Complex Architectural Settings:

An Investigation of Spatial and Cognitive Variables Through Wayfinding Behavior

A Thesis presented to

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by

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Please insert the Approval form here

To My Family:
Koly, Hridoy and Hridee

Acknowledgements

A Director of Facilities Management Division of a large hospital inadvertently planted the seed of this dissertation. He was frustrated with recurring wayfinding problems and wondered if GeorgiaTech College of Architecture would arrange a student project. I had just finished my course work and it presented an opportunity to bridge my two interests: environment cognition and description of environments from human sensibilities. This dissertation is the culmination of such a beginning.

In this endeavor, my constant motivator and challenger was Dr. Craig Zimring – my dissertation advisor. I am indebted not only for his guidance in this thesis, but also for his larger role of a mentor, friend and supporter throughout my stay in Atlanta.

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Summary

A considerable body of research, as well as common sense, suggests that people have difficulty finding their way and describing more complex settings. However, the spatial definition of 'complexity' has not always been clear. More recently, several studies of small buildings have found that 'space syntax' measures of environmental form are useful in understanding the relationships of two kinds of patterns: environmental form and the search patterns people use when they explore a building or look for a specific location. This study replicates the research in three large buildings and explores *environmental understanding* as a third pattern that can be rigorously described and linked to environmental form and patterns of search. In addition, the study employs Space Syntax and other formal descriptive tools to comprehend the *development* of environmental knowledge as people explore a setting.

One hundred twenty-eight volunteers performed several wayfinding tasks in three large urban hospitals: they performed 'open searches' where they attempted to become familiar with the hospital, 'directed searches' where they sought specific locations and various cognitive mapping tasks such as pointing to locations that were not within sight, estimating distances between known locations and sketching the hospital's main corridors and routes. Their movements were transcribed into 'search patterns.' Environmental variables were categorized into local, relational and global variables.

Correlational analysis revealed that Space Syntax measures of connectivity and integration were good predictors of the use of spaces during both open and directed search. However, when people were initially exploring the setting, they relied more on local qualities, such as how many additional nodal decision points could be seen from a given node. As they got to know the setting better, their wayfinding behavior was better predicted by global qualities such as the Space Syntax integration. This suggests that people rapidly move from a local to a more global topological understanding as they learn a setting.

Additionally, it was found that the possibility of gaining subsequent information from any space, labeled 'expectation of exploration' was an important predictor of use. Furthermore, overall search patterns are influenced by the characteristics of the starting point: if an entry is shallower with respect to the rest of the building people will tend to have a quicker understanding of the layout.

Chapter I

Introduction

This thesis is concerned with human wayfinding, environmental cognition and the complex designed environment. Specifically it focuses on those properties of the environmental that are expected to have an influence in both wayfinding and environmental cognition.

It is well known that despite individual differences, some settings are easy to understand and wayfind in, while others are difficult. In this regard an important aim of this study is to be more precise in recording these environmental differences. On the other hand, in environmental cognition research, one important area is the study of cognitive representations, frequently known as cognitive maps. This thesis explores the questions: is there a relationship between cognitive representations and environmental properties? Is there any correspondence between cognitive representations and wayfinding behavior of humans? And, what is the micro-genetic environmental learning process? To fulfill these aims this dissertation is based on the findings of two previous studies that demonstrated a correlation between search patterns of wayfinding subjects and topological properties of the environment as described by Space Syntax (Peponis, Zimring and Choi, 1990, Willham, 1992). The results of those studies are tested here and the findings expanded through the inclusion of environmental cognition.

Wayfinding is the process of determining and following a path or a route from an origin to a destination within an environment. It is observable behavior and can be quantified. On the other hand, environment cognition is an internalized understanding of any environment. Therefore it can only be demonstrated through secondary means.

From a wayfinding point of view, applied researchers such as Carpman and Grant (1993) have suggested several important environmental elements: signage, maps, information desks, architectural cues and proximity of functions according to visitor needs. Other researchers have looked at the role of specific physical elements such as color (Evans, 1980), landmarks (Kohen and Schuepfer, 1980, Cornell, Heth and Broda, 1989), connections (Best, 1970) and maps (Levine, Marchon and Hanley, 1984) that affect wayfinding. Still others, like Weisman (1981) and O'Neill (1991) have looked at the overall complexity of the layout of spaces as a factor in wayfinding. Other researchers such as Peponis, Zimring and Choi (1990), Willham (1992) and Haq (1999a, 1999b) took up the idea of relational qualities as a way of measuring environmental complexity. These studies have brought attention to the various properties of the environment and the techniques of their measurement.

The position of this thesis is that learning about buildings takes place through movement within it. This is simply because in almost all instances there are no possibilities of getting an overview of the total environment from an elevated position (although some settings provide 3-D drawings and maps). Approaching the issue of environmental learning from the point of view of movement within it, this study proposes a rethinking of environmental units. It elaborates on the concept of relational properties of the environment. This is considered to be an important aspect that has consequences on both understanding the environment and wayfinding within it.

Environmental units are defined from the perspective of a moving observer and so visual lines and changes of those lines, also called nodes, become the categories for sub division of the environment. Furthermore, since movement produces a diachronic experience of an environment, it is argued that the most influential environmental properties are those that express the relationships between the environmental units (Gibson 1979, Heft 1983). In this regard, topological and visual relations are taken as significant.

The theory and methods of Space Syntax had developed quasi-independently of both wayfinding and environmental cognition research. However, it is often described from the viewpoint of human sensibilities. Also, wayfinding and direction giving are popular examples that are widely used to emphasize the importance of spatial relationships: topological rather than metric ones (Hamer, 1999). Such relationships of topological nature are explored by Space Syntax. This theory describes the deconstruction of large environments into visually stable unit areas and uninterrupted visibility lines. Furthermore, it defines a technique by which topological relationships between those units can be calculated. It also provides a computer program that can be used to do all these analysis. Since the theories of Space Syntax are based on human sensibilities, it becomes a promising tool in research that considers the user.

