Chapter IV

Space Syntax

1 Introduction

Space Syntax is an important component of this dissertation because it deals with topologically derived configuration and has techniques that allow the environment to be considered as independent variables. Also, it was used in previous studies on wayfinding that produced encouraging results. Those studies form the precedent of this dissertation and are discussed at the end of this chapter.

Space Syntax, or simply Syntax is a research program that was developed by a team led by Professor Bill Hillier in the unit of Architectural Studies in University College London (Hillier, 1996; Hillier, 1984). Since then, it has grown into an independent research area with an increasing international community.

Primarily, Syntax is a method of investigating spatial complexes in an attempt to identify its particular structure that resides at the level of the entire configuration. The method is based upon the theory that the form-function relation in buildings and cities passes through the structural properties of its configuration (Hillier, 1998).

Space Syntax is useful in describing and analyzing patterns of architectural space, at both the building and the urban level. Such descriptions of spatial configuration then serve as independent variables in various kinds of architectural research. Space Syntax is concerned with various spatial problems and some of the
questions that it seeks to address are: how can we measure the configurational properties of spatial systems? What is the role of configuration in movement, co-presence and higher order social phenomena? (and) What is the nature of the relationship between social organization and spatial configuration?

Any good theory of architecture should have descriptive and evaluative components and preferably be applicable for various purposes. Likewise, Space Syntax is based on a rigorous technique of describing the configuration that is based on topological relationships rather than on metric distances. In many cases, it has been used to inquire into social formations (Peponis 1985, Hanson and Hillier 1982 & 1987, Peatross & Peponis 1995, Hillier 1989 & 1995). However, consistent empirical studies have also been focussed on natural movement in urban areas (Hillier, Penn, Hanson, Grajewski and Xu 1993; Peponis, Ross & Rashid 1997), social settings of housing developments (Hillier, Burdett, Peponis & Penn 1987, Hillier, Hanson & Graham 1987), understanding urban crime and pollution (Hillier 1988), and the interaction patterns and productivity in various kinds of buildings (Choi, 1999; Penn, Desyllas & Vaughan 1999, Peponis & Heden 1982).

Recently however, practicing architects have posed a different kind of question. In a e-mail discussion group, Tom Dine wrote, “I wonder how Space syntax can be used as a way of describing the way spaces are experienced? ... What can Space Syntax tell us about what places ‘seem like’? “ In this regard, Syntax theorists have tentatively argued that intelligible layout, a property discussed in Space Syntax literature, contributes to an intuitive understanding of configuration (Hillier, 1996, pp.40). They further suggest that the diachronic nature of architectural experience, as understood through an environmental unit also proposed by Space Syntax called axial lines, may be picked up by the peripatetic observer (Hillier, 1996, pp.215). A
measurable property of these lines, called integration, is a useful measure for studying this. Although they do not probe the more complex processes of the human mind, they do however, imply that this understanding is ‘non-discursive’ - i.e. it can be understood but not described (Hillier, 1996, pp. 38, Hillier 1998, pp. 39).

In contrast, the pioneering work of Kevin Lynch demonstrated long ago that an understanding of the environment can be verbalized, especially if put in the context of travelling from one point to another (Lynch, 1960). Later research in environmental cognition has further shown that other techniques too may be used to study environmental understanding that includes cognition of configuration. This opens up the possibility of incorporating axial lines and other Space Syntax units in environmental cognition research. In fact, the comprehension of axial lines may not be non-discursive after all.

In both the fields of Environmental Cognition and Environment and Behavior, the physical environment, specifically its spatial arrangement, has been considered an integral part of its focus. Nevertheless there have not been sufficient tools to allow it to be considered as a predictor variable. Environmental cognition involves the interaction of human behavior—both internal cognitive processes such as perception, memory and reasoning and more molar behaviors such as wayfinding and route choice—with the ‘real world’ that has specific form and content. However Environmental Cognition researchers have traditionally focused much more on behavior and memory recall, rather than on environmental form. Since the diachronic sequence of experiences builds up the cognitive map, a key argument that has developed in this research is that relational characteristics of environments are important in environmental understanding. This has been discussed in previous sections. In addition, Environment & Behavior (E&B) researchers have long noted the
importance of spatial configuration for predicting wayfinding, social interaction and other behaviors, but perhaps they too had few methodological and conceptual tools for incorporating spatial configuration into empirical research.

