (MVPA) (Tandon et al. 2014). Adults were found to spend 51.3% of their time within 125 meters of home, accounting for over 20 percent of their MVPA (Hurvitz et al. 2014). Moreover, as technological capabilities expand, the workforce will increasingly conduct work from home. In 2016, nearly a quarter of employed persons did some or all of their work from home and forty-three percent of workers with an advanced degree performed some work at home (American Time Use Survey 2016). While work, school, and extracurricular environments are important determinants in health behaviors, the home environment must also be considered. Provided that multifamily housing serves as both housing and a community domain (with indoor and outdoor communal areas), the way in which these developments are designed has great potential to deliberately encourage healthy behaviors.

### 2.2. Culture of Health Action Framework

This research adapts the Culture of Health Action Framework developed by the Robert Wood Johnson Foundation. Introduced in late 2015, and building on their Culture of Health vision from 2014, the framework focuses on empowering action through data being gathered across sectors, industries, communities and populations (RWJF 2015). The framework “translates the broad range of sectors and people involved in building a Culture of Health into four interconnected Action Areas.” (RWJF 2015) By outlining Action Areas, Drivers, and Measures,
RWJF provides a roadmap for outcome-driven action toward healthier communities. This project’s adaptation of the framework to the multifamily field is shown in Figure 2.

**Figure 2. Adapted research framework (RWJF, 2015)**

### 2.2. Research questions

The scope of the larger research project addressed the conceptualization of health, company mission, organizational structure, differentiation in the market, company evaluation metrics, assessment scales, decision-making processes, market trends, use of evidence-based data, internal health discussions, and investor relationships from the private developer’s perspective. This paper will particularly focus on the fundamental question of how these private developers working in different levels of the market (affordable housing, market-rate, high-end) conceptualize and discuss health strategies in their internal conversations and design processes.

**RQ 1: How do private developers define health strategies?**

In other words, for those developers that identify as early-adopters of health and wellness, what terms are used to talk about these issues during design development? Are health and wellness goals explicitly established, and how are these communicated to the design team? Do these definitions and conversations change as rent command changes (mixed income, market-rate, or luxury)? This research question focuses on the fundamental issue of how collaborating disciplines might understand health differently within the multifamily market, making the larger goal of healthier populations as outlined in public health frameworks more difficult to achieve.

**RQ 2: What strategies to support health and wellbeing are being considered and included, and why, in the design and construction of multifamily development projects?**

This question specifically addresses the engagement of health and wellness strategies throughout the design phases of the project and ultimately the operationalization of these strategies in the final project. Which design strategies are being considered, and which are actually implemented, in multifamily projects that claim to work toward healthier residents and communities? This question starts to pick apart potential relationships between building strategies particular to multifamily projects from the design side with possible health outcomes from the public health perspective. Together, these questions seek to establish a solid foundation from which to strengthen the relationship between multifamily design and public health.

### 3.0. METHODOLOGY, DATA COLLECTION, AND ANALYSIS

Given the specific research questions of *How* and *Why* early-adopters in multifamily development are addressing health and wellness in their developments, an exploratory case
study approach was used. While mixed methods were used to gather data in the larger study, interviews were the primary source of data collection for these particular questions.

3.1. Case study framework and participant sample
The case study methodology is viewed by Yin as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context” and focuses on questions addressing How and Why (Yin 2017). Creswell states that a case study is an in-depth analysis of one particular case, or a small set of cases, bounded by a particular time and activity (Creswell 2014). An exploratory case study investigates particular phenomena that lacks significant preliminary research, particularly in terms of testable hypotheses (Streb 2012). Streb (2012) also notes that these types of exploratory case studies frequently serve as a preliminary step toward causal or explanatory research in a field where these particular topics have not been clearly detailed or explored, while providing the research team flexibility with the research design and data collection.

Because interest area at the intersection of health and multifamily development is very particular, a specific, purposeful sample of participants was necessary to support the in-depth exploration needed to uncover the desired data.

Two developer partners were identified early based on their self-proclaimed, cutting-edge approach to healthy communities. One was a market-rate private developer in North Carolina, and one was an affordable housing community development organization in Florida. Both agreed to participate before the funding application was submitted, and was a partner participant from the beginning. To test the interview protocol prior to lengthy interviews in the offices of the participants, a local developer was engaged for a pilot interview. This developer has a reputation for quality and community-making, but not necessarily health engagement. The conversation during the pilot revealed that the third developer was actually considerate of health strategies in their projects, and was added to the study sample for a total of three partner developers.

3.2. Data collection
To address the research questions for this study, data needed to be rich and detailed. Because of the need to gather an in-depth understanding of participant developers’ experiences, interviews were used as the primary data collection strategy (Rubin & Rubin 2012). To allow the participants to share their thoughts and experiences freely, a semi-structured interview protocol was used. The semi-structured interview is a data collection method where the researcher team can ask participants a sequence of predetermined but open-ended questions (Ayres 2012). A series of questions were crafted to address issues ranging from company mission, to speak to the pervasiveness of the importance of health, to assessment scales, market trends, and more. The protocol was broken down by interview session to strategically frame the order and scaffolding of the discussions, and the same protocol was used with each participant developer. For each interview session, developers were asked to have a broad range of participants engaged from different sectors of their business including marketing, sustainability, design managers, leadership, construction administration, and finance. While not all could attend all eight hours of interviews, a diverse group participated in the sessions at each office.

Two rounds of interviews were held; the first series of interviews was completed in the fall of 2017, while the second was completed in the spring of 2018, after the data from the first round of interviews was preliminarily analyzed. The overall timeline for data and analysis can be seen in Table 1. The goal of the first round of interviews was to gather initial data for coding and theming, with the second round of interviews to provide a time for emergent follow-up questions as well as engage in member-checking of initial findings. However, the second round of interviews in the spring were limited to four hours in one day.
Two days were allocated for each of the partner interviews in their home offices. The first four-hour interview session was held on the afternoon of Day 1, focusing on issues such as company mission, organizational structure, perceived differentiation in the market, and market trends. The second four-hour interview session was held on the morning of Day 2, and became more specifically focused on questions of health, addressing evaluation metrics, assessment scales, use of evidence-based data, internal health discussions, and investor relationships. The gap in interview sessions was purposeful, allowing the research team to review the first session in the evening. This review time between the first two interviews enabled the research team to engage simultaneously in data collection and analysis to inform the next round of data collection, as frequently seen in qualitative research (Charmaz and Belgrave 2015). The pilot interview session was held with the first developer in June 2017, with the second in July 2017 and the third in September 2017. All follow up interviews were held the following spring.

Table 1. Data collection and analysis timeline

<table>
<thead>
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<th></th>
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<tr>
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<td>Partner 3 - Round 1</td>
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<tr>
<td>Writing/Dissemination</td>
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3.3. Data analysis
Research team members used memoing during the interviews. According to Birks, Chapman, and Francis (2008), memos can help to clarify thinking on a research topic, provide a mechanism for the articulation of assumptions and subjective perspectives about the area of research, and facilitate the development of the study design. This process allowed the researchers to be reflexing in the data collection process, facilitating a deeper understanding of the data in context. These memos were reflected upon between interview sessions, as well as throughout the overall data analysis process to help anchor the researchers to the context during data theming and synthesis.

All interviews were recorded with multiple devices and sent to a third-party for transcription. Once transcribed, the documents were read through and coded for emergent themes by different members of the research team. Before starting the coding process, the team met together and jointly coded one transcript, establishing guidelines and expectations for processes and themes. The interdisciplinary team had representatives from architecture, public health, urban planning, real estate, and business. At least two team members coded each transcript, and the same two team members reviewed all of the transcripts to ensure consistency across codes. The data collection and analysis timeline is shown in Table 1.

Initial open coding was used to establish the general categories of interest observed in the discussions. Once the initial coding was completed, those codes were then put through another round of analysis to establish themes found within the codes, both within the cases (individual developer participants) and between the different developer participants.

4.0. FINDINGS AND DISCUSSION
The coding and theming of the interviews established a series of common terms discussed when asked about health. These themes were labeled “Amenity Buckets” based on the way in which developers spoke about health strategies, and can be seen in Table 2 (Rider et al. 2018). These Amenity Buckets were then grouped into Categories of health, as described by the partner developers, which were Mental, Nutrition, Physical, Safety, Social, and Wellbeing.

**Table 2. Codes (Amenity Buckets) and Categories**

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The most frequent concept addressed in the interviews was Placemaking with 60 instances, relating back to ULI’s Building Healthy Places Initiative (ULI 2019), of which Creative Placemaking is a subset. Similarly, this is approach is supported by the literature reviewed about salutatory effects on mental health and well-being, including issues of legible places; well-maintained, safe places; places for contact with other people, and connection to green space (Sullivan & Chang 2011). The second most frequent mention was Fitness Center, which is an obvious connection to health, with approximately half of the mentions of Creative Placemaking at 31 instances. Following these, there are a group of codes with between 17 and 26 instances of mention: Healthy Food [26], Convenience [20], General [20], Walkable [17], and WELL Building Certification [17]. Of the Categories, Wellbeing was the most frequently cited with 110 instances, followed by Physical health with 94 instances.

Given the data, private developers largely define health strategies in terms of amenities, and most frequently relate the idea of health to placemaking. Participant developers discussed placemaking as not just as a marketing strategy, but more as an intentional method of community development to facilitate social interaction and support between the residents, linking back to literature around access to public green spaces including parks, fields, greenways, trails, and transportation systems (Wolch et al. 2014). They all believe that these placemaking strategies contribute to mental health and wellbeing, explaining the alignment between the leading instances of Placemaking and the instances of Wellbeing. Similarly, there is alignment between the emphasis of Physical health and Fitness Centers.

Overall, evidence-based strategies to directly support health and wellbeing are not being considered for multifamily projects. Instead, the strategies that are being considered by the participants are more general and common, such as fitness centers and swimming pools. Similarly, social spaces are included as mental health and wellbeing support, but without...
reference to literature or outcomes. Other health strategies that are considered and included in participants’ projects are strategies found in green building rating systems such as LEED (USGBC 2019) and the National Green Building Standard (NGBS 2019), such as daylight, views, and low-VOC materials.

The selected strategies are not yet connected to measurable health outcomes, nor are they strategically included for increased levels of health. They are included as amenities, not fundamentally as health strategies. Developers feel that they are providing desirable amenities, like fitness centers and swimming pools. Participants also indicated that they viewed health at the community level, and something that they were providing access to, but not that they were necessarily responsible for supporting directly in their projects. Their claim to health through placemaking was seen through both community building and connectivity. While providing spaces to socialize within their developments, they also sought to provide access to greenways, health facilities, fresh food, and entertainment.

CONCLUSION

Multifamily developers, particularly those in market-rate housing, are uncomfortable discussing and implementing strategies specifically addressing health. Instead, they consider health in terms of amenities and resident satisfaction, which they feel improves mental health through happiness and convenient lifestyles. This anecdotal approach is likely the result of little awareness of or access to evidence regarding multifamily design strategies and outcomes for health. The lack of this easily-accessible evidence thereby limits their understanding of how specific health strategies can not only benefit resident health over time, but can lead to improved market performance for their investments. For example, because developers are driven primarily by the bottom line, including lease-up rates and rent command, evidence-based health strategies need to be related to a return on investment. Ultimately, developers need clear guidance as to what strategies qualify as health promotive, how these strategies relate to both community-wide and tenant health outcomes, and case studies addressing attractive financial incentives and returns for engaging these strategies. Effective guidelines for increased health strategies in the multifamily sector will require a collaborative approach among public health and real estate. To catalyze success, health conceptualizations must be commonly understood, holistically, across these disciplines.

REFERENCES


Thermal comfort and air quality in Chilean schools, perceptions of students and teachers

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ABSTRACT: We present findings of naturally ventilated classroom conditions in primary school buildings in the city of Concepción, Chile, where there is no adherence to indoor environmental quality standards. We focused on thermal comfort and environmental perceptions of students and teachers, during fall and winter seasons. The goal is to examine the perceptions of children and teachers by analyzing responses to conditions in their classrooms, related to their socioeconomic context driven by school type. Approximately 888 students, aged 10-14 years old, were surveyed from nine schools during fall season, and 333 students from four schools during winter. A total of 2,271 subject responses were collected in two campaigns. Physical measurements included: ambient air temperature, relative humidity, airspeed, radiant temperature, and CO2. Simultaneous subjective responses were collected through electronic surveys on tablets which included questions on thermal sensation, thermal acceptability, and thermal preference. We examined thermal sensation trends, perceptions of comfort and air quality, across public, private-subsidized, private-nonsubsidized schools. Results show that about ~80% of teachers and students voted their thermal sensation primarily within the three central categories of the scale (-1, 0, +1). A small distinction can be seen in fall season in the private-subsidized school with a tendency towards a warm thermal sensation (+1), which corresponded to higher indoor temperatures. High indoor CO2 concentration levels were measured in all of the classrooms, with a maximum of 4327 ppm in winter in public schools, and a minimum of 858 ppm in fall in private-subsidized schools.

KEYWORDS: School buildings, thermal comfort, school children, Field survey, developing country.

INTRODUCTION

School buildings are one of the most critical environments because of the significant amount of time that children spend indoors at school and home during the developmental years of life. Closer attention needs to be paid to the indoor climate of classrooms, to promote comfort and well-being that support academic performance and user satisfaction. Young children are more susceptible to environmental pollutants than adults (Mendell and Heath 2005). Higher temperature and poor ventilation have been identified as elements that create unfavorable effects on children’s thermal comfort and performance, as shown in previous fieldwork studies (Cui et al. 2013; Haverinen-Shaughnessy et al. 2015; Bakó-Biró et al. 2012; Mendell et al. 2013). Thermal comfort of occupants in a given environment not only depends on physical parameters but also on the interaction of physiological and psychological factors. Children’s physiological characteristics are different from those of adults (e.g. in office settings), which may influence their perception and thermal preference as shown in the literature (Montazami, Gaterell, Nicol, Lumley, & Thoua, 2017; Mors ter, Hensen, Loomans, & Boerstra, 2011; Zomorodian, Tahsildoost, & Hafezi, 2016, Mendell & Heath, 2005). Limited studies exist in which the perspectives of children and teachers regarding their perception of the indoor environment are combined in a single study.