This dissertation uses both Space Syntax unit spaces and some other kinds that were theoretically developed for this purpose. In some cases, the Syntax methods of calculating topological values, both from adjacent spaces and from all spaces in the system, were used to quantify them.

Three complicated urban hospital buildings in a major US city were the settings for this research. Their layouts were deconstructed into basic units from the point of view of human visual abilities and Space Syntax definitions. These unit spaces were then quantified according to their visual and topological relationships to other spaces. In this manner relational qualities of the environment were calculated that were then taken as predictor variables for wayfinding and environmental cognition.

The experiment used 128 research subjects that carried out a variety of wayfinding and cognitive tasks in the three settings. These were tested against the various properties of the environment. The experiment concluded that relational variables do feature strongly in both environmental cognition and in wayfinding. Furthermore, possibilities of gaining further information predicted use of spaces and one property of the entry point, called mean depth, had some influence on how a building was explored. In this manner, the relational properties of the environment become important and provide a new way of conducting research in the areas of environmental cognition and wayfinding.

The following chapters describe the work of this dissertation in detail. Chapters II and III discuss wayfinding and environmental cognition and make a special attempt to ascertain the identity and properties of the environment that many researchers have thought to be significant. It was interesting to note that although many researchers in the 1980’s identified the need for considering relational variables, very few could actually incorporate them in their work. This was probably because of insufficient techniques available to adequately deal with environmental relationships.

Chapter IV discusses Space Syntax. It argues how the configurational approach that is the underlying theme of this theory can be successfully used to investigate the inter-relationships of the humans and their environment – in both their wayfinding and cognitive mapping abilities.

Chapter V consolidates the literature review to identify a comprehensive research agenda. In this chapter, the research hypothesis is also spelled out.

Chapter VI describes the research that was undertaken. It documents the settings in details and also explains the various units that were considered. Also, all the experimental procedures are explained in this chapter.

Chapter VII discusses the analysis of the three kinds of data: environmental, behavioral and cognitive. It also describes the statistical techniques used and the results obtained.

Finally, the concluding chapter brings all the three components together and informs the ideas that were verified. Of course, the drawbacks of this study and suggestions for future research are also mentioned here.

Section 1

Chapter II

Wayfinding

> *"As an amusement park employee, I am often asked for directions to specific attractions. Although detailed maps are given to each customer who enters the park, some people need more help. One exasperated guest approached me after she'd gotten lost using the map. "How come* these maps don't have an arrow telling you where you are?" she asked.

J.B. Haight in Reader's Digest. June, 1997, pp. 55

1 INTRODUCTION

This chapter will be devoted to the literature search on wayfinding. It will be focused on those studies that have considered the environment as influencing the wayfinding process. Specifically, this chapter aims to bring out the gradual shift from discrete properties of environmental units to relational ones. In this manner, the assumptions of this dissertation will be validated.

> "Wayfinding is the process of determining and following a path or route between an origin and a destination. It is a purposive, directed, and motivated activity. It may be observed as a trace of sensorimotor actions through an environment. The trace is called a route. The route results from implementing a travel plan, which is an *a priori* activity that defines *the sequence of segments and turn angles that comprise the path* to be followed. The travel plan encapsulates the chosen strategy for path selection. The legibility of a route is the ease with which it can be known, or

> (in the environmental sense) the ease with which the relevant cues or features needed to guide movement decisions can be organized into a coherent pattern. Legibility influences the rate at which an environment can be learned" (Golledge, 1999, pp. 06).

The term 'wayfinding' may be familiar to most readers, but it is not a word that is accepted in standard English. Encyclopedia Brittanica (on line) does not list it, nor does the Oxford English dictionary[1]. Nevertheless, it is well understood; especially by people who have had the unpleasant experience of navigating in less familiar or unfamiliar indoor and outdoor environments. Wayfinding is also an important research field in Environmental Cognition, Environment and Behavior and Geography. Recently it has become prominent with publications such as by Bovy and Eliahu (1990), Golledge and Stimson (1997) and Golledge (1999).

Arthur and Passini (1992) credits Kevin Lynch as the originator of the term 'way-finding'. Lynch had recognized that a study of 'legibility' in cities must consider the act of 'way-finding' because in such an act there "… is a consistent use and organization of definite sensory cues from the external environment" (Lynch, 1960, pp. 03).

Kevin Lynch did not define wayfinding. Strangely enough, neither did many researchers following Lynch who have either worked in this area, or have used wayfinding as a research tool to understand other issues. However, the term 'wayfinding' is commonly used to refer to the act of finding the path or paths leading

[1] Neither the 20 volume Oxford English Dictionary (1989), nor the New Shorter Oxford Dictionary (1993) list this term.

to ones destination and finding that destination itself. It is a person’s ability to navigate and find a particular point within an environment. Wayfinding “…is the… ability to learn and remember a route through the environment” (Blades, 1991, pp. 137). Furthermore, it is “purpose behavior, involves interactions between attributes of the traveler and attributes of the environment” (Allen, 1999, pp. 47).

According to Carpman and Grant, “wayfinding refers to what people see, what they think about, and what they do to find their way from one place to another. … Wayfinding involves five deceptively simple factors: knowing where you are, knowing your destination, knowing and following the best route to your destination, recognizing your destination upon arrival, and finding your way back” (Carpman & Grant, 1993, pp. 66). Furthermore, in the web page of her firm, Carpman Grant and Associates, she adds, “when people cannot do any or all of these things, outside or inside complex facilities, we say they are disoriented.”