For both of these research areas, the techniques of Space Syntax can be important. It allows rigorous analysis of buildings and settlements that is both theoretical and mathematical. Because the fundamental assumptions underlying Space Syntax are based on human sensibilities, it would appear that Syntax could be strongly linked with E&B and Environmental Cognition research. Unfortunately, it is not a tool that is widely used in these fields. On the other hand, very few Syntax researchers actually made cognitive claims. Among them Haq (1999a) has suggested the possibility of Space Syntax being a predictor of environmental cognition. Some researchers have begun to demonstrate that Syntax variables correlate with human spatial preferences (Peponis et al. 1990, Willham 1992 and Haq 1999a). Overwhelmingly research has confirmed that certain spaces as defined by Space Syntax can be expected to contain more human movement (Hillier 1987; Peponis, Hadjinikolaou, Livieratos and Fatouros 1989). Whether Syntax variables correspond to cognitive representations has yet to be explored. All in all, Space Syntax does seem to be a useful theory and methodology for understanding the role of environmental form from the point of view of topological relations in the study of environmental cognition and human wayfinding behavior.

2 Assumptions and Techniques of Space Syntax

Primarily Space Syntax is a theory about understanding architecture and urban areas from the point of view of their configuration. Two properties of
configuration are taken to be crucial. The first is that depending on one's position, a complex seems different. The second property is that small changes in any part of the spatial system will affect the structural properties of the whole (Hillier 1998). “Configuration refers to the way in which spaces are related to one another, not only pair-wise but also with respect to the overall pattern that they constitute. In other words, configuration is about the overall pattern that emerges from pair-wise connections rather than elements or single connections taken by themselves” (Peponis, Zimring and Choi, 1990). Configuration of spatial layouts is described in terms of the pattern of connections between defined ‘units’ of spaces. It does not deal with metric distances, but with topological values. One importance of this theory lies in the fact that it gives an objective measure to each ‘unit’ of space as it relates to others in a configurational system.

One assumption of Syntax researchers, that is perhaps at odds with these psychologists, is that, while configuration or the way spaces are laid out, is important, it is also something non-discursive; people cannot explain it, but they all understand it (Hillier, 1996, 1998). For example, in the image shown in figure 4.1, it is argued that despite formation by different shaped elements, the unity of configuration in each case may be understood by everyone fairly equally. Hillier then extends the argument about non-discursivity of configuration to its intuitive nature. He says:

“Configuration seems ... to be what the human mind is good at intuitively, but bad at analytically. We easily recognize configuration without conscious thought, and just as easily use configuration in everyday life without thinking of them, and we do not know what it is we recognize and we are not conscious of what it is we use and how we use it.” (Hillier, 1996, pp. 40).
This argument is then extended to space with the claim that since configuration is non-discursive but intuitively grasped, a sense of it may be attained by walking through spatial elements. This link to the understanding of configuration in real settings is perhaps not well substantiated by empirical work from the Space Syntax community.

Understanding of configuration in reality is a diachronic experience. It is built up from a series of sequential experiences that are gained through movement. Since this research is partially based on Space Syntax with respect to human understanding and behavior, one aim shall be confirmation of the claim that people do indeed understand configuration by walking through layouts. If configuration is considered important, then it follows that even if shapes, sizes and other properties of constituent element spaces remain the same, configurational experience can be quite different. Conversely, configurational experience can be the same even when moving through various kinds of unit spaces. Of course, both unit spaces and their connections influence real experience.

The theory of Space Syntax offers a method of quantifying the various levels of topological relationships within a layout. It also proposes a method of choosing Spatial units that are based on visual stability in a one and two dimension horizontal plane. These unit spaces will be discussed next as a prelude to the discussion of their topological relationships.