In adaptive thermal comfort, “occupants are deemed as active agents in creating ideal indoor thermal conditions” (Kim and de Dear 2018; Brager and de Dear 1998) through adaptive
strategies such as opening windows. In classrooms however, school children have no control over windows, unless directed by a teacher. Additional clothing adaptations are limited because of dress code policies requiring student uniforms.

This study presents fieldwork results of thermal comfort and environmental perceptions of students and teachers in naturally-ventilated primary schools in Southern Chile. This study looks deeper occupant perceptions of classroom environmental conditions, including thermal preferences as related to contextual factors such as a socio-economic status (type of school, home conditions, and health-related symptoms). The study is guided by several research questions: (1) What are the physical conditions of classrooms in schools in Concepción city?; (2) Do expectations of comfort differ between students and teachers?; and (3) Do subjective perceptions of classrooms differ between the types of schools?

1.0. METHODOLOGY

1.1. Field site selection

The fieldwork includes subjective surveys with simultaneous measurements of classroom environmental conditions of schools in the metropolitan area of Greater Concepción (hereafter MACG) in the cities of Concepción and San Pedro de la Paz, at 36ºS of latitude. The MACG is the biggest conurbation outside of Santiago (Chile’s capital). Both cities were selected because of their proximity to the city center, similar climate conditions, the highest population of inhabitants, and the number of school buildings within the MACG (i.e., a total of 104 schools from the public, private-subsidized and, private-nonsubsidized sectors).

Climate conditions for Concepción and San Pedro de la Paz, based on the Köppen Classification System are warm-summer Mediterranean (Csb), with relatively cold winters and mild summers. From historical weather data from Climate Consultant 6.0–2018, the range of annual average temperature in Concepción is 13ºC (55.4ºF), an annual average minimum of 8ºC (46.4ºF), an annual average maximum of 18ºC (64.4ºF). The maximum temperature can reach up to 28ºC (83ºF) during the summer months (December through March) and the low temperature can reach -2ºC (28ºF) during winter (June through September). Relative humidity averages can range between 58% and 90%. Sky coverage for this location has an annual average mean of 49%, an average minimum of 18% and the average maximum of 75%. Predominant annual wind direction is from the southwest, and during winter months the predominant wind direction is from north to south with a wind speed of 20 m/s (67 ft/s).

1.2. School selection and classroom description

Three types of schools exist in Chile: public, private-subsidized, and private-nonsubsidized. The differences among the three types are related to ownership, administration, socioeconomic level of the families, the index of vulnerability (IVE-SINAE index); developed by the government which measures the social vulnerability of students. This index is based on a set of criteria that allows identifying different groups of the populations of students in primary and secondary education according to the level of vulnerability they present. “Vulnerable” is classified into three hierarchy priorities: 1) socioeconomic risk, 2) socio-educational risk related school performance, attendance or desertion of the educational system, and 3) same socioeconomic risk as the second priority but without the socio-educational risk related. The IVE-SINAE can also provide subsidies for free breakfast and lunches, as well as other scholarships and government programs. The selection of the participating schools was based on their IVE index range: 100%-70% (IVE) for public school, 69%-20% (IVE) for private-subsidized and 19%-0% (IVE) for private-nonsubsidized schools. Previous studies on thermal comfort and environmental conditions in classrooms (Soto-Muñoz et al., 2015; Trebilcock et al., 2016b and Almeida et al., 2010), were performed in public school settings only. This study provides new research for other school types.

Nine schools participated in this study: four public, two private-subsidized and three private-nonsubsidized across Concepción and San Pedro de la Paz. For more detailed information, see table 1. The selection criteria included: 1) middle school grade levels (6th to 8th grade); 2)
naturally ventilated classrooms; 3) no HVAC system and limited heating; 4) similar heavyweight structure (reinforced concrete or brick with seismic design provisions); 5) similar spatial configuration of classrooms; and 6) classroom space per student ≥ 1.1 m² (11.8 ft²) (classroom density range of 30 to 45 students per classroom). From the nine schools, a total of 28 classrooms were surveyed during fall season, and 11 during winter season. All selected school buildings are multi-story, and surveys were conducted on different floors, depending on classroom location. The average floor area of the classrooms was 50.49 m² (543.46 ft²), much smaller compare to recommend ASHRAE 62.1 (ASHRAE, 2016) occupant density 35/100 m² (35/ft²).

1.3. Subjects
All subjects were from the local area of Concepción and San Pedro de la Paz with a few exceptions of immigrants from Brazil, Haiti, and Venezuela. The selection of middle school students for this study was motivated by the limited number of thermal comfort studies performed on primary schools. Also, in Chilean schools from first to eighth-grade levels, students spend all day in the same classroom versus other schools where the students might move to different classrooms for different subjects. Only the teachers move from one classroom to another. Therefore, groups of students spend a significant amount of time inside the same room, and are familiar with their indoor environment for the entire year. Middle schoolers, sixth through eighth grade, 10-14 years old (e.g., there was one case of a 19-year-old), were chosen for their ability to understand questions and reasoning at that age.

Middle school teachers were also surveyed during the fieldwork at the same time of the students in order to compare their perceptions of the classroom conditions with student responses. Most classroom environments had one teacher, but in some cases, up to three teachers were present in each classroom (headteacher, student teacher, and/or a teacher specialized in learning disabilities).

A total sample size of 888 students and 58 teachers participated in the field survey campaign in the fall season (April and May): 426 males (~48%) and 462 females (~52%). In the winter season, 333 students and 23 teachers participated (July and August): 173 males (~52%) and 160 females (~48%).

2.0. DATA COLLECTION

2.1. Ethical and responsible conduct research
Approval was obtained by the Institutional Review Board (IRB) for research involving human subjects, from both the University of Oregon and the Universidad de Concepción, prior to the start of data collection.

2.2. Measurements of indoor and outdoor environmental parameters
Measurements of indoor and outdoor environmental parameters were obtained: classroom thermal and air quality measurements were taken during the same time as the surveys were administered. In accordance with standards: ISO 7726 “Ergonomics of the thermal environment Instruments for measuring physical quantities” (ISO 7726 2001) and ASHRAE 55-2017 “Thermal Environmental Conditions for Human Occupancy” (ASHRAE, 2017), a Testo 480 data logger, with indoor probes were used to collect ambient air temperature, relative humidity, airspeed, radiant temperature (globe thermometer with a diameter = 150mm), and CO₂ concentration levels. Dylos DC1700 sensors for particle counts at PM2.5 and PM10 were used. Each parameter was measured at the height of 1.1m (3.6 ft.) above the floor level based on the recommendations of ISO 7726 (ISO 7726 2001) and ASHRAE 55 (ASHRAE, 2017). Outdoor environmental conditions, such as temperature, relative humidity, CO₂, and PM2.5 and PM10 were also collected for the duration of the study from a local weather station at one of the school sites in Concepción.
For clothing insulation, the checklist from ISO 7730 (ISO 7730 2005) and ASHRAE 55 were used to match CLO levels of Chilean students' uniforms and teachers' outfits. For metabolic rate, the students were mostly seated, doing writing or light work, and estimated as "nearly sedentary," equivalent to 1.2 met (70 W/m² or 22 Btu/ft²), according to ISO 7730.

2.3. Survey questionnaire

Multiple versions of the survey questionnaire were checked with an external assistant teacher and university professors to ensure that it was suitable for the age group. The survey design included the use of emoji images and colors for the different scales, as other studies have done (Trebilcock et al. 2017; Teli, James, and Jentsch 2013; Haddad, Osmond, and King 2017). This survey allowed the students to take the survey on a touch-sensitive interface using tablet devices. Offline software (Qualtrics) was used to collect responses. Use of these devices greatly supported engaging the students in the activity, raising interest and participation. The survey was conducted in Spanish; therefore, the scales and questions were translated into that language by the researcher. Prior to carrying out the actual surveys, pilot studies were conducted in order to ensure the proper functioning of tablets, gather feedback on the clarity of the questions, and prepare for logical administration of the surveys.

The questionnaire consisted of five parts: 1) current status of thermal comfort, air movement, and air quality using thermal sensation vote (TSV), air quality sensation vote (AQV), preference and acceptability. This section also included clothing questions regarding items worn during the class visits; 2) personal satisfaction about home and classroom environmental conditions, health-related symptoms experienced in the past; 3) house conditions; 4) impacts of environmental factors on classwork; and 5) general demographic information. For this paper, results from section a portion of section 1 are presented, since data analyses for the other sections are currently in progress.

Survey questionnaires were administered 20 to 30 minutes after students/teachers had settled in their classroom environments. Specific classroom times were selected for visits, to avoid time periods when students had PE class on the day of the survey, to minimize higher activity levels. Measurements were collected during two classroom visits in the same day (morning 8:30–11:30 am and afternoon 1:00–4:30 pm respectively) during fall and winter season. The field study used a longitudinal survey approach, the same classrooms and students were surveyed in both seasons. Because of school academic schedules (ending first semester and winter break) in June and July months, the study was conducted in four schools only during the winter season, instead of all nine in the first campaign. It is important to note that these four schools had the same participating subjects from the first field study during fall, with minor changes due to newly registered students or withdrawn students from the classroom.

3.0. RESULTS

3.1. Assessments of physical environmental measurements

During the field study campaigns in fall, the average outdoor dry bulb temperature was 12.5°C (54.5°F) for April and 11.6°C (53°F) for May, with a minimum temperature of 8.5°C and a maximum of 18°C. The lowest temperature was registered early in the morning between 5, and 6 am, whereas the highest temperature was reached around 2 to 3 pm, just before school release. The mean indoor air temperature (Ta) of classrooms was 19.9 °C, with a maximum of 23.8 °C and a minimum of 16.5°C during fall. The mean indoor relative humidity (RH) was 65.8% with a range of 42%–85%. In winter, the average outdoor temperature ranged between 9 and 10°C during July and August, with a minimum temperature of 5.6°C and a maximum of 15°C, respectively. Classroom average indoor air temperature in winter was 18.8°C, with a minimum of 15.0°C and a maximum of 23.8°C. Public schools registered the highest mean value of relative humidity of 75.3%, and a maximum of 85% during fall. However, in winter the maximum of 85% was measured in Private-subsidized. High levels of CO2 was also recorded with a mean average of 1625 ppm and a maximum of 3330 ppm in Public schools during fall. However, CO2 average levels of 2066 ppm and the maximum of 3580 ppm in Private-nonsubsidized during winter. The high mean indoor air temperature was registered in Private-
subsidized schools with an average of 22°C and maximum of 24°C. Low mean indoor temperatures were measured in Public school of 16.5°C during fall and of 15°C in Public and Private-nonsubsidized schools. It is important to note that air velocity in all classrooms during visits was very low, almost imperceptible, with an average of 0.09 m/s in fall and winter and a maximum of 0.16 m/s. Due to low outdoor temperatures, windows were mostly closed. In all surveyed schools, they relay solely on operable windows for air renovation, since there is no mechanical system or use of fans in any of the classrooms. High concentration levels of CO2 were measured across all schools, with maximum concentrations of 4,326 ppm in winter in public schools and a minimum of 858 ppm in fall in private-subsidized schools. Average CO2 ranges between 1,600-1,900 ppm, more than 1,000 ppm above outdoor levels (average ~500 ppm).

The operative temperature (Top) for this study was calculated as the average of the air temperature (Ta) and the mean radiant temperature (MRT), as specified in ASHRAE 55 (ASHRAE, 2017). For prevailing mean outdoor air temperatures, an exponentially weighted running mean temperature was used based on the studies of Humphreys (Humphreys & Nicol 1998; Humphreys and Nicol 2002) and ASHRAE 55 (ASHRAE, 2017). An exponentially weighted mean temperature puts more weight on temperatures from days closer to the current one, as noted by Nicol and Humphrey (Humphreys & Nicol, 1998). People’s responses depend heavily on their immediate thermal history. As seen in figure 1, indoor operative temperature plotted in ASHRAE 55-2017 adaptive chart, ranging from ~7.5 to ~11 ºC, falls outside the comfort zone. Only at the beginning of the study (April) temperatures were inside the comfort zone.

Table 1. Summary of classroom visits, building details, sample size, and number of surveys for different seasons

<table>
<thead>
<tr>
<th>School type</th>
<th>No. of classroom surveyed</th>
<th>No. of floors surveyed</th>
<th>Average height of classroom (m)</th>
<th>Average floor area of classroom (m²)</th>
<th>Classroom seating capacity (n of tables)</th>
<th>Classroom density area/n students (m²)</th>
<th>Sample size (N) Students</th>
<th>Sample size (N) Teachers</th>
<th>Total number of surveys (ns) Students</th>
<th>Total number of surveys (ns) Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>14</td>
<td>2, 3</td>
<td>3.25</td>
<td>47.81</td>
<td>30–35</td>
<td>1.36</td>
<td>386</td>
<td>32</td>
<td>762</td>
<td>36</td>
</tr>
<tr>
<td>Private-subsidized</td>
<td>6</td>
<td>2, 4</td>
<td>2.95</td>
<td>60.45</td>
<td>40–45</td>
<td>1.34</td>
<td>202</td>
<td>8</td>
<td>332</td>
<td>8</td>
</tr>
<tr>
<td>Private-nonsubsidized</td>
<td>8</td>
<td>2, 3</td>
<td>3.02</td>
<td>43.21</td>
<td>25–30</td>
<td>1.44</td>
<td>300</td>
<td>18</td>
<td>448</td>
<td>18</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>3.07</td>
<td>50.49</td>
<td>25–30</td>
<td>1.38</td>
<td>888</td>
<td>58</td>
<td>1542</td>
<td>62</td>
</tr>
</tbody>
</table>

3.2. Thermal sensation votes and preferences

Results in Figure 2 show approximately 80% of the teachers and students voted their thermal sensation primarily within the three central categories of the scale (-1, 0, +1). The mean TSV for students is 0.92 (SD 1.15) in fall and -0.4 (SD 1.27) in winter; for teachers, mean TSV 0.03 (SD 1.0) in fall and -0.28 (SD 1.37) in winter were found.