Wayfinding, or the more general term human movement, can be of many categories and its classification varies according to the criteria chosen. For example, if differentiated by their *guiding process*, then it is of two kinds: navigation and wayfinding (Golledge, 1999, pp. 6 and 7). The former is used to guide humans travelling over undistinguished territory either water or air. Navigation usually takes place over very large natural settings and may involve the use of distant elements as a source of direction, the stars for example. The sea or the desert are some settings where navigation is required. On the other hand, wayfinding is defined as the process of selecting paths from a network or a configuration of paths. Typically wayfinding is carried out in comparatively smaller settings, but they are usually large enough for humans to need cognitive abilities to operate in them. Cities and complex buildings are some settings for wayfinding.

From the point of view of *purpose*, human movement may typically be of three kinds: travel to familiar destinations, exploratory travel and travel to novel destinations (Allen, 1999, pp. 51).

From the point of the *strategies* used, wayfinding is also of three kinds: the most basic kind where one simply follows a path to a destination, tracing a sequence of decision points without necessarily being able to conceptualize either the total trip or the entire environment, and maintaining geometric relations through an extra-ordinarily detailed cognitive map (Weisman, 1979). It should be noted that knowledge about the destination, or lack of it, is not featured in this model.

Again, from a different perspective, if *choices provided by the environment* is the criteria for classification, then wayfinding can hypothetically be of three kinds also: totally guided by the environment, the environment has some influence and the environment has no influence at all. If one is walking a mazelike path that has no branches at all, then s/he is entirely guided by the environment (see figure 2.1). S/he has no choice or decision in the travel. In this case there is no fear of getting lost, but in complicated layouts, a very slim chance of actually understanding it. On the other hand, if the environment is entirely undifferentiated, then it cannot have any effect on wayfinding (see figure 2.2). It will depend entirely on the person. This kind of movement can be compared to drawing on a white paper, where the strokes are determined by the thoughts of the artist only. In contrast, the former kind is comparable to ‘connecting the dots’ kind of children’s activity. In this case, the child has no control over the picture that is simply a factor of the position of the numbered dots. Real life wayfinding is of course somewhere in between the two extremes described above. In this case some movement decisions are guided by the individual and some by the environment.

This research aims to look closely at those *environmental properties* that are expected to have some influence on human wayfinding and cognitive mapping. In this process the literature of both wayfinding and cognitive mapping is reviewed to find out what environmental properties have been considered important by various researchers.

The next section will discuss various research on wayfinding; especially those that has considered the different properties of the environment as forming essential parts of the wayfinding process. Although the discussion is organized according to important 'models' of wayfinding, the environmental components of each are discussed separately.

2 WAYFINDING RESEARCH

The study of wayfinding is the examination of "how humans navigate from an origin to a destination" (Devlin & Bernstein, 1997, pp. 99). Wayfinding involves two components: the actual environment 'out there' and the way it interacts with people. In conjunction, these two produce the action of wayfinding. Since wayfinding involves environmental understanding and a response to it, the 'act' of wayfinding, or behavior, which can be documented, becomes an important aspect for research. Traditionally scholars have looked at this 'act' and have used it for a theoretical understanding of wayfinding, developing strategies and techniques for efficient wayfinding and to research on a horde of related issues such as spatial decision making (Garling, Saisa, Book and Lindberg, 1995), spatial recognition (Arthur and Passini, 1992), spatial orientation, spatial distribution, travel planning, route selection, route learning, influence of related environmental properties and so on (see Golledge, 1999 for a detailed review). Simultaneously, wayfinding has also been important in other areas of research such as aging, environmental learning, urban design (Lynch, 1960), transportation (Burns, 1998), artificial intelligence, map learning, typography, cartography, etc.

Applied research aimed at improving wayfinding includes the suitability and design of wayfinding aids such as signs, maps, booths, information terminals etc. (Devlin and Bernstein, 1997), creation of efficient navigation tools (Carpman, 1993), designing layouts for 'wayfinding friendly' conditions (Peponis, Zimring and Choi, 1990), improving the route guidance systems in vehicles (Jackson, 1998) and so on.

Research in wayfinding can be broadly categorized into two kinds. On one hand, many scholars put forward the 'cognitive model' of wayfinding; also called the mediational model. This is where some kind of internal process is said to mediate between the environment and the wayfinding behavior. They claim that the sensory input from the environment is supplemented and enriched by knowledge that is already possessed by the perceiver. This is the position that this study takes.

On the other hand, a few researchers accept the theories of ecological perception as proposed by Gibson, (1979) and hypothesize that the environment directly acts upon wayfinding behavior, without cognitive mediation (Heft, 1983).

2.a Wayfinding as a Mediated Activity

In mediational studies of wayfinding certain human processes are expected to mediate between the environment and the behavior it produces. In most cases, human cognitive maps are thought to be that mediator.[2] Most wayfinding researchers take this position in their work but vary as to how they conceptualize wayfinding occurs and what environmental qualities and human abilities are important.

Wayfinding literature in this category either discusses theoretical models or documents empirical research. Gluck (1991) refers to them as competence and performance literature respectively. Competence literature sometimes extends the theoretical models of wayfinding into computational ones. On the other hand, performance literature contains empirical results on how people find their way.

2.a.1 Theoretical Models / Competence Literature

Competence literature includes theoretical proposals for various wayfinding models. Although it deals with human behavior, some scholars have actually developed them further to produce computational models that mimic human wayfinding and spatial learning. These models touch on both human abilities and environmental characteristics. Some important wayfinding models are briefly discussed below, followed by an introduction to some significant computational models.

2.a.1.1 Wayfinding models

2.a.1.1.1 Wayfinding as Spatial Problem Solving

[2] Since cognitive mapping is a very large and complex issue, a separate section is devoted to its discussion.

