Spatial Layout and the Promotion of Innovation in Organizations

Jean Wineman, Felichism Kabo, Jason Owen-Smith, Gerald Davis
University of Michigan, Ann Arbor, Michigan

ABSTRACT:

Research on the enabling factors of innovation has focused on either the social component of organizations or on the spatial dimensions involved in the innovation process. But few have examined the aggregate consequences of the link from spatial layout to social networks to innovation. This paper reports preliminary data from a larger study that explores the role of spatial layout as it interrelates with social networks to promote innovation among scientists and engineers working in two very different research-intensive organizations, a non-profit life sciences institute dedicated to translational research on cancer and at one of the research labs of a multinational software corporation. The study applies space syntax analysis to map and characterize physical space in conjunction with survey data capturing social contacts among researchers at the two organizations.

Social networks play important roles in structuring communication, collaboration, access to knowledge, and knowledge transformation. These processes are both antecedent to and part of the innovation process. Spatial layout structures patterns of circulation, proximity, awareness of others, and encounter in an organization. These interrelationships become fundamental to the development of social networks, especially those networks critical to the innovation process.

This paper focuses on the role of spatial layout as it affects innovation volume and impact at the individual level. Our methods of spatial analysis provide the opportunity to examine potential effects of spatial layout at both the local and global levels.

This study extends our understanding of the complicated organizational, social, and physical correlates of innovation. Results support our understanding of the effects of spatial layout innovation outcomes. We hope to identify opportunities to guide the social and organizational structure and spatial layout of workspace to create more effective, efficient, and innovative organizational processes.

KEYWORDS: organization theory, innovation, spatial analysis, workspace design

INTRODUCTION

This paper reports on preliminary results from a portion of a larger study that examines the joint effects of social networks and spatial proximity on innovation. Research on the enabling factors of innovation has focused on either the social component of organizations or on the spatial dimensions involved in the innovation process. But few have examined the aggregate consequences of the link from spatial layout to social networks to innovation. This project enriches our understanding of how organizational innovation works by exploring the social dimensions of innovation as they are embedded in a specific spatial milieu. This project, funded by a grant from the NSF[1], is by its conception, interdisciplinary. Our interest is to bridge disparate disciplines, and their respective bodies of knowledge, to explore the social dimensions of innovation as they are embedded in specific spatial milieu.

The research focuses on scientists and engineers working in two very different research-intensive organizations: a non-profit life sciences institute dedicated to translational research on cancer and at one of the research labs of a multinational software corporation. We employ the methods of space syntax to map and characterize physical space with survey data capturing social contacts among researchers.

We investigate the associations between innovation within these organizations and the organization's social structure, as revealed through its social networks. Social networks play important roles in structuring communication, collaboration, access to knowledge, and knowledge transformation. These processes are both antecedent to and part of the innovation process.

As built space structures patterns of circulation, co-presence, co-awareness and encounter in an organization, these interrelationships become fundamental to the development of social networks, especially those networks critical to the innovation process. In particular, this paper explores the contributions to innovation outcomes of various approaches to the in-depth analysis of space as represented by alternative methods of space syntax analysis.

The techniques for the analysis of spatial form or "space syntax analysis", developed by Bill Hillier and his colleagues at University College London (Hillier & Hanson, 1984), provide rigorous methods of measuring both global and local spatial network characteristics and relationships between them (Peponis and Wineman, 2002). Principles of spatial organization affect the generation and distribution of movement patterns in space, space use, and the ways in which occupants encounter others in space (Hillier and Penn 1991; Peatross and Peponis, 1995; Peponis, 1985).

One of the exciting aspects of syntax analysis is the opportunity to explore quantitative representations of space. Different syntax methods focus on different characteristics of space and are therefore more or less appropriate for quantifying alternative aspects of spatial layout. For example, 'lines analysis' describes spatial layouts as lines of physical access, where longest lines are drawn that cover all potential paths of access on a plan, and can be applied to either urban layouts or building plans. One of the advantages of these approaches to the representation of space is that, once the approach is selected and applied, we can quantify relationships among spaces at both the local level and the global level for each spatial system.

BACKGROUND

This paper examines the comparative contributions of three alternative ways to characterize physical space as represented in syntax analysis: lines analysis, convex analysis, and visibility analysis. Hillier and Hanson (1984), in the development of space syntax analysis, described their work as dealing with topological and numerical parameters, and propose measures of accessibility that are functions of the number of direction changes made, the number of boundaries crossed, or the number of spaces traversed. In this early work, metric distance was explicitly not factored in the measures. Syntax analysis involves the translation of a two-dimensional spatial layout into a graph. Where a graph consists of a set of nodes, or vertices, and a set of lines, or edges, and each line makes a link between two of the nodes of the graph.