2.a **Spatial Units**

So far, in this discussion, the terms ‘space’ or ‘unit space’ was used. Theoretically of course, any kind of space can be subject to Syntax analysis. However,
it is extremely important to look at Space Syntax spatial units, because it is on these
that the entire body of the theory rests. Syntax theory proposes two conventional
ways of breaking up a configuration into its constituent spaces: convex spaces and
axial lines.

Convex spaces are two-dimensional extensions and comprise of the fewest
and fattest spaces that can cover the entire layout. They are those spaces within
which all points are directly visible from all other points within the space (see figure
4.2). They are the largest units that can be fully perceived at one time within the
layout; they can therefore be taken to represent the local constituents of it. Convex
spaces are the most elementary units of analysis.

Axial lines deal with linear extension and are represented by an axial map
(see figure 4.3). This comprises the least number of straight lines that must be drawn
in order to cover all the available connections from one convex space to the other.
Axial lines represent the longest views across spaces whose full area may not be
visible. In this way, the axial map captures the sense of connections that a person
gets while moving about a building and so recalls the global constituents of a layout.

2.b Quantification

Space Syntax theory quantifies the way in which an axial line is connected
to another or to all the other lines. A connection between two axial lines is said to be
shallow or deep when a few or many intervening lines have to be traversed when
going from one to the other. A space is said to be integrated when all the other
spaces of the building are relatively shallow from it. In other words, it is the function
of the mean number of axial lines and connections that need to be taken from one
space to all other spaces in the system. Thus, from a space with a high integration value, fewer changes in direction are necessary in order to move from that space to all other spaces in the system. In this way, integration value measures the relative position of any space or axial line with respect to the overall building configuration.

It should be pointed out that in the concept of integration the idea of depth and not metric distance is used to define a space in relation to all other spaces in the system. Hence it is both topological and global.

The most important concept here is that of depth. In figure 4.4, the four layouts may look similar in plan, but their configurational relationships make each of them unique. This is a factor of how they are connected, both to adjacent ones and to all the other spaces. These are topological relations. A space may be said to be directly related to its adjacent one, or be separated by various degrees of ‘depth’, depending on how many intermediate spaces one needs to pass through, to go from one to another.

Again, within one configuration, each unit space can have different values. The configuration seen in figure 4.3 may appear deep from the outside (shown with a x), but from P this would seem shallow. These are shown in graph form, called Justified Graphs, discussed later. So a spatial system can appear to be different depending on where one is located. Extending this kind of analysis, if every space was considered, then a mean depth value can be developed for every one of them. The space that will have the least depth is called the most integrated and the one that has the most depth is called the most segregated. In other words, integrated spaces are, on an average, closer to all other spaces in a system. On the other hand, a person in any segregated area will be distant, on an average, from all other spaces in the configuration.
The measure of integration, or its opposite, segregation, is expressed by Real Relative Asymmetry or RRA value. This value is obtained by the analysis of a graph representing the number of changes in direction between one axial line or space to all other lines or spaces. It is based on the number and depth of spaces that must be traversed from one space to all other spaces in the configuration. Mathematically, Integration is measured by the inverse of relative asymmetry (RA). This is given by the equation \( RA = \frac{2(MD-1)}{(k-2)} \), where MD is the mean depth and k is the number of spaces in the system. Since the number of spaces is a consideration for RA, it follows that size can have an effect on the level of RA values in real systems. So, to compare between different sized systems, the modified unit Real Relative Asymmetry (RRA) is used. This is comparison of RA values with those for a theoretical ‘root’ or a diamond shaped pattern. It is given by the equation \( RRA = \frac{RA}{D_k} \), where \( D_k \) is the D-value of the system with the same number of spaces as the real system. Therefore consideration of RRA values gives the opportunity to compare between environments (Hillier, 1984).

An intermediate topological unit called integration of depth 3 is also used sometimes. The calculation of this value is similar to calculating integration except that it counts all other connected spaces up to a depth of three only.