Comparing thermal sensation students and teachers, across types of schools during fall (Figure 3A), similar distribution patterns occur with very slight shifts towards the warm side of the scale for students and the cool side of the scale for teachers (Figure 3B). For students, there are no significant differences between school types, except for private-subsidized which showed a slight shift toward a warm thermal sensation, corresponding to higher indoor temperature measured in those classrooms.
Figure 1. Indoor operative temperature plotted on ASHRAE 55-2017 adaptive charts for fall and winter seasons. Each point represents an individual classroom indoor operative temperature per survey test (am and pm).

Figure 1A, 1B. Distribution of thermal sensation votes (TSVs) for student in all schools, based on ASHRAE 7-point scale, during winter and fall seasons.
Figure 2A, 2B. Distribution of thermal sensation votes (TSVs) for teachers in all schools, based on ASHRAE 7-point scale, during winter and fall seasons.

Figure 3A, 3B & 3C. Comparison of students thermal sensation votes (TSVs) distributions for different schools type during fall. Top: public schools; center: private-subsidized; bottom: private-nonsubsidized.
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Figure 4A, 4B & 4C. Comparison of teachers thermal sensation votes (TSVs) distributions for different schools type during fall. Top: public schools; center: private-subsidized; bottom: private-nonsubsidized.

Regarding their thermal preference (TPV), corresponding to the question “how would you prefer the temperature of your classroom?”, more than 50% of both teachers and students preferred “no change.”

CONCLUSIONS
Primary school children, aged 10-14, were capable of understanding thermal sensation and preference rating scales, and their responses are similar to adult responses. The distribution of thermal sensation votes for student and teacher, more than 80%, fall within the three central categories of the scale (-1, 0, +1) of the ASHRAE thermal sensation scale during the fall season. However, in winter 68% (students) and 72% (teachers) votes are concentrated in three central categories, suggesting the consistent responses between students and teachers.
across all schools. Teachers’ thermal sensation had a slight tendency towards slightly cold scales, which can correspond to their lower metabolic rate compared to students whose tendency was towards slight warm scales.

The perceptions of the students across different school types do not show a significant difference. A small distinction can be seen during the fall season for private-subsidized schools with a small tendency towards a warm thermal sensation, which is corroborated by the measured indoor temperatures compared to other schools. The latter suggests that students can perceive the conditions of their classroom based on the physical measurements collected.

Air quality across all schools was poor, with very high concentrations of CO2 levels due to high-density classroom and little air movement (i.e., windows were mostly close), which limits the air ventilation. Thus, affecting the performance of students by feeling tired and difficulty concentrating at the end of each period. Also, high percentages of relative humidity across all school types, in some cases presence of mold, can have a more significant impact on health and well-being of students and teachers, thus suggesting new strategies need to be implemented through better architectural design, that can improve indoor classroom conditions.

ACKNOWLEDGEMENTS
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REFERENCES


Assessing circadian stimulus potential of lighting systems in office buildings by simulations

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ABSTRACT: Daylighting research has been primarily focused on the visible light spectrum for enhancing the quality and quantity of light in the built environment. Lighting design has been focusing on the reduction of glare and illuminance availability. A new assessment approach has been developed in recent years to address the non-visual effect of light such as circadian entrainment and alertness. The first objective of this study is to evaluate the glazing performance in terms of circadian stimulus potential, visual comfort, and task performance. The second objective is to evaluate the circadian stimulus potential of artificial lights. ALFA is used to measure the three glazing performance at eye-level in office spaces. Equivalent melanopic lux is measured at 1075 virtual nodes over 12 hours on March 21st. Results show that the electrochromic three zones system performs the best among the three glazing options.

KEYWORDS: Daylight; Non-visual effects; Health and Wellbeing; Circadian system; Office building; Electrochromic glazing; ALFA

INTRODUCTION
Given the fact that people in the modern societies spend more than 87% of their time indoors (Konis, 2018), the importance of designing a healthy lighting environment for building occupants becomes more evident (Klepeis, 2001). A well-daylit space not only enhances visual comfort and energy efficiency, but also has the potential to improve the non-visual effects of influencing occupants’ health and well-being (Hattar et al, 2002)(Amirazar et al, 2018). Since the discovery of the third class photoreceptor in the eye - ipRGCs, the impact of the non-visual aspect of light on stimulating the circadian system and consequently affecting the alertness and sense of wellbeing has received increasing attention (Berson et al, 2002) (Hattar et al, 2002). Irregular long-term or short-term exposure to natural light can cause several health issues and disrupt human body mechanisms, such as endocrine function, digestion, core body temperature, sleep-wake cycle, depression, mood, and fatigue (Figueiro et al, 2008) (Blask et al, 2005) (Stevens et al, 2013). Considering the importance of the non-visual aspect of (day) lighting, establishing a standardized measurement is critical (Lucas et al, 2014). Therefore, new performance standards, such as EML, CS, and nvRD, are developed to determine the important role of light in maintaining healthy human biological functions. These novel measurements can be adopted along with the conventional metrics for assessing visual task performance and visual discomfort. (Pechacek, et al, 2008) (Amundadottir, et al 2017)

The circadian stimulus potential attempts to determine where, when and to what extent circadian entrainment and alertness effects are likely to occur in a space. In the other words, it is understood as how often over the year someone looking for a specific view direction at a specific location would experience light levels that are above the threshold for non-visual effects. Because the effect of light on non-visual system is cumulative, instantaneous evaluations are inappropriate due to five fundamental characteristics of the light that stimulates non-visual system over time, namely: quantity, spectrum, timing, duration, and prior light history (Rea, et al, 2002). While the human circadian system is most sensitive to light spectrum at 460 nm (blue region of the visible light spectrum), the visual system is most sensitive to 555nm (green region of the visible light spectrum) (Rea, et al, 2010) (Thapan et al, 2001)
However, the recently discovered photoreceptor - intrinsically photosensitive retinal ganglion cells (ipRGCs), contributes with other photoreceptors (cones and rods) to the non-visual mechanisms (Berson et al, 2002) (Hattar et al, 2002). For circadian stimulus potential measurement, the International WELL Building Standard Institute (2017), a “building certification system with the objective of measuring, certifying and monitoring the performance of building features that impact health and well-being”, has developed a metric named Equivalent Melanopic Lux (EML) for evaluating non-visual effect of light. The current version of WELL building Standard (2017) has proposed the threshold of 200 Equivalent Melanopic Lux (EML) and 150 EML measured on the vertical plane facing forward for daylighting and electric lighting spaces, respectively, during the hours between 9:00 and 13:00.

Since the effect of light exposure on the non-visual system is accumulative and dependent on the time of the day and duration of time exposure, Andersen et al (2012) has proposed to divide a day into three time periods, 6:00–10:00 (circadian resetting), 10:00–18:00 (alerting effects of daylight), and 18:00–6:00 (bright light avoidance, dim light only). While the natural light can improve human health and visual comfort, and increase the connectivity to the outside, direct sunlight can create visual discomfort in the form of glare (glare) and overheating of the indoor space (Jakubiec, J.A, et al, 2015) (Asadi et al, 2018). Advanced glazing systems, such as electrochromic glazing (EC), are therefore developed to modulate natural light introduced into indoor spaces, and to improve comfort, health and well-being of building occupants. Previous studies on EC glazing have been mostly focused on evaluating light quantity, visual comfort, and energy consumption. Few research has investigated how EC glazing can enhance the non-visual effect of light. There is also a lack of tools. An overview of the ongoing and past research reveals that very few computer tools are available to assess the non-visual effect of light to facilitate the process of building design. The aim of this paper is therefore to employ simulation-based workflow to investigate the circadian effectiveness of indoor spaces illuminated by daylighting and electric lighting. Specifically, the present study is designed to investigate the performance of three different glazing systems in terms of their abilities to deliver circadian potential stimulus by daylight and compare the circadian efficacy of eight different electric lighting systems.

1.0. METHODOLOGY
This study adopts a simulation-based approach by using newly released simulation software - ALFA to collect light exposures in order to quantify the influence of various light sources on the non-visual (health) needs of occupants. Data related to non-visual effects of light and amount of direct light that hits the sensors are collected by placing sensors on the vertical surface at eye-level height (1.2m) above the floor. Work plane illuminance is measured by virtual sensors located on the horizontal surface 0.76 m above the floor.

2.0. THE SETTING
The study setting is a side-lit open plan office space located in Minneapolis, Minnesota with a window facing south. The dimensions of the space are 22.5 m deep, 14m wide and 3.3m high. The floor is covered with 1075 sensors spaced 0.5 m apart in both directions on the vertical and horizontal measurement grids at 1.2m and 0.76m above the floor, respectively. Sixteen different directions are chosen for each grid point on the vertical plane to represent all possible view directions of seated occupants. The sensor height is set at 1.2 m above the floor to represent users’ eye level height. The space is divided into three zones (zone A, zone B, and zone C) based on their distance to window (see Table 1). The depths of the zones are 5 m, 8 m, 8 m, and respectively. Since typical office schedule is from 7:00 to 18:00, the study only considers the first two time frames (6:00 to 10:00 and 10:00 to 18:00), and the 6:00 -7:00 period is removed from the analysis because typically no occupants work during that hour. The simulation is performed on March 21st from 07:00 to 18:00 with one hour interval. Table 2 shows the specification of the different glazing systems and artificial lighting that are used in this study. EC glazing stands for Electrochromic glazing. The difference between the EC single zone and EC three zones is that for EC single zone the whole glass is tinted or cleared.
completely, whereas in the EC three zones, the glass is segmented to three equal horizontal rows (zones), and each row is tinted or cleared independently.

<table>
<thead>
<tr>
<th>Table 1. Model Properties</th>
<th>Number of Sensors</th>
<th>Depth</th>
<th>Number of Artificial light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
<td>Number of Sensors</td>
<td>Depth</td>
<td>Number of Artificial light</td>
</tr>
<tr>
<td>A</td>
<td>250</td>
<td>5 m</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>400</td>
<td>8 m</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>420</td>
<td>8 m</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Glazing and artificial type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glazing</td>
</tr>
<tr>
<td>Artificial light</td>
</tr>
</tbody>
</table>

3.0. THE SIMULATION WORKFLOW

The space is modeled in Rhinoceros (Figure 1) (Rhinoceros 3-D Modeling Program). The ALFA software, a plug-in to Rhinoceros, is used to evaluate lighting conditions based on their impact on circadian health and alertness (Solemma, DIVA for Rhino). ALFA assigns radiance materials to all surfaces. The data output indicates the average illuminance in each view direction at each zone. The performance of three glazing strategies is compared in terms of their abilities to provide enough light needed for daytime conditions. The materials’ surface reflectance values are shown in Table 3 - melanopic reflectance and photopic reflectance, respectively. The characteristics of the three glazing strategies in terms of melanopic and photopic transmittance are shown in Table 4 with the consideration of the dynamic pattern of electrochromic glazing the tinting state alters glazing transmittance for different time of the day (Malekafzali, 2018).

![Figure 1. The 3D Model of the Office Space Created in Rhino](image)

<table>
<thead>
<tr>
<th>Table 3. Material reflectance</th>
<th>Ceiling</th>
<th>Column</th>
<th>Interior wall</th>
<th>Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melanopic reflectance (%)</td>
<td>76.8</td>
<td>76.8</td>
<td>76.8</td>
<td>37.6</td>
</tr>
<tr>
<td>Photopic reflectance (%)</td>
<td>81.2</td>
<td>81.2</td>
<td>81.2</td>
<td>41.8</td>
</tr>
</tbody>
</table>

4.0. RESULT AND DISCUSSION

The analysis is conducted into two parts: daylit and non-daylit. In the daylit section, the glazing performance is estimated in terms of the daylight quality on vertical and horizontal surfaces, task performance, visual comfort, and health effect (circadian stimulus potential). In the non-daylit section, different artificial lights are compared in terms of the health effect (circadian stimulus potential) during the non-daylit period. Based on the WELL Building Standard (2017) the desirable circadian stimulus potential should be above 200 EML, the vertical direct illuminance in a view should be under 1500 lux to minimize glare risk, (Jakubiec, J. A, et al, 2012) (Jakubiec, J. A, et al, 2015) and the work plane illuminance should more than 300 Lux
according to the established daylight performance metric - Daylight Autonomy (DA300) (Reinhart, et al, 2006).

Table 4. Characteristics of three glazing systems

<table>
<thead>
<tr>
<th>Glazing</th>
<th>Melanopic transmittance</th>
<th>Photopic transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrochromic Glazing Fully tinted state</td>
<td>1.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Electrochromic glazing 2nd intermediate state</td>
<td>7.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Electrochromic glazing 1st intermediate state</td>
<td>18.7</td>
<td>17.6</td>
</tr>
<tr>
<td>Electrochromic glazing Clear state</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Double IGU clear Tvis 63%</td>
<td>61.7</td>
<td>63.3</td>
</tr>
</tbody>
</table>

4.1. Daylit

Figure 2 - 5 summarize the glazing performance in terms of circadian stimulus potential, visual comfort, and task performance. In Figure 2, although the best performance in terms of melanopic illuminance EML is with the double glazing system, the EC three zone provides the balance between the range of photopic illuminance (daylight availability) and melanopic illuminance (health performance). Although the range of photopic illuminance with the double glazing system is most desirable, the daylight intensity is significantly higher than the “comfort” level. The two versions of EC glazing (EC single zone and three zone) perform well in controlling the incident daylight. Moreover, the performance of EC three zones is better than that of the EC single zone in terms of health performance - the percentage of the circadian stimulus potential in EC three zone is higher than the single zone version. In the double glazing, the percentage of the views with vertical direct illuminance under 1500 lux collected during the first time period (7:00-10:00) is low in all zones. Moving away from the window, the percentage of views with vertical direct illuminance under 1500 lux is increased, which means zone C has better lighting condition in terms of visual comfort. In EC single zone, the percentage of views with vertical direct illuminance under 1500 lux in zone B and C are 100% in both time periods. In zone A, the graph indicates that the view direction ranging from the 45°-135° facing the window in the second time period, and the view direction ranging from 135°-225° facing the window in the first time period are about 70% under 1500 lux. As expected, the distance from the window in the daylit space is found to have a significant impact on the predicted stimulus potential. In terms of the circadian stimulus potential, by moving away from the window the percentage of views above 200 EML is decreased. In EC three zones, by moving away from the window the percentage of views with vertical illuminance under 1500 lux is significantly increased. In comparing EC single zone with EC three zones in zone A, the percentage of the direct sun entering through the single zone EC glazing is higher. The EC three zones system performs better in creating the balance in daylight availability between visual comfort and work plane illuminance. In EC three zones, the zones that are far from the window have less percentage of views about 200 EML than those close to the window.