An important model of wayfinding was proposed by Passini in 1984. He developed it through three experiments utilizing 36 subjects done in five large urban complexes in downtown Montreal. In the experiment, he analyzed the decision protocols of the subjects that were collected by asking them to speak into a tape recorder that recorded their spatial decisions and the reasons behind them.

Passini's model is built around the core concept that wayfinding is a result of hierarchically structured spatial decision making. It takes into account the many interrelated issues that come to bear while a person is performing a wayfinding task. According to this model wayfinding is

> "... cognitive processes comprising three distinct abilities: a cognitive mapping or information generating ability that allows us to understand the world around us; a decision making ability that allows us to plan actions and to structure them into an overall plan; and a decision executing ability that transforms decisions into behavioral actions. Both decision making and decision execution are based on information generated by cognitive mapping" (Passini, 1984.).

From this point of view, the necessary units of wayfinding are environmental information, decisions and behavioral actions. Environmental information comes from three sources: sensory information, memory information and any combination of the previous two kinds. Passini cautions however, that access to information is influenced by personal and cultural characteristics. This information once obtained, has descriptive, locational and temporal components. For example, the descriptive part has, among others, content description, labels, taxonomy etc.; the locational information may be structured in a ego-centric or a relational manner, or be structured in reference to an abstract orientation system like the cardinal directions. Of course, the temporal component is also important because the information that comes from experience provides a sense of how long it took to accomplish a particular task and that, in turn, helps to decide how long a future task component will take. Together these environmental and cognitive components contribute towards dexterous decision making and hence efficient wayfinding.

In his model Passini puts the most emphasis on the human aspects by focussing on the spatial decision making process. He proposes that this is done from hierarchically structured decision plans or travel plans where the most general ones are at the top and those leading to spatial behavior are at the bottom (see figure 2.3). Executions of these travel plans lead to behavior.

Since a travel plans have to be carried out at a specific location, they obviously has environmental components. These include both cognitive and physical dimensions. Although Passini has presented an extensive description of the decision making process, he provided less identification of specific environmental properties that would be relevant to wayfinding. However, he picks up this issue in a subsequent book (Arthur and Passini, 1992) and stresses recognition of environmental features as an important component of wayfinding. He points out that only after recognition can a decision, such as turning left or right, can be carried out. From this point of view Passini discusses environmental elements and includes entrances, exits, circulation systems, and signage as the physical components of wayfinding. Additionally, he advocates logical zoning and an architectural expression of those to facilitate wayfinding. Unfortunately most of the environmental discussion takes the form of classification of the various elements with comments on suitability for wayfinding. A critical discussion on the environment is not initiated.

2.a.1.1.2 Wayfinding as Formation and Execution of Travel Plans

Although similar to Passini's, Garling, Book and Lindberg's (1984, 1986) model is built around the idea that wayfinding is formation and execution of travel plans (see table 2.4).

A travel plan is one element of a cognitive map. It specifies how to go from one place to a number of other places (Garling et al., 1984). It is conceived as a set of instructions specifying how to travel, information about the environment, and an ongoing acquisition of information. Travel plans are action plans that are formed through a process of several hierarchical stages of information processing. The information about the environment is accessed through direct observation, media (i.e. signs and maps) and the cognitive map itself. While being carried out, a travel plan is constantly being updated as new information is acquired. Garling says, "The travel plan could attune the traveler to features of the environment in a way analogous to the manner in which cognitive sets influence the perception of the environment" (Garling et al., 1984).

This model is more extensive because it distinguishes between the different capabilities of the wayfinder. For example, in both formation and execution of travel plans, some people, especially newcomers may rely more on media like signs & maps and on direct observation, while others may be more dependant on their acquired cognitive maps (Garling et al., 1986).

Most importantly, the environment is not ignored in this psychological, information-processing model of wayfinding. To be successful in finding one's way, information about certain environmental properties must be gained. The relevant environmental properties that were identified are function, attractiveness, identity and location (Garling et al., 1984). Later, Garling also proposed a system of classifying environments according to three physical setting variables that he theorized would affect the ease with which spatial orientation and wayfinding is accomplished. These variables are *degree of differentiation, degree of visual access* and *complexity of spatial layout* (Garling et al., 1986).

Degree of differentiation is the degree to which different parts of an environment look the same or different. Obviously, it will affect people's ability of recognizing places. Differentiation may be achieved by "varying size, form or architectural style, or by using different colors" (Garling et al., 1986, pp. 58). *Degree of visual access* in an environment refers to the extent to which different parts of the environment can be seen from other parts. This supports recognition, localization and orientation. *Complexity of spatial layout* is a property that Garling found difficult to define. It is related to environmental size and he mentions the number of destinations and routes, their intersection characteristics i.e. at right angles or not, etc.

Garling's model is distinguished from that of Passini's in two important ways. First, it differentiates between the environmental needs of newcomers and people with various degrees of environmental knowledge, and second he includes important descriptions of spatial variables. To Garling, the physical variables are an important aspect of wayfinding. However, this model only provides an indication of important properties. Differentiations, degree of access and complexity of layouts, as important environmental qualities, certainly make intuitive sense. But for research purposes, a way of rigorously defining them and measuring them is essential.

It is also important to recognize that these three variables only make sense when the entire environment is considered in totality and they become meaningless if each space is considered in isolation. For example, degree of differentiation or degree of visual access only matters when one space is understood *in comparison* to all the others. It loses meaning when a space is considered independently. This distinction is thought to be extremely important and to differentiate between these two kinds of environmental properties the following terms are introduced for the purpose of this thesis: *relational* and *discrete*[3]. Relational properties are those that take other spaces into consideration while discrete properties can be understood from the space itself. This will be discussed in detail in chapter VI.