Connectivity is another important Space Syntax measure. This refers to the number of other axial lines or spaces that are directly connected to any one line or

\[ \text{1 However, Teklenburg, Timmermans and van Wagenberg (1993) have argued that Integration is not dependent on system size. They have reported a different measure of integration that is independent of the number of included spaces.} \]
space. Since this information is directly observable from a space, it is considered a local measure.

A higher order of measure in Syntax is intelligibility. This value refers not to individual environmental units, but to the entire system configuration. A system’s ‘intelligibility’ is measured by the correlation between global and local variables, most commonly between global integration and local connectivity. This is expressed by Pearson’s Product Moment Coefficient (r). Intelligibility values can be used to quickly compare between different environments. Intuitively it means that in a layout of high intelligibility, information about local connectivity allows a person moving through the system to comprehend the overall structure of the configuration (Hillier, Burdett, Peponis, & Penn, 1987). The stronger a correlation, the more global configuration of a space may be inferred from its directly observable local connections.

Space Syntax theorists accept the fact that space layout is also produced by the organizational rules and practices. However, a central argument of this theory is that configuration by itself can be used as a predictor of space use. Thus they argue that configurational properties of a layout can create probabilities of encountering others. In previous studies, this has been found to be biased towards more integrated spaces, i.e. one is more likely to encounter people in more integrated spaces (Hillier et al., 1987; Peponis, Hadjinikolaou, Livieratos, & Fatouros, 1989). However it is not clearly known if this has a cognitive component. If it does, i.e. if users can intuitively or directly recognize integration, then we can expect to find more wayfinding people in more integrated areas. This is one component of this study.
3 Justified Maps and Mean Depths

Integration value of any space is derived from consideration of its depth from all points within the configurational system. Sometimes it is meaningful to look at particular points to determine how it relates to the rest. For this research purpose, the entry points of the settings were considered important.

The analysis tool used is called ‘justified map’ or the ‘justified permeability map’ (Hillier & Hanson 1984). Here, the entry space is put at the base of a graph. Then all spaces that are directly accessible from it i.e. of depth 1, are arranged horizontally above it, all spaces of depth 2 arranged horizontally above the first and so on until all the spaces in the system is accounted for. All the connecting lines are then drawn in to show their relationships to each another. By definition, lines can only connect within a layer or one layer adjacent to it. In figure 4.4 the ‘justified permeability maps’ of corresponding layouts from their entrances are shown. These give a visual representation of ‘depth’ from a space, i.e. how shallow or deep it is in connection to all the other spaces in the system.

Depth can also be mathematically expressed. This is denoted by mean depth and is calculated by

“... assigning a depth value to each space according to how many spaces it is away from the original space, summing those values and dividing by the number of spaces in the system less one (the original space)” (Hillier and Hanson, 1984, pp. 108).

The mean depth in figure 4.5 is shown as 2.00 and 3.75 respectively from P and from the outside, which is marked with an X.
4 SYNTAX TOOLS

The different Syntax values of axial lines can be measured by a computer program called Spatialist or AxmanPPC. Assigned values can be displayed both as a table and as a color-coded axial map. In this map the lines are displayed in a range from deep blue to deep red; blue signifying segregation and red signifying integration. Thus an objective measurement can be given to each unit of space within a layout. Consideration of the top 5% of the integrated areas gives the integration core. Also, the average integration value can be used to compare between different configurations.

Unfortunately, tools for measuring syntactic values for unit spaces (corridor intersections, for example) were not available from the Syntax group. Therefore, these were computed separately using a commercial computer program. Of course, this did not produce a visual output; that had to be manually created (see figures 6.26, 6.27 and 6.28).

5 PREVIOUS USE OF SPACE SYNTAX IN WAYFINDING AND COGNITION RESEARCH

A rigorous attempt to examine the relationship between objective measures of the components of physical environment as determined by Syntax analysis and observational measures of wayfinding performance was undertaken by Peponis, Zimring, & Choi (1990). This study is important because of a number of aspects. First, in the cognitive realm, the authors presented a theoretical distinction and a relationship between specific wayfinding tasks and an overall understanding of the environment that was termed as ‘general intelligibility’. Second, in the aspect of
methodology, they introduced the twin ideas of open exploration and directed search and developed the methods of quantifying them.