The most socially significant properties of space evoked in the literature of "space syntax" can be stated in graph theoretic terms. "Depth" characterizes the relationship of a node to the graph that contains it. The depth of a node is the sum of the lines that are necessary in order to reach all other nodes in turn. "Integration" is the major graph-based measure used in the "space syntax" literature. Integration is an algebraic function of the mean depth of a node from all other nodes in a system. In this sense it is a measure of the interrelationships among spaces for the entire spatial system at a global level. "Connectivity" refers to the number of links associated with a given node, it is, in other words, a simple and very local measure of connection. Similarly, we can look at a more localized measure of integration, by calculating mean depth for only those nodes in the immediate vicinity of a node (typically for a local measure of integration (integration3) the calculation is limited to nodes that are three nodes from the origin).

In principle, the question of the definition of distinct spaces can be addressed separately from the graph-based part of the theory. For this paper we will explore convex analysis, lines analysis and visibility analysis. From any given position, our sense of space is characterized by the convex area that contains us as well as the lines of potential movement or visibility that direct us to other convex areas beyond. To capture the underlying spatial structure that is associated with movement, space syntax analysis represents spatial layouts as sets of intersecting lines. The "axial map" or "linear representation" (Hillier and Hanson, 1984) comprises the fewest and longest lines that are needed

in order to cover all the ways of moving around a layout and in order to reach all the spaces. Our prolonged occupation of a space is associated with our sense that there is a region of space within which we are located and to which we have reciprocal visual access to others located within that space (we see them, they see us). Both intuitions can be linked to the idea of convexity. The "convex map", which comprises the fewest convex spaces that are needed to cover a layout, was proposed as an appropriate method for identifying two-dimensional spatial units (Hillier and Hanson, 1984).

Another definition of distinct space is the visual field or visual "isovist." The "isovist" (Benedikt, 1979) comprises all the area that is visible around a particular position and offers us a way to study plans in terms of visual fields. Movement and prolonged occupation are fundamental poles of our experience of space. Seeing beyond the present position in some particular direction is an aspect of how movement is possible. To capture the underlying spatial structure that is associated with movement, layouts can be represented as sets of overlapping visual fields. On any given layout plan, a great many different isovists can be drawn, and in order to fully analyze the layout a convention must be followed to decide where the isovists can be rooted. One convention is to cover the plan by a square grid of a given size, as if to "tessellate" it, and then to draw one isovist from each square unit (Batty, 2001; Turner, Doxa, O'Sullivan & Penn, 2001).

The convex spaces that can be occupied, the lines along which we can move, and the visibility polygons that are available to us are three fundamental ways in which we may interpret plans as discrete patterns of relationships (see Figure 1).

METHODOLOGY

For each of our two study organizations, the life sciences institute and the software company, we apply each of the three spatial analysis approaches to understand their relative contributions to predicting our innovation outcome measures. We emphasize two key aspects of the discovery process; the ability to access new ideas by conscious search or serendipity (*prospecting*), and the ability to activate colleagues' support to validate and promote those ideas, or *mobilizing*. Both are activities that can be nourished by social network connections or encounters in physical space, or some combination of the two.

For these two organizations we use two measures of innovation: patent applications and publications.

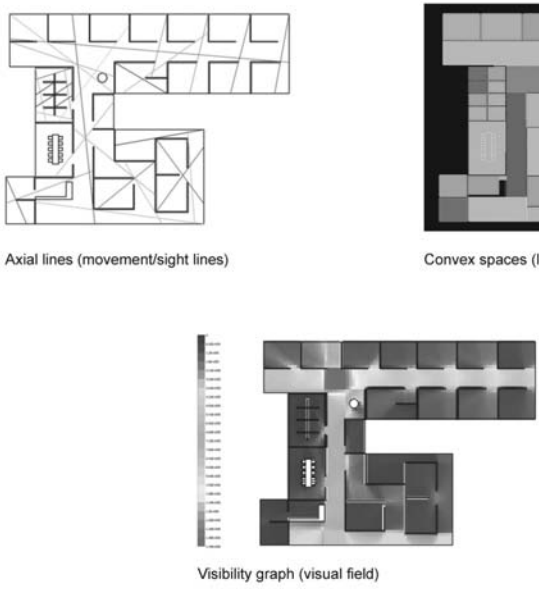

Figure 1: Convex Analysis, Lines Analysis, and Visibility Analysis

All professional personnel in each of our study populations were asked to complete a social network survey. This survey collected sociometric data on the nature of the relations between the professional colleagues in the groups or departments of interest. Given the multidimensionality of our innovation research, we will explore networks that reflect the collaboration networks of actors as well as the strength or importance of these collaborations.