At this point, one may compare Garling's relational variables with those put forward much earlier by Weisman in his doctoral dissertation regarding wayfinding (1979). Approaching the study of wayfinding from the evolutionary perspective of environmental knowing proposed by S. Kaplan (1976), Weisman identified four important spatial variables: *perceptual access, visual differentiation, configuration* and *'signs'*. Among them, the first three are very similar to Garling's proposals of *visual access, degree of differentiation and complexity of spatial layout* respectively (Garling et al., 1984).

[3] This differentiation is also emphasized by Hillier who uses the terms *local* and *nonlocal* properties (Hillier, 1999)

2.a.1.2 Computational Models

Most of the computational models of wayfinding are mainly concerned with human processes and aim to interpret them through artificial intelligence. Therefore it is interesting to see what aspects of the environment are considered important here.

Among the computational models of wayfinding, Kuipers (1978) proposal called TOUR was perhaps the earliest. This LISP program copes with incomplete knowledge of the environment and learns about it as more information is received. It incorporates three kinds of information: sensorimotor procedures or a set of sequential actions required to travel from one place to another, *topological relations* to describe the non-metric attributes of the environment such as containment, connectivity and order and *metric relations* to describe the measurable attributes such as distance and direction.

ELMER was another computerized wayfinding system. It was composed of three modules, MAP, PLANNER and EXECUTOR (McCalla and Schneider, 1979, 1980). The PLANNER would devise the plan to go from A to B using *route information* from MAP and then send it to the EXECUTOR. The EXECUTOR would modify the plan according to pragmatic everyday knowledge and carry it out, after which it would report back to MAP for updating, specifically with regards to the routes. Thus like humans, it was capable of learning from experience.

Leiser and Zilbershatz's (1989) TRAVELLER is a detailed model that simulates the learning of *networks.* This system starts with empty memory and tracks origin and destination nodes along with required actions in wayfinding. In this manner a dynamic *node-link network* is developed. When searching for destinations it looks for new routes in a forward breadth first search. All nodes accessible from the original node are scanned for a goal node. If found, then the route is complete, otherwise it scans in an increasing radius until it finds the destination. This knowledge is then translated as a sequence of production rules. Like humans, this system does not know ahead of time which nodes will be encountered in a journey, but learns from experience.

NAVIGATOR was another Artificial Intelligence (AI) model that uses both spatial information and non-spatial description of environmental objects (Gopal, Klatzky and Smith, 1995). It contains an object environment module and a cognitive module that collects a subjective representation of an environment. NAVIGATOR was based on psychological and developmental theories and attempted to incorporate both its modules with aspects of theorized human activities and abilities. For example, it can ‘imagine’ a scene from different positions, has a working memory and a long-term memory, and also incorporates multiple stages of processing, filtering, forgetting and other empirically validated aspects of human spatial cognition. Although it simplifies many aspects of cognitive structures, this is an important model because it serves to simulate the various interactions of the human processor in the production of movement.

In an attempt to take such computational models one step further and closer to human processes, Gross and Zimring (1990, 1992) and Zimring and Gross (1991) hypothesized that people bring into the wayfinding task a very large store of prior knowledge about typical layouts. They suggested that these could be incorporated into the AI models as a set of schemas. A database of such schemas could provide the important *expectations about layout* that informs explorations and route selections of wayfinders.

Computational models attempt to design intelligent systems that are capable of finding their own way. These models not only consider human abilities and environmental properties but also the interactions among them. In this process, some environmental properties attain greater significance.

In the models discussed in this section the following environmental features have been underscored: *topological relationships, metric relationships, route information* and *node-link networks.*

2.a.2 Performance Literature / Empirical Research

Before a discussion of important empirical findings in the performance literature, it must be pointed out that many researchers have had difficulty in incorporating the environment into their work. There could have been two reasons for this: 1. due to an emphasis on cognitive mapping, most researchers have considered environmental qualities from the point of view of their representation in cognitive maps and 2. there is a dearth of tools and methodologies that could be used to quantify the environment from the point of view of behavior in it. For instance, the pioneering work of Kevin Lynch (1960) distinguished *nodes, paths, districts, edges* and *landmarks* as being important for legibility of cities. He identified them from the study of sketch maps, interview transcripts and trip description of his experimental subjects in three US cities. Although his work is extremely influential and has been the base of many studies, his environmental units are vague. Take for example, the concept of landmarks. What a landmark is to one person may not be the same to another. Therefore objective definition becomes difficult. Also, as was shown in the previous section, relational variables were theorized as important but could not be easily incorporated in empirical work. Thus, whatever environmental qualities were taken as predictors of wayfinding, researchers invariably had an uphill battle in trying to rigorously define or quantify its properties.

In most cases, the environment was considered from within a working definition of cognition and the wayfinding process. For example, Passini's 1984 model stressed the processing of environmental information as an important component of wayfinding and so he described the environmental elements from this point of view. Similarly, Garling et al.'s (1986) three physical setting variables *degree of differentiation, degree of visual access* and *complexity of spatial layout* are also developed from requirements for some basic cognitive processes like recognition of parts, localization of reference points, recall, selection and sequencing of destinations.

Of course, theoretical arguments become meaningful when backed up by empirical evidence and in many cases empirical work serves as a background for theory. Many researchers have used the environment as predictor variables in wayfinding performance. Looking at the paths taken by 135 subjects in a town hall of a European city, Best (1970) reported high correlation (r=0.93, p=0.03) between 'lostness', i.e. deviations from a most direct route, and *the number of choices in that route*. Evans, Fellows, Zorn and Doty (1980) found that when *color-coding* was added, subjects' (n=14) wayfinding performance and orientation improved. Braaksma and Cook (1980) described terminal buildings as a *node-link network* where origins and destinations were nodes and the visibility between them, either directly or through signs, the link. By measuring the connectivity of such a graph, indices for visibility between locations inside ten airports were developed. Informal interviews with patrons in two airports showed that wayfinding problems were associated with areas with low visibility indices.