As mentioned above, the WELL Building Standard measures the circadian stimulus potential by the percentage of views (min. 75%) that have at least 200 equivalent melanopic lux. Circadian stimulus potential is assessed for at least the hours between 9:00 and 13:00 on the vertical plane facing forward 1.2 m above the floor to simulate the view of the occupant. Based on this standard, Clear IGU 63% has above 75% percentage of views in term of circadian stimulus potential. In EC single zone, the percentage of views in zone B, and C is negligible, and in zone A, the percentage of the view directions ranging from 225° to 315° facing the window is above the minimum requirement. In EC three zones, the percentage of views is higher than the WELL Building Standard at the zone close to the window, but by moving away from the window (zone C), the percentage drops under the desirable range. In zone B, the view directions ranging from 0° to 180° facing the window provides enough EML to stimulate human circadian system.
Figure 2. Compare the daylight performance of three glazing strategies within two-time periods for three zones (Zone A, Zone B, and Zone C) at the south-facing façade.

Figure 3. Compare the circadian stimulus potential of three glazing strategies based on the WELL Building Standard in the time period from 9:00 - 13:00 for three zones (Zone A, Zone B, and Zone C) at the south-facing façade.

Figure 3 shows that the best glazing performance is EC three zones regarding the desirable melanopic illuminance range, which is minimum 200 EML, and the desirable photopic illuminance range, which is maximum 1500 lux. It is critical to balance between circadian stimulus potential and vertical illuminance (visual comfort). Figure 3 shows that the vertical illuminance of the Clear IGU 63% is too high, although its melanopic illuminance range is desirable. This glazing provides minimum 200 EML for nearly 100% of views in two time periods in Zone A. In Zone B and C, the second time period has better performance than the first one. The double glazing performs better in terms of the circadian stimulus potential than the advanced glazing systems - the percentage of the melanopic illuminance in all zones A, B, and C is higher than 75%. However, the melanopic illuminance is not the only metric to assess the glazing performance. The EC three zone works better than the single zone version. In zone A, the percentage of the EML is higher than the minimum threshold, but in zone C the percentage of the EML is under the threshold.
Figure 4. Compare the daylight performance of three glazing strategies within two-time period for interior and perimeter zones at the south facing facade

Figure 4 shows the percentage of daylight illuminance more than 300 Lux in the work plane. The performance of the new EC glazing (EC three zones) performs better than the old version (EC single zone) regarding the daylight availability in the workplace in both zone A and B and in both time periods, by considering the balance between visual comfort (vertical views under 1500 lux) and workplane illuminance. To summarize, three glazing types are compared in terms of daylight availability in horizontal illuminance (workplane), vertical illuminance (visual comfort), and the non-visual aspect (health aspect). A parallel coordinate chart (Figure 5) is created to illustrate the following points:

- **Photopic Illuminance**
  The range of the photopic illuminance in EC three zones and EC single zone in all zones (A, B, C) between 7:00-18:00 are under 1500 lux. In Double glazing system just in zone A the range of the photopic illuminance is above 1500 lux. In zone B and C, the photopic illuminance is under 1500 lux.

- **Melanopic lux**
  In zone A, the double Glazing system, EC three zones and EC single zones all provide melanopic lux level above 200 EML in all time periods and in all view directions. In the double glazing system the level of photopic illuminance is above 200 EML in all zones. EC three zones provides 200 EML or higher and provides acceptable photopic illuminance range between 7:00 and 17:00 in view direction facing the window (45' - 135') in zone B. In zone C, it provides 200 EML or higher between 7:00 and 8:00 and between 15:00 and 17:00 in view direction facing the window (22.5' - 157').

- **Workplane illuminance**
  The zone A of the double glazing system provides 300 lux or higher for office tasks. However, in zone B and C the illuminance level is lower than 300 Lux during 7:00-17:00 and 9:00-16:00. In both EC glazing systems, the range of the workplane illuminance is lower than 300 lux in all the time periods in zone C. The zone A of the EC three zones system achieves the desirable daylighting range in all time periods, but in zone B it only achieves the range between 8:00 and 17:00.

- **Melanopic lux EML > 200, Photopic Illuminance < 1500**
In zone A, both versions of the EC glazing achieve this balance, but the double glazing does not meet this condition. Although the double glazing performance is relatively poor in zone A, it performs better in zones away from the window.

![Figure 5. Parallel Coordinates plot of daylighting assessment metrics, melanopic and photopic of three glazing in three zones (zone A, Zone B, and Zone C) from 7:00 - 18:00 at the south facing facade.]

### 4.2. Non-daylit

As the previous study concluded, electrical lighting can affect circadian rhythm disorder. Moreover, artificial lighting can also improve indoor environment by providing sufficient light stimulus to residents. Regarding the second study objective, different types of artificial lighting in terms of their non-visual effects are evaluated. In addition, artificial light source is introduced as an additional source to assistant glazing to enhance healthy circadian. In this section 8 different artificial light sources are compared in three zones during the non daylit time period. The number of artificial lights installed in model is 18 in total with 6 in each zone. In zone A, based on the Well Building Standard, only LED Blue achieves the range higher than the minimum EML standard. In zone B and C, both LED Blue and FLU 1.28 has EML level higher than 75%.

The results suggest that for all views and all zones LED Blue meets the threshold of 200 EML. In contrast, the EML ranges of LED Red and LED Orange are negligible. This finding aligns with the previous literature (REF) that non-visual system is more sensitive to blue-enriched light.

### CONCLUSION

The comparison among different glazing systems and artificial light sources in terms of circadian stimulus potential, task performance and visual comfort are conducted in this paper by using computer simulations. The outcome is dependent on distance from windows. Due to the discovery of the novel photoreceptor and the melanopic sensitive wavelength, photopic illuminance is found to be an inappropriate measurement for circadian stimulus potential. Findings from this study show that the electrochromic three zones glazing provides the best performance in creating the balance among the metrics.
Figure 6. Compare the circadian stimulus potential of three glazing strategies based on the WELL Building Standard in time period from 9:00 - 13:00 for three zones (zone A, Zone B, and Zone C) at the south facing façade.

REFERENCES


Can hourly-based annual daylighting simulations predict daylight availability in dynamic sky?

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ABSTRACT: For successful daylight harvesting in buildings, daylight availability should be accurately evaluated and predicted. Daylight availability can be evaluated by either point-in-time computer simulations under a predetermined sky condition for a given site’s geographical location or climate based daylighting simulations with standard meteorological datasets. However, predetermined sky condition or hourly climate data might not be able to predict drastic changes of dynamic sky. As daylight harvesting performance depends on daylight availability, it is important to check whether or not there is significant discrepancy between hourly-based daylighting simulations and real time measurements of luminous environment under dynamic sky conditions. Located in San Antonio, a closed office space with south facing windows was selected for both field measurements and computer-based daylighting simulations. Constant monitoring of indoor and outdoor luminous environments were compared to hourly-based daylighting simulation results in order to verify its effectiveness in predicting daylight availability in dynamic sky conditions. Vertical and horizontal illuminance levels were measured to document natural light distribution inside the office every minute for a 40 day period. Collected data shows how quickly and drastically indoor luminous environment has changed under the actual sky conditions, which would greatly impact electric lighting and interior blind controls.

KEYWORDS: Daylight Harvesting, Dynamic Sky, Weather Data, Daylight Availability, Daylighting Simulations

INTRODUCTION

Daylight harvesting has been a crucial strategy to save electric lighting energy consumptions and to promote occupant comfort in buildings. For successful daylight harvesting, daylight availability in buildings should be accurately evaluated and predicted. Daylight Availability is the ratio between the amount of natural light outside buildings and the amount of daylight inside a building (Kensek and Suk, 2011). Different from Daylight Factor which was developed to evaluate daylighting design performance under overcast sky condition, Daylight Availability was developed to evaluate daylighting design performance in dominantly clear sky conditions or dynamic sky conditions such as mostly cloudy or partly cloudy skies.

Daylighting performance evaluations have evolved and have become more sophisticated with the improved computer performance and sophisticated daylighting metrics. Also, climate data (weather data) is publicly available for researchers and practitioners to create a climatic condition close to what has happened for several decades. Daylight availability can be calculated by either point-in-time computer simulations under a predetermined sky model for a given site’s geographical location or climate based daylighting simulations with standard meteorological datasets. These approaches seem promising as they not only consider actual sky condition history for a given location but also allow hourly-based simulations for an entire year. However, accurate prediction of daylighting performance has been still challenging for dynamic sky conditions. Predetermined sky model or hourly climate data might not be able to predict drastic changes of dynamic sky conditions such as San Antonio, Texas. As daylight harvesting’s performance depends on daylight availability, it is important to check whether or not there is significant discrepancy between hourly-based daylighting simulations and real time measurements of luminous environment under dynamic sky conditions.
For this reason, it is critical to understand how much discrepancies can happen between simulated daylight levels and actual daylight conditions inside a building. Post occupancy evaluation study is one of the efforts to understand the gap between computer simulation and real world conditions. By performing and comparing field measurements in a completed project, more accurate and reliable daylighting performance predictions can be made (Nicol et al., 2016; Katzenstein, 2013; Hirning et al., 2013; Suk and Schiller, 2012; Suk et al., 2013; Konis, 2013). Even though many entities have made post occupancy evaluation studies, drastic changes of dynamic sky condition have not been addressed yet. This paper reveals the discrepancy between computer simulations and field measured daylight levels. In addition, it also explains potential issue of inaccurate estimations of energy saving benefit from daylight harvesting. Clear understanding of these issues can help achieving accurate evaluation of daylighting design performance.

1.0. METHODOLOGY

A closed office space with south facing windows was chosen in San Antonio, Texas in order to document dynamic sky conditions (Figure 1). San Antonio, Texas is categorized in hot and humid climate (climate zone 2A) and is well known for hot summer season and dynamic weather conditions throughout a year (Baechler et. al., 2015). Collected weather data shows that July is one of the sunniest months in San Antonio with 74% sunshine percentage and 9 days of clear sky in a month (Weather Underground, 2017).

The selected office (3.65m x 4.26m x 2.74m) has (2) two ceiling recessed electric lighting fixtures with (3) three 32W T8 fluorescent lamps without dimming capability. Also, vertical interior Venetian blinds can be manually controlled. The selected office has been monitored for 40 consecutive days from sunrise to sunset. During the study period, the space was completely unoccupied and solely illuminated by natural light through the south facing window. Interior blinds were fully open in order to avoid any reflection or diffusion of incoming sunlight.

The field measurements were made from July 6th to August 15th, 2016. In order to fully track drastic changes of daylight levels inside the selected office space, Li-Cor photometric sensors and data logger were utilized. The photometric sensors were installed at six different locations throughout the space. Horizontal illuminance levels were measured at three different locations on top of the desk: 0.6m, 1.2m and 1.8m away from the south facing window. Another horizontal illuminance level was measured at the ceiling surface looking downwards at 1.2m away from the window. Two vertical illuminance levels were measured: one at the center of the window facing outwards and the other mounted at human eye position looking at the computer screen. The view direction of the sensor at human eye position is shown in Figures 1 and 2. These six different illuminance levels (four horizontal illuminance and two vertical illuminance) were recorded at 1 min. interval for a 40 day period. All six sensors were calibrated prior to the study.

The office space was virtually modelled in Rhinoceros software for daylighting simulations (Figure 2). And, daylighting simulations were performed for the same time period as the field measurements. Daylighting simulation plug in tool, Diva for Rhino with Radiance engine, was used for detailed simulations using climate data. A weather data file of the city of San Antonio was utilized for hourly-based annual daylighting simulations. Interior surface material properties have been defined in Diva for Rhino: 80% reflectance of the ceiling, 50% reflectance of the walls, 20% reflectance of the floor, and 71% visible transmittance of the double plane windows.

Figure 3 shows an example of simulated daylight illuminance levels (in lux) on task plane inside the office. Even though the entire space has been calculated in Diva-for-Rhino, illuminance values for the measurement locations (0.6m, 1.2m and 1.8m away from the window) were only collected and compared. In addition to these sensor points, two vertical sensor points at the windows and human eye position were calculated.
ARCHITECTURE FOR HEALTH AND WELL-BEING

Figure 1. Fisheye image of the interior of the selected office space in San Antonio, TX.

Figure 2. Angular fisheye rendering of the selected office on July 28 at 12:00PM (left) and false color image of the rendered view (right).

Figure 3. Simulated illuminance levels inside the office for July 21st 12:00PM.

2.0. ANALYSIS
Illuminance data collected for a 40 day period was first analyzed with the actual weather history of San Antonio for the study period. The collected weather history data shows that various sky conditions occurred during the study period: 71% clear sky, 15% partly cloudy sky, 8% mostly cloudy/overcast sky, and 5% rainy sky condition. Comparison between the weather history and the measured illuminance level patterns helped explain what actually happened under each of the sky conditions including clear sky, partly cloudy sky, and overcast sky. It also helped reveal any abnormal daylight pattern throughout a day.