The authors started with the hypothesis that “navigation through any complex architectural environment cannot depend wholly upon direct visual perception... but requires a more abstract understanding of the way in which local parts are interrelated into a whole pattern” (Peponis et al., 1990, pp. 559). To deal with this issue, they took configuration as one measure of the physical environment. In contrast to its meaning as ‘survey knowledge’, configuration was considered as a spatial concept whose description and quantification was given by the theory of Space Syntax. Therefore they dealt with topological relationships. The authors considered paths and nodes as the spatial units. Paths were the axial lines as defined by Space Syntax and nodes were essentially the decision points in a path and were operationalized as the intersections of two syntax axial lines.

Wayfinding behavior was quantified by tracking 15 students doing two tasks: exploring the experimental setting that was a hospital building (open exploration) and doing specific wayfinding tasks within it (directed search). These tasks were quantified by ‘search patterns’ and ‘routes’. Open exploration behavior was measured by the number of ‘visits’ each unit of space received by the research subjects. Directed search was measured by ‘Redundant Node Use’. This was use of those nodes that was not necessary i.e. not in the shortest route between the origin and the destination. In all the scenarios considered by the researchers, use of a space was consistently found to be highly correlated with its integration value. In open exploration, correlation of line use and integration value from the public corridor system was .76, and it was .62 when integration value was considered from all the rooms in the floor. Value of the nodes derived from the public system correlated with use at .78 and it
was .61 when the values were determined from the entire floor. In directed search, the correlation between redundant node use and integration values from the public system was .75 and it was .65 when the whole floor was taken into account.

This study concluded that some users were “biased towards some spaces more than towards others, in proportion to their degree of integration” and “when in doubt, go to an integrated space” (Peponis et al., 1990, pp. 570 & 573). This led the authors to suggest that an abstract set of global relationships within the environment may influence the cognitive terms of reference of the wayfinder.

Later, for his Masters thesis, Willham (1992) took up the study of Peponis et al. (1990) and sought to supplement it by being more critical in his description of spaces. He re-analyzed the original data to investigate if any other measures influenced the wayfinding process and also duplicated the experiment using the same building and the same methodology, but having 12 older people as the subjects. He focused specifically on nodes i.e. the intersections of the corridors. These were described from 3 ‘realms’ of configurational scale: local, relational and global. The local realm consisted of the immediate visual field, the global realm included the entire layout and the relational realm was one that he hypothesized as mediating between local and global realms. His local descriptors were local node space, degree and landmarks (art, doors, objects, signs, volume and windows) and relational descriptors were relational node space and decision point degree (DP degree). The global descriptors were derived from Space Syntax methodology and were given by integration values. Willham’s research results were similar to the previous study and he advanced it with the conclusion that as new comers people rely on the local measure degree for wayfinding, but as learning occurs relational and global measures become more important.
A similar procedure was taken up by Haq (1999a, 1999b) in his study of wayfinding in a large urban hospital. He too found a good relationship between wayfinding use of axial lines and nodes and their Syntax integration values.

The use of Space Syntax in these studies allowed the authors not only to quantify each unit of the environment, but also to do so from purely topological considerations. Willham’s categorization of three levels of environmental measure is also useful. Their findings of significant correlations between objective properties of the environment and willful behavior of the research subjects suggest a cognitive aspect. This was expanded by Haq (1999a), who found that with increasing environmental experience people rely more on global properties and less on local ones. Since wayfinding was described as an activity that is mediated by cognition, Haq interpreted his findings as an indication that Integration does have a cognitive component. This thesis aims to explore such a proposition.
Figure 4.1  Configuration is independent of constituent units.

Figure 4.2  Convex Spaces. All points are visible from all other points in each space.
Figure 4.3  Deconstruction of a layout into convex spaces and axial lines
Figure 4.4  Depth can vary even if shapes do not.

Figure 4.5  Mean depth is different from different spaces in a configuration.