In 1981 Weisman used 73 self reports regarding wayfinding in ten university buildings and found that ‘simplicity’ of *floor plan configuration* as rated by 100 judges (see figure 2.5) was a strong predictor of self reported wayfinding performance. Later in 1989 he considered wayfinding from both perceptual and cognitive points of view and proposed four kinds of environmental information as important: *signs and numbers, architectural differentiation, perceptual access* and *plan configuration*.

In a later study, Michael O’Neil (1991b) measured layout complexity as the average number of *topological connections per choice point* in a floor plan. He called this ‘Inter-Connection Density’ (ICD). This was used as a dependent measure to test both wayfinding and environmental cognition. For the experiment O’Neill used 63 student volunteers and three independent sections of a library building. Using sketch mapping, photograph sorting and actual wayfinding tasks he found that as topological floor plan complexity increases, people tended to experience greater cognitive mapping and wayfinding difficulty.

In a different study, Peponis, Zimring and Choi (1990) used Space Syntax theory and methodology to examine spatial search behavior. They asked 15 subjects to explore a small hospital in ‘open exploration’ and then asked them to find several locations in ‘directed search’. The researchers recorded their routes for both phases and found that the subject’s open search patterns were strongly predicted by the Space Syntax measure of accessibility of a space called *Integration*. (Axial integration, as used in the Peponis et al study, measures topological accessibility by computing the number of turns necessary to reach all spaces in a system from every space, then normalizing this statistic to allow comparison among systems of different sizes. Space Syntax is further discussed in Chapter IV of this document.) In addition, when people were lost, they also tended to use 'integrated' paths. This research suggested that people use an abstract set of global relationships within the environment when they make wayfinding choices. However, it is not clear if they also included these relationships in their cognitive processes or whether there is a gradual development of understanding from more immediate spatial relationships to global relationships. The crucial question one may consider is this: do these abstract global relationships mediate wayfinding through cognitive representations or do they act directly in an ecological manner?

Later, Willham (1992) replicated the Peponis et al.'s study and further quantified the 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 with 12 older people as the subjects. His description of interior spaces considered *local, relational* and *global* parameters. Local parameters included the characteristics of spaces themselves, relational parameters were derived from visual relationships with adjacent spaces and global parameters were calculated from relationship with all the spaces in the system. An important conclusion for Willham was that as people spent more time in the setting the strongest predictors of their route choice shifted from local to global spatial qualities.

Still later Haq (1999a) used a similar methodology in a larger and more complicated urban hospital. With data collected from 32 young subjects he too found *Integration* as an important predictor of wayfinding. Additionally, he claimed that since wayfinding is a conscious act of choosing ones paths, and since Syntax values are strongly correlated with wayfinding use of these paths, then perhaps Space Syntax could also be a useful tool to study environmental cognition. Haq also showed that with increasing familiarity correlations of space use and *global variables* increased while correlations with local variables decreased. In other words, as people learn more and more about their settings their reliance shifts from local to global environmental variables.

These studies suggest that the overall pattern of layout or configuration is important for predicting the search patterns of way-finders. They seem to provide additional clarity about the role of choice and complexity in buildings. However, further work is necessary to determine whether this finding generalizes to more complex settings.

2.b Ecological Model of Wayfinding

A different model of wayfinding is based on Gibson's (1979) ecological approach to perception. Gibson addressed the relationship between environment and behavior, such as locomotion, through his concept of affordances. He defined affordances as the measure of potential interactions between an organism and its immediate environment. Environmental information is directly perceived through 'hierarchical' light structures or optic arrays that has enough information for the organisms to act without any cognitive mediation. Movements of a person's eyes, head and body induce transformations in the ambient light arrays. These transformations enable the perceiver to detect rigid structures in the environment as understood by certain non-changes in the context of an otherwise changing optical array. The non-changes or invariants and changes or variants in the ambient array each provide information to the perceiver. Among them, the invariants are more significant because those specify the environmental layout. Also, because non changes are detectable in the context of change, the information about the environment will be perceivable over time and as a person moves through the environment.

Putting this model into a wayfinding situation, Heft (1983) argued that information critical to wayfinding is revealed when an individual moves along a path, as a series of successive vistas and a sequence of transitions between vistas.

> "A vista is an extended region of the landscape that can be seen from one's present location … the view of each successive vista is occluded from view by visual barriers and, each successive vista is *revealed at the edge* of the visual barrier and simultaneously, the vista just traversed leaves the field of view" (Heft, 1983, pp. 137, authors italics).

Heft further asserts that in a wayfinder's route, the sequence of transitions will be invariant and such transitions of vistas *afford* looking ahead. This is thought to be critical to wayfinding behavior.

From this point of view, a route can also be described as two nested sequences of information: a sequence of vistas and a sequence of transitions that connect those vistas. Furthermore Heft asserted that transitions are more important because they serve to give continuity to the vistas. This is where one may make a distinction with cognitive mediational models. Whereas the cognitive researchers believe that transition between the vistas is a cognitive act, Gibsonian researchers like

Heft assert that continuity of discrete environmental information is provided by such invariant sequence of transitions.

Since wayfinding involves the perception of information over time and the most important information for this task is in the invariant sequence of transitions between vistas, Heft hypothesized that wayfinding behavior can also be studied from the point of view of such vista transitions. In this regard he has provided empirical results to support this assertion. He has used 46 subjects in an experiment that incorporated film to replicate a route through an urban neighborhood. One group was shown the complete route, while another was exposed to its vistas only, and a third to the transitions within that route. Later, they were taken to the site and asked to indicate the correct turn at every corner. When the three groups were compared, the results supported Heft's argument because the vista transitions group had indeed committed fewer errors. Following up with a second experiment using another 48 subjects, he also found that information about vista transitions *fed in a sequential manner* is sufficient information for wayfinding purposes. This is better than information about the vistas only and is comparable to information about both vistas and transitions.