Figure 4 shows an example of the measured horizontal and vertical illuminance data from 9:00AM to 6:00PM on July 7th. The fluctuation of the measured illuminance levels clearly represents how dynamic the sky condition is in San Antonio. Based on the weather history data of San Antonio, the sky condition of July 7th was categorized as a clear (sunny) sky. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Based on the weather history data of San Antonio, the sky condition of July 7th was categorized as a clear (sunny) sky. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day. Vertical illuminance level collected at the windows (shown in a purple line in Figure 4) shows how much natural light was introduced through the windows and it fluctuates for the entire day.

2.1. Comparison of incoming natural light

In the daylighting design practice, it is quite common to see discrepancy between daylighting simulations and actual measurements because of differences in between virtual and real environmental conditions and building material settings. In order to make a fair and accurate comparison of daylight levels between simulations and measurements, it is critical to calibrate computer simulation settings and results to real world conditions. Figure 5 compares the collected vertical illuminance values (incoming natural light in a solid line) to the simulated illuminance values at the windows (in a dashed line) under clear sky condition. It is quite surprising to see the huge discrepancy between the simulated and measured values especially when this specific day had a sunny (clear) sky condition. At noon, the calculated illuminance level is up to 8,000 lux while the measured illuminance level is around 1,700 lux. When a virtual model was built in Rhinoceros, 71% visible transmittance value was assigned to the window’s material property for a typical double glazed window without additional tint or film. It was found that this assumption was too optimistic as there was no consideration of dust accumulations on the outer surface of the existing windows. To compensate the discrepancy between the
virtual model and real world building condition, additional 60% visible transmittance (VLT) reduction was applied to the window material property assumption which lowered its VLT to 42.6%. This additional VLT reduction was carefully calculated from the entire dataset collected for the 40 day period.

Figure 5. Measured and simulated illuminance levels at the windows for July 9th with clear sky condition in San Antonio (vertical axis: illuminance (lux) and horizontal axis: time of day (hour: minute)).

Measuring incoming daylight (available natural light in buildings) is critical to ensure the validity and accuracy of daylighting simulation results. Material settings in a virtual model can greatly affect simulation results and cause huge discrepancies between computer simulations and field measurements. Considering potential dirt accumulations on window surfaces in computer simulation would be appropriate for more accurate daylighting performance predictions in design phase. It is important to note that weather history data can accurately represent real world sky conditions and luminous environments only when validation procedure is conducted.

2.2. Horizontal illuminance levels at task plane

Computer simulations were performed again with the adjusted window material properties. And, the measured illuminance data was then compared to the calculation results. As lower visible transmittance of the windows was applied, this recalculation has reported lowered daylight levels inside the office. As both measured and simulated horizontal illuminance values were collected from three different sensor locations, average illuminance values were calculated for each day. Figures 6 through 8 compare average horizontal illuminance values between measurements and simulations for each of the three typical sky conditions: clear (sunny), partly cloudy, and mostly cloudy (overcast) sky. In all three figures, discrepancy between the calculated and measured illuminance values is quite obvious. In Figure 6, the solid line for the measured illuminance levels fluctuates for the entire day of July 30th. It is important to point out that the sky condition was clear and sunny based on hourly weather forecast data. On this specific date, fluctuation of illuminance levels greater than 50 lux has occurred more than 50 times from 9:00AM to 6:00PM. Illuminance level changes greater than 150 lux have occurred several times throughout the day. Different from the measured illuminance levels, computer simulation provided a stable illuminance value for every single hour as it is based on the hourly weather data collected at a weather station. An average measured illuminance level is 163.9 lux while an average calculated illuminance is 189.9 lux. The daily average measured illuminance is 13% lower than the simulation.

Figure 7 compares the measured and simulated daylight patterns in a partly cloudy sky condition on August 5th. For the entire day, the measured illuminance values are lower than the calculated values with the weather data file. Similar to the clear sky condition example shown in Figure 6, the measured illuminance values fluctuate up to 120 lux throughout the entire day. It is observed that more clouds in the sky makes daylight level fluctuations less severe than the clear sky condition. However, an average measured illuminance value is very
similar to the clear sky condition example which is 168.4 lux. An average calculated illuminance is 238.5 lux. The measured illuminance is 29% lower than the simulated illuminance.

Figure 6. Clear sky condition on July 30th- avg. horizontal illuminance levels on top of the desk. Calculated values in dashed line and measure values in solid line.

Figure 7. Partly cloudy sky condition on August 5th- avg. horizontal illuminance levels on top of the desk. Calculated values in dashed line and measure values in solid line.

Figure 8 shows daylight patterns of August 13th under a mostly cloudy (overcast) sky condition. For the entire morning and early afternoon, the measured illuminance values are very low in a range of 25 lux to 60 lux. The calculated illuminance value pattern is very different from the measured values. The measured illuminance values became higher than the calculated values at 3:30PM and afterwards. It is possible to assume that this mostly cloudy day still allowed direct sunlight/solar radiation in the late afternoon. Different from the examples of clear sky and partly cloudy sky conditions, drastic illuminance fluctuation did not occur under mostly cloudy sky condition. An average measured value is 97.4 lux while an average calculated illuminance is 228.0 lux. This comparison shows that the changes of sky coverage cannot be accurately predicted or evaluated in computer simulations using a weather data file. It is also possible to assume that the discrepancy between daylighting simulations and real world measurements becomes larger as there are more clouds in the sky. The discrepancies observed between the calculated and measured illuminance values in Figures 6 through 8 were also found from the rest of the 40 day study period.
2.3. Daily average horizontal illuminance levels

Figure 9 compares daily average horizontal illuminance levels between the measurements and simulations for the 40 day study period. The figure shows that daylighting simulations predict higher daylight availability than the actual measurements even after calibrating the virtual model settings based on the amount of incoming natural light. A daily average measured horizontal illuminance level is 157 lux while a daily average simulated value is 184 lux. The daily average measured illuminance level is 27 lux lower than the calculated illuminance level. A computer based office task requires 150 lux horizontal illuminance level at task area and both simulations and measurements show that the selected office space has enough natural light for the task during the study period (DiLaura et. al., 2011). However, the amount of daylight is not sufficient for a paper based office task which requires 300 lux.

2.4. Need for electric lighting

In order to estimate potential electric lighting energy saving benefits of daylight harvesting, the number of hours with horizontal illuminance levels below 150 lux thresholds were calculated for each day. Figure 10 compares numbers of hours with horizontal illuminance below 150 lux between computer simulations or field measurements. The blue bar represents the number of hours with the measured illuminance levels below 150 lux (Figure 10). Orange bar shows the number of hours with the calculated illuminance levels below 150 lux. The higher a bar is, the
more usage of electric light is required during the office hours. For example, one hour period with illuminance levels lower than 150 lux would require occupants to turn on electric lighting fixtures inside the room for one hour so that required light levels can be provided for computer based office tasks. On July 21st, the measurements show that electric lighting should be turned on for 8.6 hours while the simulations predicted 5.0 hour’s operation of electric lighting. Average values for the entire study period are 4.0 hours per day from the measurements and 2.7 hours per day from the computer simulations. For the 40 day study period, a total of 104 hour of electric lighting operation was predicted by the computer simulations but electric lighting had to be turned on for 155.6 hours based on the actual daylit conditions. This clearly shows that the need of electric lighting can be underestimated by the computer simulations using a weather data file.

When considering wattage of the electric lighting fixtures inside the office, additional 249.6 watt-hour (0.25 kWh) should be consumed per day compared to what was predicted by the computer simulations. It becomes 69,888 watt-hour (69.8 kWh) energy consumption for an entire year when assuming the office will be occupied for five days a week (from 9:00AM to 6:00PM) and when assuming the same discrepancy happens for the rest of a year. This additional energy consumption might look insignificant but it is important to point out that this number is calculated only from one small office space (15.5 m² or 166.8 sf) of a large building. Inaccurate predictions of daylighting design performance in dynamic sky condition can result in inaccurate assessment of energy saving benefit in buildings.

![Figure 10. Comparison of numbers of hours with horizontal illuminance levels below 150 lux at task plane between measured and calculated.](image)

CONCLUSION

The comparative analysis shows that hourly-based daylighting simulations using a weather data file or pre-determined sky model cannot make accurate predictions of daylight performance in dynamic sky conditions. Drastic changes of indoor illuminance levels were observed under dynamic sky conditions including both clear sky and partly cloudy skies. Hourly-based daylighting simulations cannot predict these drastic illuminance changes and its high frequency. Also, it was found that hourly-based simulations become less accurate as the sky is covered by more clouds. Inaccurate estimation of daylight availability can make energy saving benefit of daylight harvesting unreliable. More accurate daylight performance prediction particularly for dynamic sky is required.

Drastic changes of daylight availability inside a building can cause occupants visual discomfort and make them want to rely on electric lighting systems instead of natural light. Also, high frequency of drastic changes in luminous environment can force occupants to adjust shading
devices and electric lighting systems many times throughout a day. It would be very challenging to optimize lighting energy saving and occupant’s visual comfort when hourly based daylighting calculations are performed for a project in dynamic sky conditions. Further study is required to investigate subjective response to drastic light level changes and high frequency of the changes in daylit spaces.

The findings from this study can help daylighting design professionals to be aware of potential issues of daylighting simulations under dynamic sky conditions. It is important to note that the study was performed only for 40 day period and further investigation is required for a longer period of time to ensure consistency of the findings in the study.

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REFERENCES
Kensek, Kensek. and Jae Yong Suk. 2011. Difference between Daylight Factor (overcast sky) and Daylight Availability (clear sky) in Computer-based Daylighting Simulations, Journal of Creative Sustainable Architecture & Built Environment (CSABE), Volume1
Nicol, Mark, Jerrod Kennard, and Mario D Goncalves. 2016. Analysis, sensors, and performance- closing the loop with post-occupancy data analysis. Proceeding of Façade Tectonics World Congress, Los Angeles, CA
Suk, Jae Yong and Marc Schiler. 2012. Investigation of Evalglare Software, Daylight Glare Probability and High Dynamic Range Imaging for Daylight Glare Analysis. Lighting Research and Technology
Sensorial architecture: design for well-being

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ABSTRACT: According to the Anxiety and Depression Association of America, 18.1% of adults suffer from an anxiety disorder and 6.7% suffer from Major Depressive Disorder in the U.S. alone. However, less than half are receiving any kind of treatment for these disorders. Architects Soderlund and Newman in their article, “Improving Mental Health in Prisons through Biophilic Design,” argue that the role of nature and an individual’s surroundings highly influence and reinforce our psychological and physiological potential to heal, by either a progressive, or regressive pathway. This means that our surroundings can have a positive, or negative, effect on our mental health and well-being. For humans to perceive a healthy space, the stimulation of the senses is very important. This is because when our senses are activated in a carefully designed way, it can lead to a more positive, perception of the built environment. The thesis will embody the provocation of the senses from the experience of the individual by designing acute atmospheres to address the problem that everyone does not heal the same way. I plan to accomplish this through a series of 5-architectural principles specific to my thesis. These architectural principles consist of: 1.) non-uniformity of space, 2.) sensorial differentiation, 3.) creation of multitude of paths, 4.) experiential clarity, and 5.) acute atmospheres. Each space will address at least one of these 5-principles by encapsulating the full engagement of a singular human sense. This research aims to interrogate the relationship between neuroscience and phenomenology in order to create a place of well-being. The project will interrogate a sense of well-being, particularly in response to the condition of depression in its various forms. Architectural design, with an emphasis on mood and atmosphere, will take a central role throughout this exploration. Various applications of architecture will be tested in order to generate a new aid to the ever rising illness of depression. By examining current typologies being used to treat and attack depression, the project will reveal new developing research approaches to tackling the illness to create a typology that will truly be able to formulate a relief to those suffering.

Holistic sustainable city planning: opportunities for fostering mental and physical Wellness

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Wellness and city planning belong together. This research explores the impacts of the built environment on human’s mental and physical health. The design process for creating cities requires critical understanding of place-making, architecture, urban issues and sustainability. Social, economic, environmental, and cultural aspects are keys in design processes that respond to the needs of the end users. Architects and planners need to create projects in comprehensive manners based on the context of the neighborhood, climatic situations, functions of the buildings, and sustainability considerations. The research question is: “How does holistic sustainable city planning contribute to long lasting environments aimed at wellness of the residents?” Aside from the more evident positive impacts on mental and physical health, there are numerous other benefits in such sustainable city planning. For example, holistic planning optimizes active transportation, re-uses existing materials, manages
storm water, reduces energy consumption, and increases biodiversity. To provide insights on the pressing research question, the authors deployed a methodology for the meta-analysis of the best practices as well as examining multiple case studies. Based on the professional experience of the authors, the urban sprawl phenomenon in cities, and rapid growth of the suburbs, drives commuters to travel longer distances. On one hand, the inner city areas are not meeting the ideal density targets from an urban planning perspective. On the other hand, from an architectural point of view, the creativity, beautification and long-term durability elements in buildings have been commonly neglected. People do not communicate with each other in communities where they live. They routinely commute from one destination to the other destination with decreasing social interactions. Residents do not talk with their neighbors because they do not know each other. This trend in our modern world has caused increasing rates of depression which is one of the most troubling psychological disorders of our time. Dysfunctional architecture and planning propagate and propel issues such as poor access to facilities, severe traffic, noise pollution, decreasing quality of living, stress, escalating affordability issues and other serious problems. Such dimensions have been threatening our mental and physical well-being. Therefore, the authors argue the roles of architects and planners must be revisited. This paper contends that people will be happier, realize higher quality of life, and will be healthier in a more holistically designed sustainable city. Such urbanity is densified in inner areas and is shaped by architecturally strong buildings, designed with enjoyable complete streets, and benefits through transit oriented development. Such vital dimensions are explored in this paper. Research in academia and in practice illustrates that multi-disciplinary collaboration is required to usher in better cities. Architecture and city planning departments must cooperate and be more innovative. This paper investigates novel approaches and emerging strategies for transforming modern cities to healthier places. The paper proposes a well-functioning integrated conceptual framework for a more holistic approach to city planning which advocates and advances human wellness. In such places, there will be a well-designed and well-functioning built milieu that supports heightened wellness and better quality of life.