We analyze the workplaces of our research sites in terms of spatial design characteristics by applying space syntax analysis to the floorplan layouts. The three approaches to syntax analysis, convex, axial, and visibility analysis (as described above), are compared in this paper. Thus, we will be looking at how accessible the spaces are, and what kinds of visual relationships exist amongst different areas. Using space syntax software we calculate two measures for each of these analysis methods, *integration* and *choice*, and examine each of these measures from the scale of the layout as a whole (global) to the scale of individual spaces and work groups (local).

We argue that network positions and beneficial office locations influence workers' ability to prospect for new ideas and mobilize the resources and attention necessary to implement those ideas. In particular, we examine how *proximity* (as measured by the variable integration) and *inescapability* (as measured by the variable choice) influence the rate of innovation.

Spatial Proximity and Inescapability. There appear to be few substitutes for face-to-face interactions in knowledge intensive work. As physical distance increases, the likelihood of collaboration decreases (Olson and Olson, 2000). Olson et al. (2002) report that radical collocation doubled the productivity of software engineers by increasing the team's ability to monitor and learn from one another's work. Early studies exploring the link between space and work processes focused on the effects of linear or geometric distance on processes such as communication. Allen (1977) showed that the probability of communication between engineers dropped precipitously at the 30 meter mark. Allen's work was also seminal in suggesting that other physical aspects of the pathway between individuals, such as doorways and stairs (barriers) or turns in the corridor (topologic characteristics), extended the perceived 'distance'.

The importance of proximity (integration) is not limited to one's local work group. As Allen indicates from his studies of engineers, the most powerful ideas were reported to develop not from communication within the workgroup, but through communication beyond the workgroup with others in the organization. So we see proximity operating at two levels, the local level encompasses links to colleagues in one's immediate vicinity, and the global level identifies links that connect individuals across areas of the organization.

Hypothesis 1: As proximity to colleagues increases, the rate of innovation rises.

We have suggested previously that a good idea is not the sole ingredient for innovation; but an individual must coordinate and mobilize a collective effort to bring these new ideas to innovative outcomes. Thus, an important aspect of innovation is the process of mobilizing collective effort. If an individual comes into contact with many colleagues, and in particular those that are from across the organization, he/she would be more likely to be successful in this process of mobilization.

In exploring how spatial layouts connect individuals across the organization, it becomes clear that particular layouts of corridors and offices can tend to concentrate movement along a few main corridors, or distribute movement across multiple access routes. The extent to which the layout concentrates use will affect the likelihood that any individual will serendipitously encounter others in the organization. The measure of 'inescapability' (choice) captures this concept of a corridor or other locations that concentrates use. If alternative routes do not exist, individuals do not have a choice, but must pass through this location, bringing them into contact with other users of that location.

Hypothesis 2: As proximity to locations of 'inescapability' increases, innovation rises.

FINDINGS

Regression models were applied to examine the contributions of background variables (job type, status, PhD degree, previous patent applications/publications), social network power and prominence, and

spatial proximity (as measured by the variable *integration*) and inescapability (as measured by the variable *choice*) to innovation outcomes (publications, patent applications).

Results indicate significant contributions of spatial proximity (integration) at both the local and global level to outcome measures of both publications and patent applications.

Spatial proximity as measured by convex space analysis generally provided stronger contributions than the measure based on axial analysis. Visibility analysis did not provide strong explanatory power.

No significant contributions were found for spatial inescapability (choice).

SOFTWARE COMPANY

At the local (workgroup) level, the more one is located in close proximity to other work colleagues, the more likely s/he will publish. We have significant results for convex integration ($r= 1.83$, $p<.05$).

At the global level, the more an individual is located in close global proximity to others in the organization, the less likely they will publish. We have significant results for convex integration ($r= -5.32$, $p<.05$) and axial integration ($r=$

-2.08, $p<.05$).

There is a significant but weak relationship with visibility (calculated for the local floor area). To the extent that one is more visible to colleagues on the floor, s/he is less likely to publish (visibility integration, $r= -.57$, $p<.01$).