Although Heft's work is encouraging, it would seem that an ecological approach to the study of wayfinding may be appropriate only for the study of exploratory travel i.e. when one is negotiating in a strange new environment without the assistance of a prior environmental understanding. Additionally, it may be applicable to the immediate process of route selection and not to the larger process of reaching distal locations. Nevertheless, the argument and research finding that an initial stage of information processing -- perception, is sufficient information to guide wayfinding, is a strong one. Also it serves to bring attention back to the *environment* in the study of environment and behavior. Furthermore, it supports the assertion that learning about environments takes place through movement within it.

3 DISCUSSION

Since this study is more interested in the environment as it relates to human behavior, it seems to be a good idea to return to the various environmental properties that were considered in the research discussed above.

If the studies are chronologically considered, then an interesting pattern begins to appear. As shown in table 2.1 whereas the earlier studies dealt exclusively with discrete elements, the work done in the decade of the 80's show a concern regarding the relationships of spaces as an important environmental indicator. However, at this time, there seemed to be a lack of appropriate tools and techniques to allow these properties to be defined or considered as predictor variables. Some attempts at this time were inter-subjective methods (Weisman, 1981). Although useful to prove theoretical arguments, they could not objectively describe or measure relational properties. The work of the 90's saw wayfinding researchers engaged either in incorporating theories of relational variables that was developed elsewhere (Peponis et al., 1990, Haq 1999a), or themselves developing theories and methods of such relational properties (O'Neill, 1991a; Willham, 1992).

This research takes the position that wayfinding is a process that is mediated by cognitive maps. Therefore, before proceeding to the research itself, a discussion of environmental cognition and cognitive mapping is warranted.

Table 2.1 The Environment in Wayfinding Research

	Year	***Author***	***Environmental Elements / Properties***
Mostly Discrete elements	1970	Best	Number of Choices in a route
	1978	Kuipers	*Topological relations* Metric Relations
	1979	McCalla et al.	Route Information
	1980	Braaksma	Visibility between destinations. Visibility Graph
	1980	Evans et al.	Color differentiation
Theoretical Arguments for Configuration	1981	Weisman	Visual Access to Cues and Landmarks Architectural differentiation Signs Plan Configuration
	1986	Garling et al.	Degree of differentiation Degree of visual access Complexity of spatial layout
	1989	Leiser et al.	Node-Link network
Configurational Measures	1990	Peponis et al.	Syntax Integration
	1991	O'Neill	InterConnection Density (ICD)
	1992	Willham	Distinguished Global, Relational and Local properties.
	1999	Haq	Interaction of local and global variables

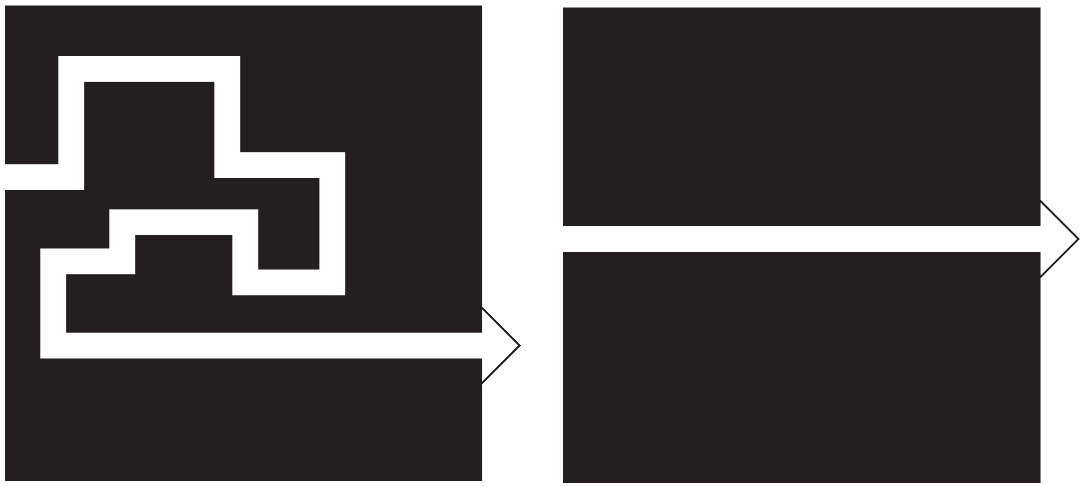


Figure 2.1 Movement is controlled by the environment.
Here, the person may or may not understand the overall environment.
This depends on how simple or complicated the environment is.

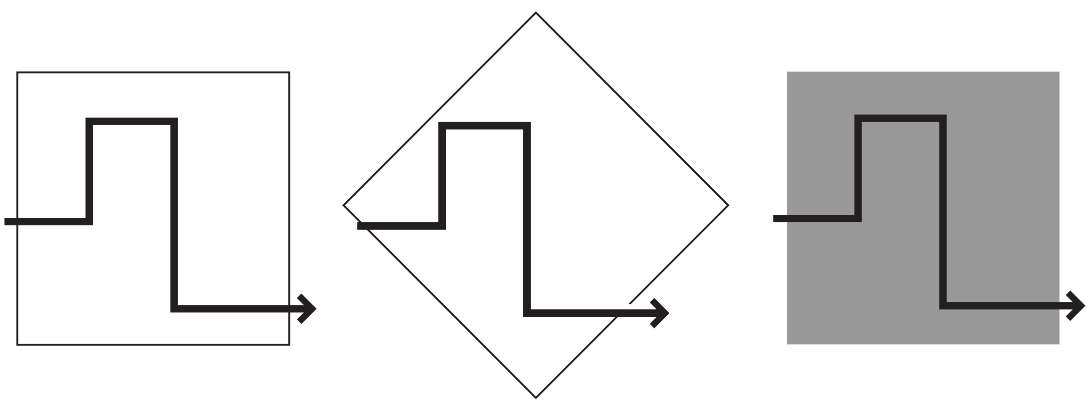


Figure 2.2 Movement is controlled by the person.
In this case of learned movement, the environment does not have any effect.