Skater conscious: extending urban infrastructure

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ABSTRACT: As a designer, I continue to be fascinated with the relationship between skating and architecture. Skateboarding is made possible by the built environment, but without architecture necessarily being designed for its occurrence. Without knowing it, designers have created environments that facilitate a social and artistic culture to thrive. And this has happened – for the most part – in leftover pieces of landscape, infrastructure, and urban settings. Skaters move through and experience space in unique ways. While their boards enable this experience, there is more; most spaces are not designed for them – and some are even designed to keep them out – but, nevertheless, skaters persevere through invention and creativity. Skaters actively search for interesting spaces or even modify a site in order to enhance their experience. Over time, skateboarders develop a new way of thinking; a “skater conscious.” They build upon the seemingly mundane cityscape and imagine and embody another world. Non-skaters do not often share this resourcefulness; nor the dynamic movement, physical engagement, or spatial exploration. This project proposes that a deeper understanding of skater’s methods of interaction with their physical surroundings will aid in the production of architectural interventions that enhance the built environment for both skaters and non-skaters. In a way, skaters are architects; planning experience, developing form, recording their work.
Research will use similar methods undertaken by skaters themselves; maps and surveys will record existing skate spots and routes, time lapse photography will capture motion and form, video will document levels of speed, risk, area covered, and control. Computational analyses of existing skater and non-skater spaces will be used to test and imagine new expressive forms and novel spatial experiences. A series of design protocols will then be developed to define the parameters necessary to make spaces that work for their original design and to be manipulated so it can work for both groups. As skaters investigate and produce themselves within unused spaces the research will further focus on revitalizing existing, underused infrastructure.

How well are hospitals handling nurse comfort: IEQ survey of a hospital

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Among all of the staff at a hospital, nurses are the most necessary for patient recovery because they ensure the proper treatment of patients and their speedy recovery. From signing the patients into walking them out the door, they are the front line of defense and are indispensable to a hospital’s success. Therefore, a building’s comfort control systems should be set up to promote nurse comfort, rather than treating them as an afterthought. By minimizing nurse discomfort a hospital can expect nurses to have higher production values. Using IEQ driven data, occupant surveys, and observational information allows us to understand how nurses view their space. The datasets were collected from sensors establishing the workspaces’ IEQ, a comfort survey, and architectural observations. Data collection occurred over several days to ensure that anomalies were minimized, by doing so additional layers of information about the space were observed. A more complete picture occurred when the IEQ and architectural observations were compared to the occupant surveys, giving a more complete understanding of the problems occurring in each space. The nursing surveys showed common complaints that were caused by some insufficiencies leading to discomfort. Based on the analysis, a set of guidelines was produced. To ensure that these results are not anomalies to the overall comfort values of nurses, more data needs to be collected from a variety of hospitals.

Locally-sourced architecture: social capital and local materials as drivers of economic development

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Architectural projects contribute to economic development through many channels, including the specifying of materials and building systems. As specification systems become more standardized, relying on familiar manufacturers or product lines, architects inadvertently contribute to concentrations of opportunity — and potentially resulting wealth — along established supply chain channels. With increased globalization of product manufacturers and supply chains, those who benefit from this system are frequently distant from the community in which the project resides. This research identifies an interdisciplinary process to help refocus the economic benefits of material choices through repositioning the design professional within the ecosystem of those decisions. This process leverages architectural
services to enhance local economies through social and material capital. Developed through a national research consortium connecting academia and architectural practice, the research is led by HGA Architects & Engineers and the University of Minnesota who teamed to explore these questions beginning in 2016. Our research project probes the following questions: 1) Do current architectural material procurement processes reinforce existing wealth distribution, thereby rewarding global supply chains at the expense of local networks? What are the potential roles for the architect in this trend?, 2) What are the economic drivers that privilege non-local sourcing, and how can they be disrupted? And 3) How do traditional design and documentation processes contribute to these trends? How could these processes evolve to re-center the investment benefit?

The research team gained insight from interviews with various interdisciplinary collaborators, including a state economist and a municipal planning and economic development department, to better understand the impacts of the construction industry in local and regional economies. The data gathered through these conversations guided the team to pilot selected research findings on a live project within the architecture firm -- a critical access hospital located in a rural, coastal community. The research team targeted the use of local materials as the driver for local economic development very early in the design process, a strategy that sought to increase economic benefits generated from otherwise traditionally-sourced, imported materials. Preliminary outcomes of the research identified ways architecture projects could embed data-driven processes to an effective economic development strategy, in turn opening possibilities for architects to impart positive change in a project’s local economy and improve their agency in the systems of material and social currency that enable local economic growth. Through this process a ‘locally-sourced’ design framework, or toolkit, was developed. This toolkit included a process for embedding the data of local economic experts within the traditional material and systems selections for maximum impact and tracking the benefits of these selections for ultimate sustainment. This research not only offers architects an expanded toolkit, it also posits an equitable design and construction process with the potential to enhance client relationships, increase supplier partnerships, and benefit local communities.

**Explanation for the prediction of thermal comfort & sensation with building HVAC automation application**

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Thermal comfort optimization is crucial for HVAC automation, which adjusts thermal conditions automatically, based on occupants’ real time thermal preferences. However, the most standard recognized thermal comfort models, such as PMV, have not considered individual thermal preferences. In many cases, it is reported that the prediction of PMV is not accurate enough, especially for individual-use, where thermal preference is relatively subjective for everyone. Above all, previous research on how some physiological indexes represent people’s thermal comfort state, while psychological factors (that would impact people’s preferences) are practically ignored because of the difficulty in quantifying occupants’ psychological activities. This research aims to develop an algorithm that uses human indexes to predict an individual’s thermal comfort, and to estimate the thermal sensation state, based on environment parameters that are regarded as signals that trigger a work mode change in HVAC devices to optimize the indoor thermal environment to comply with preferences of a building’s occupants. This study adopted a series of human subject experiments, that were performed in an environmental chamber at USC, and that collected different types of data, such as human body
indexes, including skin temperature (°F), electrode activity (µS), and the rate of low frequency to high frequency (LF/HF) for heart rate variability. The last two represent the occupants’ reflections on outside stimulations and their stress levels, respectively; as well as environmental parameters, including indoor temperature (°F), relative humidity, radiant temperature (°F), and CO2 concentration (ppm). The study used machine learning to define algorithm, and used it to touch a HVAC auto control process, based on real time sensor data. The research outcome shows the potential correlations between the human indexes/environment factors that we chose, and the thermal comfort/thermal sensation levels, respectively, plus the control design. It presents the application of HVAC auto control, based on designed thermal condition estimation, with real time data from wearable sensors.

Tapping into urban recycling for housing alternatives: developing a waste cardboard-based building system for low-cost housing for urban areas in developing countries

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This poster contains a description of the methodological approach of a study that is exploring and testing how to fabricate construction materials with waste cardboard for building a low-cost housing system. The study proposes a workflow for assembling a prototypical building unit in a “real context situation”. The case study is in Asuncion, Paraguay, where there is an existing informal network of self-employed waste cardboard collectors and a population that needs housing alternatives. The study is divided into four different stages: a) studying the local context of the cycle of waste cardboard in an urban area in a developing country; b) exploring different methods and tools for producing building materials with waste cardboard – this includes a proposal for a production workflow; c) prototyping and testing building materials and systems for low-cost housing, and d) testing transferring the building system to the field through constructability experiments. The preliminary results demonstrated the potential of reusing waste cardboard in combination with other standardized building materials – repurposed plywood and studs that can also come from the trash, external waterproofing, and fireproofing procedures – to construct a panelized housing system that can be assembled using unskilled labor, minimal hardware, and conventional tools.

The mantle of Piranesi: hybrid explorations between analog and digital marking and making

Andrew Hart

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If baroque architect and master engraver Piranesi were around today likely he would be presenting photogrammetric models of historic ruins, GIS mappings of Roman countrysides revealing yet-unfound echoes of the past – and proposing even more extreme possible
artifacts hidden beneath those visuals- driving Google Maps vehicles down the Scalinata di Trinità dei Monti, and presenting impossible imagined cavernous spaces in virtual reality moviescapes in 3D IMAX. Armed with the cutting edge architectural and representative tools of his day Piranesi pushed perspective to its limit, collaborated to create one of urban mappings standards, and author a tome of works unmatched in breadth and detail. Giovanni Battista Piranesi is widely known for his Vedute di Roma streetscapes and perspectives of Baroque Rome and cognoscenti of Piranesi will prize him for his Carceri della Immaginazione – Imaginary Prisons – or the more the poetic translation – Prisons of the Imagination. While these collections represent the most well-known and certainly most architectural body of his work, Piranesi was also an adept publisher and businessman crafting a wide variety of further engravings and designs. Spurred by enthusiast's hunger to collect his compendium, Piranesi turned his skill at engraving to interior design to augment his architectural, archeological, mapping, surveying, and baroque visual science fictions. His series of engravings of urns and mantles provided the Piranesi collectors on the Grand Tour ample purchasables to take with them back home. While these works may be generated more for the grindhouse of clients than the grandiose Vedute Piranesi put the same tricks of the trade to work as utilized in his famed perspectives – warping centerlines, implying movement by asymmetrically balancing composition, and embedding hidden construction lines and reworkings in the layers of linework. These tactics also had the inbuilt effect of lending an inherent copyright to the work – the print of an urn was not enough material for the object to be made in the purchasers home country, the asymmetry of the design would create an object so off balance it could not stand upright and would implode under its own unbalanced weight. Utilizing a close study of the engravers works with recreations by hand and thorough digital manifestations these subtle tactics can be slowly revealed and newly appreciated. The facility of these tactics can then be applied using modern technological means of making. Undertaking a similar design series, a set of mantles and urns have been created using the technology Piranesi might use today – CNC milling to create life sized woodcut prints and sculpture, high definition fabric printing to create billowing linework for mantles, wall hangings and perhaps even shower curtains. This paper will explore the hidden depths of some of Piranesi’s prints of urns and mantles and chart its remaking hybridized between his craft against the contemporary means of production. Revealed within this study are the unseen tactics Piranesi took to push his craft and protect his art and how those same tactics can must be utilized in modern context.

Bienvenido a los vecinos: hacking public policy to unite rural needs and refugees

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Existing social and spatial strategies continue to be challenged by the plight of the Syrian Refugees in European Cities. This gridlock calls for immediate and transformative action, and complex issues are rarely afforded the time for a solution. Instead refugees and citizens make do with current policy. Existing UNHCR and EU processes are overwhelmed by the number and speed of refugee arrivals. Digital communication outpaced bureaucratic paperwork. Urban housing – already expensive and limited in many urban areas remains pressured. Solutions for housing, educating, and acclimatizing refugees has proven expensive and slow. Urban housing schemes favor large hasty construction needing time, funding, and insulate their population from adapting to their host culture – in turn inaugurating new problems for further generations. Before the crisis the Syria was a highly developed economy in the middle-east with an extensive educational system for men and women, one of the highest literacy rates in the world, and a mature professional and working class – all of whom were equally affected
and ejected by the military onslaught. Running parallel and simultaneously to the refugee crisis in Europe is a demographic crisis which, while slower to develop, is becoming a reality for vast rural areas of an increasingly urbanizing world – rural population aging and shrinkage of rural towns and village population. This is demonstrated particularly keenly by the Pueblos Abandonados of the Iberian Peninsula – entire towns which are uninhabited, and villages which lay close on the spectrum containing either only a few senior citizen residents. Myriad factors consort for this rural predicament, agricultural mechanization, urban job availability, global financial constrictions/booms – towns in Spain have experienced a generations-long brain drain as successive young Spaniards urbanize leaving communes and pueblos with a lack of professionals, teachers, families, and farmers and an overcapacity of infrastructure and housing. Can two crisis find a solution in the spatial-social arithmetic of their combined needs? One group a displaced professional and working class in need of housing, but left homeless in expensive urban areas and with limited relief funding; the other a ponderous abundance of small scatter site housing with a population in need of families, teachers, doctors, professionals and workers to continue the traditions. Rather than proposing a solution with new policy; the question is posed – is it possible to utilize existing policies and funding to remap existing resources to meet both needs with immediacy and personal connection? We will explore a suite of existing interfaces and policies; including UNHCR and EU refugee relief schemes, regional cultural, agricultural and infrastructure projects which could be tapped to connect the needs of these two disparate groups to empower each to become part of each other’s recovery. This poster will demonstrate several spatial-social projects both in practice and proposed to solve multiple economic, environmental, social, spatial and cultural needs synergistically and simultaneously – using an old concept familiar to any town – and new method of design thinking – neighbour-sourcing.