For this organization, we also find contributions of our syntax measures to explaining patent applications. At the local (workgroup) level, the more one is located in close proximity to other work colleagues, the more patent applications s/he will likely submit. We have significant results for convex integration ($r= 3.21$, $p<.01$).

At the global level, the more an individual is located in close global proximity to others in the organization, the fewer patent applications they will likely submit. We have significant results for convex integration ($r= -3.39$, $p<.10$) and axial integration ($r= -3.54$, $p<.05$).

LIFE SCIENCES INSTITUTE

For this organization, the only spatial predictor of the likelihood of publication is at the local level; the relationship is significant but weak. At the local (workgroup) level, the more one is located in close proximity to other work colleagues, the less likely s/he will publish. We have significant results for axial integration ($r= -.86$, $p<.05$).

The only spatial predictor of patent applications is at the global level. The more an individual is located in close global proximity to others in the organization, the fewer patent applications they will likely submit. We have significant results for convex integration ($r= -9.95$, $p<.10$).

There is a significant but weak relationship with visibility (calculated for the local floor area). To the extent that one is more visible to colleagues on the floor, s/he is less likely to submit patent applications (visibility integration, $r= -.72$, $p<.10$).

In sum, the literature suggests that there appear to be few substitutes for face-to-face interactions in knowledge intensive work. As physical distance increases, the likelihood of collaboration decreases. Olson et al (2002) showed that radical collocation doubled the productivity of software engineers by increasing the team's ability to monitor and learn from one another's work. However, for these two particular organizations differences in their focus, scientific orientation and mission appear to support very different results.

For the Software Company, results support the importance of close spatial proximity (local) for both publications and patent applications. The results are tentative for the Life Sciences Institute, but local *proximity* seems to work against publication. For both of these organizations, people whose physical locations put them in close spatial proximity (globally) with colleagues across the organization were not at an advantage for either publication or patent applications. Thus at the organizational scale, we did not see spatial proximity fostering the ability to mobilize individuals across the larger organization, an ingredient we hypothesized as integral to bringing new ideas to fruition.

CONCLUSIONS

Our preliminary findings demonstrate how physical space (proximity and inescapability) influence the rates at which scientists and engineers working in different research-intensive organizations innovate. Differences between types of innovation (patents and publications) and variation in the focus, scientific orientation and mission of the organizational settings allow us to examine how physical space effects on innovation are shaped by broader institutional contexts. Thus, we suggest that innovation is a process that occurs at the intersection of social and physical space and that the relationships between salutary network positions and beneficial locales themselves derive from institutional contexts that shape the priorities, opportunities, goals and practices of discovery.

REFERENCES

Allen, T. 1977. *Managing the flow of technology*. MIT Press: Cambridge, MA.

Batty, M. 2001. Exploring isovist fields: Space and shape in architectural and urban morphology. *Environment and Planning (B): Planning and Design*, 28, 123-150.

Benedikt, M.L. 1979. To take hold of space: Isovists and isovist fields. *Environment and Planning (B): Planning and Design*, 6, 47-65.

Hillier, B. and Hanson, J. 1984. *The Social Logic of Space*. Cambridge University Press: Cambridge.

Hillier, B. & Penn, A. 1991. Visible colleges: Structure and randomness in the place of discovery. *Science in Context*. 4(1), 23-49.

Olson, G.M. and Olson, J.S. 2000. Distance matters. *Human Computer Interaction*. 15, 139-178.

Olson, J .S., Teasley, S., Covi, L. and Olson, G.M. 2002. The (currently) unique value of collocated work. In S. Kiesler and P. Hinds (Eds.) *Geographically Distributed Work*. Academic Press: Cambridge, MA.

Peatross, D. and Peponis, J. 1995. Space education and socialization. *Journal of Architectural and Planning Research*, 12(4), Winter, 366-385.

Peponis, J. 1985. The spatial culture of factories. *Human Relation*, 38 April, 357-390.

Peponis, J. and Wineman, J. 2002. Spatial structure of environment and behavior. In Bechtel, R. and Churchman, A. (Eds.) *Handbook of Environmental Psychology*. John Wiley: New York, 271-291.

Turner, A., Doxa, M., O'Sullivan, D. and Penn, A. 2001. From isovists to visibility graphs: A methodology for the analysis of architectural space. *Environment and Planning (B): Planning and Design*. 28, 103-121.