Ford as developer: from Detroit to Dearborn and back again

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An icon of the past becomes a vision for the future — and we couldn’t be more excited to embark on this journey with you, Detroit. #fordetroit pic.twitter.com/UnaVoOQbNV — Ford Motor Company (@Ford) June 20, 2018. In June, the Ford Motor Company announced that it had purchased Detroit’s dilapidated train station. An 18-story building that towers over the surrounding area, the train station has been an open wound in the city’s psyche, a reminder of what once was and an unavoidable visual reminder of decline and decay. This sale comes as Ford is already investing in its Corktown facility with an aim to broaden its Detroit footprint. Through mappings and GIS data, this poster looks at Ford Motor Company’s long history of property and cultural development within the Detroit and the greater Metropolitan area (Highland Park, Dearborn and Allen Park) beginning in the early 19th century and most recently with plans of redevelopment in Detroit’s Historic Corktown. The following questions are mapped and considered:

- What role has property development played in the production of the identity and culture for the corporation?
- Does the Corktown campus development mark a new era of urban corporate neighbourhood branding? How will this impact existing historical branding?
- What influence will the corporate presence have with the role of Ford as a developer and major lease holder of Corktown properties?
- How has the Ford Corporation influenced development and city (cultural) identity in Dearborn? How does this differ in Corktown?
Reframing redevelopment and gentrification

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A number of studies show that people who know their family history are more resistant to stress and anxiety. Our family and individual histories are intertwined with not only our personal memories but also with places, in which we live. Urban redevelopment has an immense impact on these relationships; a promise of creating a better place, but in truth, dismantling and displacing community networks, erasing the traces of those that lived before. In 1964, this is what Ruth Glass referred to as Gentrification. Building upon this original definition, this poster looks at Gentrification as more than just the affluent displacing the poor, but argues that redevelopment creates a process of “urban restructuring”. This restructuring is characterized by not only displacing people and their sense of belonging but also, intentionally erasing their history along with social and physical character of the place. This has been a pattern of urban redevelopment of neighbourhoods in the city of Atlanta. Developers are disguiseing displacement as urban redevelopment projects. Unfortunately, this is the story of the poor, the underprivileged, and the marginalized through urban policy. Oftentimes, this is a reality and fate of those living in low-income communities across the United States. This is also what is happening in the West End, a neighbourhood in Atlanta. The West End is a low-income neighbourhood that has built a stable social network that fosters leadership and progress. It is a place that people are deeply rooted within its cultural and historic places. However, people are beginning to be uprooted from their homes and signs of unifying West End’s culture to match a more generic culture mocks the community’s unique identity. This thesis explores how policies and design can slow-down the gentrification of neighbourhoods by sustaining its low-income communities within the urban core. With this intention, redevelopment should not equal pure gentrification because whole city suffers a loss when an established community is destroyed. I believe it is possible that a neighbourhood can be redeveloped so that existing low-income residents retain the right to live in their neighbourhoods, while at the same time, welcoming new faces moving in.

Mixed reality and its effects on an individual in society

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Mixed Reality, when integrated into architecture, will enable open spaces and the perception of the built environment to change rapidly with little physical fabrication. As architects, we design with the desired experience of space in mind and don’t typically design with a rapidly changing built environment to meet a floating programmatic demand. Theater Program, however, often requires such rapid changes to the perceived environment, that is the stage, and is an activator of social interaction based on a shared experience of the performances. What would be the architectural implications if we were to integrate mixed reality as a factor of the built environment? To help answer this question Theater with Mixed Reality integrated into the design process will be the main programmatic research and output of this project postulating both a built environment and flexible use space as nodes of the larger network that is Theatre. The research explores how Architectural studies and knowledge can be applied to
the principles of technology and guide the technology in a way that produces only positive psychological effects on a person. As a focus of the study, the Microsoft HoloLens will be the medium in which to study Mixed Reality. The research will then explore how this particular piece of Wearable technology interacts with the built environment and how these interactions then produce a psychological effect based on phenomenological precedents and guidelines. Based on these outcomes the studies will then produce a Theater with Mixed Reality integrated as a successful design component for architects and (MR) application designers to follow as an example in order to design buildings and applications with Mixed Reality in mind.

Investigating the ecology of metal double-skin living wall facades towards a circular economy

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Buildings consume about 50% of the energy supply of the United States. The design of buildings to enhance their thermal performance and reduce energy demands has been on the rise in recent years. Existing literature suggests that double-skin facades systems (DSF) are effective in reducing solar heat gains for temperate and tropical zones. These DSF systems not only improve energy efficiency but also provide buildings with a distinct appearance and character. DSF systems have evolved from simple applications of necessity to forms which represent identity. Technological discoveries enabled the use of metal to grow substantially in the 19th and 20th centuries for building fronts and structural functions. The introduction of exterior metal facades (skins) accelerated construction time and enabled designers to introduce more complex shapes in their design. Metals have permanence and flexibility that has brought it to the forefront in applications by notable architects from Buckminster Fuller in his “Dymaxion House” to Frank Gehry in his Guggenheim Museum. An ecological understanding of materials used for metal double-skin façades will serve as a basis to create new value streams for materials. This concept of ecological material consciousness is advanced for environmental awareness of the effects of available sources and applications of metal double-skin facade materials.

The role of thermal comfort in successful urban design: subjective and objective dimensions

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Thermal comfort is an important consideration in the design of buildings, neighborhoods and cities. This research seeks to achieve a better understanding of the linkages between the built environment and its impact on people’s movement patterns in a high-density urban context. The underlying hypothesis is that the characteristics of the built environment have influence on people’s movement patterns while using outdoor open spaces. The magnitude of affect depends on a range of physical variables usually assessed over a wide spectrum of spatial scales. Physical spatial dimensions, and architectural and landscape architectural elements in
an urban environment are known to have far-reaching effects on human thermal comfort. By corollary, they are a force that influences human perception. However, there is an overwhelmingly slim body of scholarship elucidating the relationship between human perception, thermal comfort and changes in human movement patterns due to the conductive, convective, radiative and insulating properties of the surrounding environment. Hence, there is a dearth of understanding of the demonstrable impacts that thermal comfort has on human's movement patterns. The present research deploys an array of methods from meta-analysis of the literature to case studies and logical argumentation. Initial results of the present research demonstrate that a purely physiological or psychological approach proves inadequate. Successful urban design with functioning outdoor spaces is central and critical to enhance public engagement. In this perspective, an in depth understanding around shift in human's movement patterns due to thermal comfort can be greatly beneficial. The outdoor thermal environment significantly influences how humans use the space and move through it. The current research examines such issues in an exploratory manner, and proffers a conceptual guidance to planners, architects, landscape architects, urban designers, policy makers and other entities in charge with shaping our cities, and making them comfortable, vibrant and healthy.

ROOTED: cultivating social inclusiveness + food equity

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Abandoned by the state and ignored by the federal government, New Orleans found itself in the midst of an unprecedented civic disaster after Hurricane Katrina in 2005. Outrage and concern about the slow political response culminated in the creation of a citizen-driven food network. This local food network consists of community-based farms and organizations that devote their resources to providing under-served residents with sustained access to fresh produce. These local farms and gardens primarily began to sprout up in the hardest hit and most devastated neighbourhoods. More often than not, these affected neighbourhoods contained the largest percentage of vacant lots or abandoned homes. Soon the network’s purpose rapidly outgrew its intent and it expanded into the distribution and sale of locally grown produce; leading it to become an economic driver and physical link across the city. What originally began as a small-scale response to political neglect, quickly grew into a citywide movement resulting in the emergence of a citizen operated food system dedicated to reviving and rebuilding neighbourhoods and communities. By creating a series of food-centric public interventions of varying scales and functions a framework, or infrastructure, is developed to expose and celebrate the existing food network. These interventions look to promote economic inclusiveness and food equity so that this citizen-driven network can continue to thrive and contribute to an already culturally rich urban environment. To best understand the needs of the existing network it was dissected and examined as multiple layers and various scales. These determined the programmatic requirements for three sites that reflect the complexity and potential social implications of the network. This thesis looks to identify existing social and economic gaps, and craft new connections by preserving and enhancing existing food relationships related to production, consumption, and distribution.
Learning from lost wages: the necessity of design research for practice

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Frank Lloyd Wright’s firing by Louis Sullivan in 1893 and his rapidly growing family set him on an urgent course to seek his own voice. The bootleg houses, designed outside the contract terms Wright had with Adler and Sullivan caused the separation, likely fueled by both Sullivan and Wright’s ego, which left Wright alone, separated from his “Lieber Meister[1].” These early houses by Wright were adaptations of various styles popular in the times, Neo-Colonial for Blossom, Victorian for Parker and Gale, each, as Wright explained were not “radical” because “I could not follow up on them.[2]” Wright, like many young architects, had not yet codified his ideas and strategies for activating space and form. How does one undertake the search for one’s language of these architectural essentials? Does one randomly pursue a course of trial and error casting about through images that capture one’s attention? Do we restrict our voice to that which has already been voiced in history? While the houses that followed Wright’s departure from Sullivan lack the formal coherence of the skillfully adapted “Bootleg” houses, these transitional houses constitute important markers of Wrights practice based research towards finding a harmonious relation between plan and section, space and mass, a structure for form and space. Practice based design research is essential to architects and architecture and can offer students and new practitioners a strategy to accelerate their own growth. Frank Lloyd Wright’s hundreds of houses offer a unique glimpse into the development of an expression of beliefs in form and space. This paper will present a timeline and study of Wright’s earliest, sometimes awkward steps, and propose that it is an ornamental structure, learned by Wright at the desk of Sullivan, was the catalytic force that freed Wright from historicism and set him on a path of clear principle that would deeply influence the works that have made him a Master.

Proto-branding: an alternate history of corporate modernism

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Since the first decade of the 2000s, much of what we encounter in our man-made environment, from what we eat, wear, and drive to where we live, work, vacation, and otherwise spend our time, has been consciously branded. Everything has a precisely defined personality and gives off a deliberate emotion, or vibe. Architects and designers are doubly implicated in the pervasiveness of branding. When employed by others, they contribute to their client’s branding efforts through architecture and design. The author of this poster asks, Can we trace architectural branding to an earlier historical moment – to modern architecture for corporate clients? A history of architectural branding is new scholarship that is needed to give further texture and nuance to the study of modern architecture. This posters examines four select American corporate headquarters in the mid-twentieth century to posit examples of proto-branding: The PSFS Building by Howe and Lescaze, The Johnson Wax Building by Frank Lloyd Wright, Lever House by SOM, and the Röhm and Haas Building by Pietro Belluschi. By studying these buildings through their primary sources, especially their business papers, I demonstrate a cross-displinary study that will show how the collaboration of business and design led to proto-branding.
Tensegrity cushions: tensile formwork for cast-in-place concrete walls

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The dominant method of construction employed in a region controls the dissemination of intellectual and economic prosperity, along with exerting a direct impact on individual self-worth within a society. Eugene Viollet-le-Duc’s dissection of why Greek artisans did not use arches notes the desire by the elite to maintain a caste system. Held by the sculptor, the art and knowledge of construction was removed from the subjugated, on-site labour. The removal of craftsmanship from the labour class dehumanized their work, in turn, removing their opportunity for pride and status. A century later, Eladio Dieste’s paramount work in brick structural form, idealizes the enriching possibilities of knowledge springing from the ground-up. Eladio notes the satisfaction that his workers and the community take of the work executed. In today’s fervour for computational design and digital fabrication, it is easy to see Dieste’s concerns regarding the “tyranny of the drawing board” translate into “tyranny of the abyss of model space” as the act of construction has decreasingly less influence in design processes. How do we utilize the tools at our fingertips, while not removing the knowledge and pride of construction for the act? The research presented investigated a logic of construction that cycles between the investigation of unique low-tech construction assemblies and computational testing of variations. This article presents a tensile, fabric formwork for casting structural concrete walls that utilizes a tensegrity space-frame system. Based on analytical and scaled physical modelling, a series of full-scale proof-of-concept concrete casts demonstrate the methods, techniques, and sequence of construction along with the variation and tolerances achieved. Presented as an alternative to current cast-in-place concrete construction techniques, the tensegrity formwork provides a base logic for novel and emergent behaviour in the final form while demanding comparably minimal material, equipment, and labour skill-sets. Empirical testing of the proof-of-concept casts document three points of control: the formwork system’s ability to maintain industry standard coverage of structural steel; an acceptable tolerance on the location of structural connections; and, a reliable formula for estimating concrete volume. Further development of the assembly will include the testing of structural connections along with embedding programmatic and environmental design responses.

Seeding sequence: a systems thinking approach to a critical design process

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Engaging architecture as an emergent, complex system, this paper examines the implementation of a critical design approach -- the Seeding Sequence -- in two diametrically different studio courses: A 5th year Integrative Design and a 1st year Beginning Design one. The Seeding Sequence process guides the students to work in a recursive cycle between two competing modes and scales of investigation: a modelling method that focuses on material and construction techniques at the level of the ‘part’ and a drawing method which considers the ‘whole’. In the modelling method, the students develop structural hierarchy in adaptive assemblies. The drawing method facilitates a sensitive engagement of the interconnections of
those adaptive assemblies within the site. Rather than strict coordination between the
methods, the Seeding Sequence guides students to distil and diagram the essential qualities
of the adaptive assemblies to seed the drawings, in turn, the drawings are free to adapt,
pursue, and discover emergent behaviours in response to site, program, and environmental
strategies. Through selective examples from both studios this paper discusses the effects of
this design process on three aspects of the students’ work: 1) the ability to fearlessly begin
drawings or models without preconceptions of the end result. 2) the capacity to critically
question the design decisions made in one of the two methods of investigation against the
concerns of the other. 3) the skill to draw direct connections between the structural design
and the unique attributes of the materials, program, and site of the project. This paper
concludes noting that the specific methods of investigation are selected to challenge the skill
level of the students and the resolution of architectural design thinking required by the course.
But more importantly, the pairing of two methods -- specifically with dramatically different
benefits and outcomes -- establishes an awareness in the student to actively question what
each new method brings to their design process.

**Soft architectural assemblies**

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The project presented here proposes the integration of material dynamics into a material
assembly, with the goal of rethinking the assembly as an adaptive and dynamic material
system. The project shows the use of a pneumatic system as a form of actuation. It presents
research into the capacity of pneu structures to generate kinetic movement within a
component-based assembly and produce a responsive and ‘programmable’ architectural skin.
This is a prototype-based exploration that demonstrates different kinds of movement achieved
by different silicone muscle types and proposes a light modular construct, its components, and
patterns of aggregation that work in unison with the silicone muscles to produce a dynamic
architectural skin. The project brings together two strategies for designing dynamic
architectural skins. One is concerned with the combinatorial capacity of a light structure built
by aggregating small self-similar components. The other one focuses on the integration and
distribution of pneumatic muscles within that aggregated structure. The proposed system
demonstrates the performative potential of a component-based material system whose
properties range from rigid/stable (self-supporting) to pliable/active (dynamic). Such a system
can produce the structure whose variable material capacity can seamlessly blend structural
and non-structural regions due to the components’ shape and the overall geometry of the
assembly pattern. This system could potentially ‘grow’ into a number of different spatial
configurations and therefore fit into a variety of spatial conditions. The light modular structure
is built using self-similar elements with a non-orthogonal alignment. It is aggregated through
slot-friction connections and it can result in a number of different configurations. The
configuration of the construct is driven by the requirements for stability (self-support) and
kinetics, which are equally important to support dynamic transformations. The soft body of
the project is a continuous and interrelated network of pneumatic muscles integrated into the
modular structure assembly pattern. It consists of clusters of interconnected soft inflatable
pneumatic muscles. When inflated or deflated, these clusters move entire regions of the
modular structure, producing apertures that open and close. The muscles are conceived as
modular elements that fit with the system’s components interchangeably; two muscles (S and
V) were designed to integrate into the assembly grid pattern while the other two (B and M) nest
within the voids of the grid. The main motivation for the development of this system is to
produce a material system that can support a variety of configurations and a range of
performative effects from rigid to pliable, from hard to soft, and from structural to dynamic. The
key feature of the project is its actuation system that is embedded into the overall structural
pattern. Other important features are its modularity and the use of slot friction connections for
all components in the assembly, including the pneumatic muscles. In nature, the functionality
and materiality of a material system are blended and integrated. In similar fashion, this project integrates functionality and materiality of soft/dynamic and hard/structural layers to produce dynamic architectural assembly.

Kolkata | Ecological Urbanism for Bridging Socio-Spatial Gap

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Kolkata, a city in East India, also known as a “City of Joy” for its vibrant diversity and as one of the most important cultural centers in country and yet it exemplifies many issues that are related to overpopulation, weak enforcement of planning regulations, informal housing, natural ecological degradation, and lack of social cohesion. The urbanization of the city triggered a drastic shift in migration as people move into modernized neighborhoods causing a disconnect between generations. Wetlands, an important source of water, provides 30-50% of food and livelihood for more than 30,000 people, has been diminishing due to urban developments. The lack of necessities and services cause spatial shift as slums and homeless population increases, per 2011 census it is estimated that more than 1.5 million people live in slums and 70,000 are homeless, making up 22 percent of the Kolkata’s population. According to the World Health Organization, Kolkata is the 2nd most polluted metropolis in India. My project springs from the charge of bringing together the old and the new, the rich and the poor, the diverse social groups, and restoring the natural habitat at the edge of the city. Building upon the concept of "hybridity" proposed by Homi Bhabha, an Indian English scholar, and critical theorist, the thesis explores similarities between two places to overcome the dialectic gap between natural and man-made, formal and informal, social classes, tradition, and modernity. The thesis reflects on the issues ingrained into the social and spatial conditions of Kolkata by reforming the urban ecology of the canal that brings together cultural, traditional, and vernacular identities. My design will express the importance of diversity, equity, accessibility, and preservation by framing space to construct power relations between the people and the environment. In doing this my aim is to help mitigate socio-spatial displacement.

Living architecture – an anthropocentric and biocentric review

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In the event of the environmental urgency, the necessity for ecologically friendly architecture was the driving impetus behind the emergence of living architecture. The perplexity overarching this notion bars architects from embracing and implementing it into their designs. This Study is an attempt to define living architecture; what are the similarities and differences with other trajectories of green architecture approaches, also, what it represents for both human and the environment, removing the ambiguity that overshadows it. Built on the philosophical and historical literature reflected on a range of world known case studies, it demonstrates what living architecture entails from an anthropocentric and biocentric approaches, to answer weather it is possible to create an architecture that can serve human and environment synergistically. It is believed that a clear understanding of the living
architecture role and importance will result in proper implementation by designers whether we build for human or nature. Living architecture is a relatively new and thriving concept; yet, it lacks coherence due to the complexity of its components which mandates the architectural community for continuous research.

**Healing the healthcare continuum**

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The public healthcare system in the United States is vast and complex. Due to capitalistic entities, insurance companies, and pharmaceutical companies; notions of wellness and biophilic design are often lacking in most of the buildings. Based on the CVS Health and Wellness study 63% of Americans agree with the fact that the U.S. healthcare system does not work for them. But what is even more appalling is the 23% of Americans say their healthcare has gotten worse. This thesis questions how architects can redesign typical healthcare typology in response to the medical and sociological needs of the community while integrating the measures of wellness and biophilic design. By redefining architectural programs within a wellness clinic, this can allow the facility to prioritize the communities needs through non-medical determinants. The research will look at both the social and medical needs of a community, along with 'The Seven Standards of Wellness' as defined by the Well Building Standard and 'The Fourteen Patterns of Biophilic Design' as defined by the Terrapin Bright Green, to develop a connection between the facility and the community. The Mott Haven and Melrose in South Bronx will be the focus site for this project. This site was chosen due to the lack of medical clinics that serve these neighborhoods and a singular overcrowded public hospital that serves 2.3 million patients yearly. The purpose of this research is to create an architectural framework for wellness, self-inclusion and early detection/protection. This thesis defines a new archetype: ‘the in-between’ that attempts to create a more holistic narrative by exploring patterns of biophilic design by redesigning the public spaces within the healthcare facility of the Bronx.

**Towards application of machine learning algorithms to generate multiple desired design options in the early stages of design**

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Despite the big contribution that Computer Aided Design did to design workloads in terms of drafting and design drawings, it did not have any constitutional impact on the design process and thinking. Computational design brought a new perspective on design perception and made a huge revolution in design process by providing algorithmic and dynamic platforms capable of generating novel design options through design variable ranges. Computational design software such as Revit, Rhino, Dynamo, and Grasshopper to name a few, have presented a novel generation of innovation that is much beyond the ability of conventional design platforms such as AutoCAD. Despite the remarkable development of computational design tools, most of the methods require the primary inputs and specifications of a building to generate an output or assess the performance of the outcome. However, in many cases, the architects urge for a
specific output solution though not confident of the design input. The advent of artificial intelligence technique has brought a novel realm of perception of data in many fields of science and engineering. Machine learning and beyond that, deep learning algorithms provide an intelligent workflow in which the system has the ability to learn from the dataset that has been fed in the earlier stages of the training process. Artificial intelligence, AI, has been studied largely in many recent studies mostly in science and engineering; however, very few research is done in the application of AI in architectural design and practice. This study applies a reverse method using machine learning algorithms toward generating demanded design option(s) in the early stages of design. In this study, a single objective problem is investigated to initially predict a label of an unseen sample and later to generate a novel sample based on an arbitrary dataset consists of six types of 2D shapes.

Listen to the land: learning to meaningfully connect in an increasingly disconnected era

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Central to indigenous culture, values and vision in North America is an unswerving acknowledgement of the importance of the earth and our connectedness to the land. Origin stories tightly weave our planet and its inhabitants into a single system where respect for nature and an intense land ethic inform steps and inspire action. It is inconceivable that harm inflicted to any part of the system does not bear consequences for the whole. Further, such understanding moves beyond the physical and the three dimensional. Time is a vital aspect of the indigenous world view. We cannot live only in the present, ignoring yesterday and dismissing tomorrow. Cycles are paramount and dimensions are manifold. Directions transcend the cardinal to embrace above, below and center. Rocks speak. Animals guide. Wind reveals. The many rituals of the many nations of our first peoples most notably serve to underscore such connections and to remind us of our place. The sweat lodge returns us to the earth while the sundance binds us to the heavens. Our modern world, both Western and Eastern, is increasingly disconnected from such holistic thinking. Our reliance on the truth of science and our dependence on the convenience of technology serve to separate us from the visceral, detach us from the natural and distance us from interdependence. Politicians debate climate change and question global warming. Nations collide, conflict and wage war to solve differences. We chase money and we buy stuff. Undeniably it is both easy and perilous to generalize in a world replete with complexity, complication, turbulence and troubles. That said, perhaps it is important to consider other ways of seeing, thinking and acting that transcend the conventional. Indigenous cultures present us with potent lenses with which to better understand our world and through which to start to repair what is undoubtedly a broken approach. The present research critically examines and explores indigenous culture with an eye to redefining and redesigning ‘sustainability’. Using methods that include meta-analysis of the literature, case studies and logical argumentation, the research reveals aspects of indigenous world views, and ways of life, that provide us with a pause to reflect and reasons to reconsider. The author, an architect and psychologist who works extensively with indigenous communities, creatively explores a series of views that challenge the status quo and offer potential for better outcomes. Included in the discourse are pedagogical efforts, pertaining to the author’s indigenous-focused architecture studios, that reveal novel ways of educating towards sustainability. Learning to listen to the land is at the core of innovative teaching approaches that aim to realize design projects for aboriginal communities. It is argued that the
lessons learned in this research, and in the associated teaching work, hold promise for applicability and impact well beyond the boundaries around given students, studios, cultures and communities.

Application of artificial intelligence algorithms in smart building systems: a literature review

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One of the rapidly growing interests in the field of building technologies is smart and intelligent building controls. The objectives are to improve building performances, providing better occupants' satisfactions at the same time. Artificial Intelligence (AI) is one of the emerging technologies in many areas such as drones, intelligent robots, health care, self-driving cars, and so forth. The AI technology became a tool or system that can be utilized to compare observations, interpret, predict, and monitor behaviors in various systems and operations. In building sectors, interests in AI have also been rapidly increased due to its application potential in the smart and intelligent building controls. Now, AI is at the center of the 4th Industrial Revolution, which was presented at the World Economic Forum in Davos, Switzerland in 2016. The 4th Industrial Revolution has three main characteristics: (1) super connectivity to link people and things through the Internet network, (2) super intelligence that analyzes big data based on the super connectivity, and (3) predictability, which predicts a phenomenon based on the analysis of results. AI is being advanced at an increased pace based on these three characteristics. The global AI market is expected to grow at a Compound Annual Growth Rate (CAGR), which is a useful measure of growth over forecast period, of 36.62% from 2018 to 2025. This shows the anticipated adoption of this type of technology. The expected global AI market is $21.46 billion in 2018 and $190.61 billion in 2025. Various AI algorithms have been developed ranging from those with simple forms to those with complex and diverse equations. However, it is not easy to know which algorithm is appropriate in what research and application areas. The potential advantages and disadvantages are also dependent on case by case applications. In buildings, AI can be used for optimal controls in Heating, Ventilation, and Air-Conditioning (HVAC) systems to maintain the thermal conditions of spaces. It can also be used to predict heating and cooling loads of buildings, which is a very important in building controls for energy efficiency. The challenge is, however, that applying AI for the development of whole building system optimal controls is very much complicated due to the unpredictable and qualitative parameters such as the behavior of occupants. This paper presents the characteristics and algorithms of AI that can be used and applied in the area of smart and intelligent building controls. They include the functions of learning and predicting human behaviors in building spaces. Advantages and disadvantages are discussed, which can help better understand the development directions of AI algorithms. This paper concludes AI algorithms proposed as suitable ones that can be applied in the smart building systems controls. The findings can be used as useful information in terms of applying AI to controls in various building HVAC systems.
Sea Level Rise as Design Stimulus: Regulation to Environmental Ethics

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Environmental ethics as presented by acts of conservation can challenge regulations that favor economic and political interests. However, sea level rise (SLR) and the escalating probability of total inundation presents such uncompromising realities that has the great potential to bring together competing interests with appropriate design intervention. Yet there exist an imbalance in the practice of design that prevents a fair negotiation between environment and urban factors. Regulations can allow designers to knowingly skirt rules to benefit the client, be rewarded by industry and practice, and to even disguise such acts as environmentally responsible. The study here shows the great differences in perspectives between urbanity and environment as it applies to state of Rhode Island (RI). SLR as an act of environmental disturbance offers to open up ecological opportunities, yet the destruction also offers to reactivity the cultural landscape; a point aligned with RI’s desire to economically develop and to preserve its large collection of historical places and structures as one of the oldest states in the nation. SLR allows us to challenge the traditional methods of development based around economies, and preservation that emphasizes physical appearances, which allows for the inclusion of marginalized historical threads and extended geological time frames. Coastal regulations, which are meant to protect and conserve the ecological landscape, also present complications with SLR. The predicted speed at which SLR will transition the landscape will unfortunately be too fast for important landscapes like coastal wetlands to establish. Even more complex are the political origins of these standards that prioritize the human interest over non-human ones in developed locations. Allowing private land owners to maintain existing coastal structures that dominate the coastal landscape is an incentive to assert landownership and as a result discourage environmental action. Presenting a less binary and more visually complex set of SLR consequences has the potential for landowners to reconsider the less environmental, more expensive maintenance today if they were required again soon. Designers would be better served if they could acknowledge the immense bias toward the human and individual over the less identifiable ecological factors that shape the environment. The environmental law professor Shi-Ling Hsu calls this the “identifiability bias,” and is a major structural impediment to taking meaningful environmental action. Coastal regulations are bound by a “wicked problem,” which must respect the legal rights of the landowner, while committing to society’s mission to protect the more complex inter-county-state-region coastal realm. This hierarchy of importance places unfair responsibility on environmental regulations to defend their policies against designers with interests to the contrary, which creates contentious atmospheres and arbitrary justifications. SLR opens up the opportunity to unearth the developed and developable landscape. It helps to refresh a designers position because of the environmental bias that SLR exposes. For a project in RI, it highlights interconnections of hydrological landscape and wildlife conservation efforts that dominate the environmental dialog across the state. Regulations, even as they change, should be a bar far below the great imaginative ethic that SLR portends to create.
IN THE WORLD OF INCREASING COMPLEXITY AND COMPETING IDEAS, APPROACHES, RESOURCES AND TECHNIQUES, HOW DOES ARCHITECTURE MEDIATE THESE TENSIONS? WHAT IS THE ROLE OF ACADEMICS AND RESEARCHERS IN DEVELOPING RESEARCH OUTCOMES THAT ARE MEANINGFUL AND MEASURABLE? WHAT IS THE ROLE OF PRACTICING DESIGNERS (ARCHITECTS, ENGINEERS AND SCIENTISTS) IN DEVELOPING AN APPLIED RESEARCH AGENDA IN ARCHITECTURE?

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