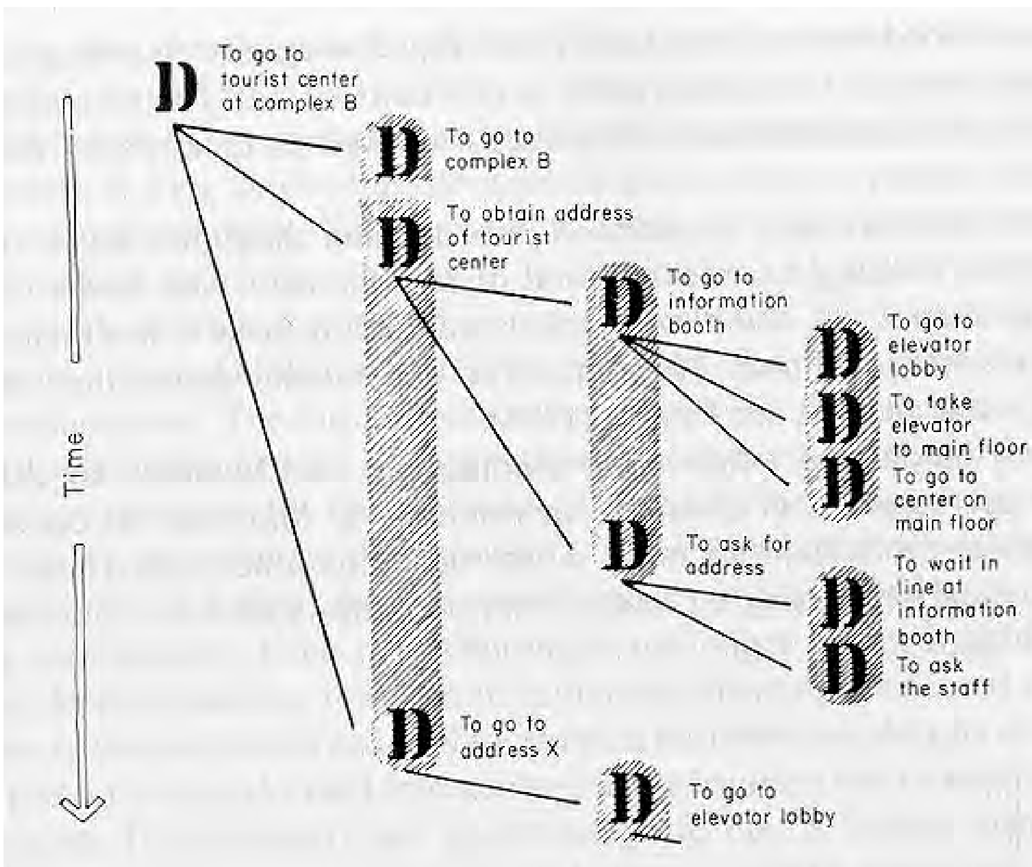


Figure 2.3 Passini's Decision-making model.

This is a tree-like structure where general ones are near the 'trunk '(top of the diagram) and specific ones, those that lead to spatial behavior, are in the branches.

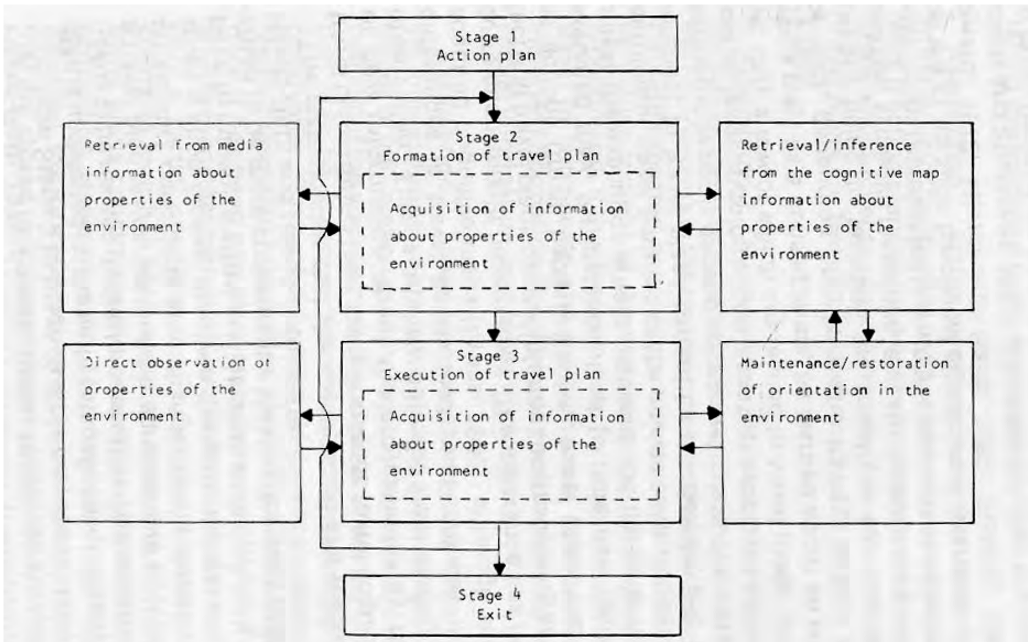


Figure 2.4 Garling's model of the formation of Travel Plans.

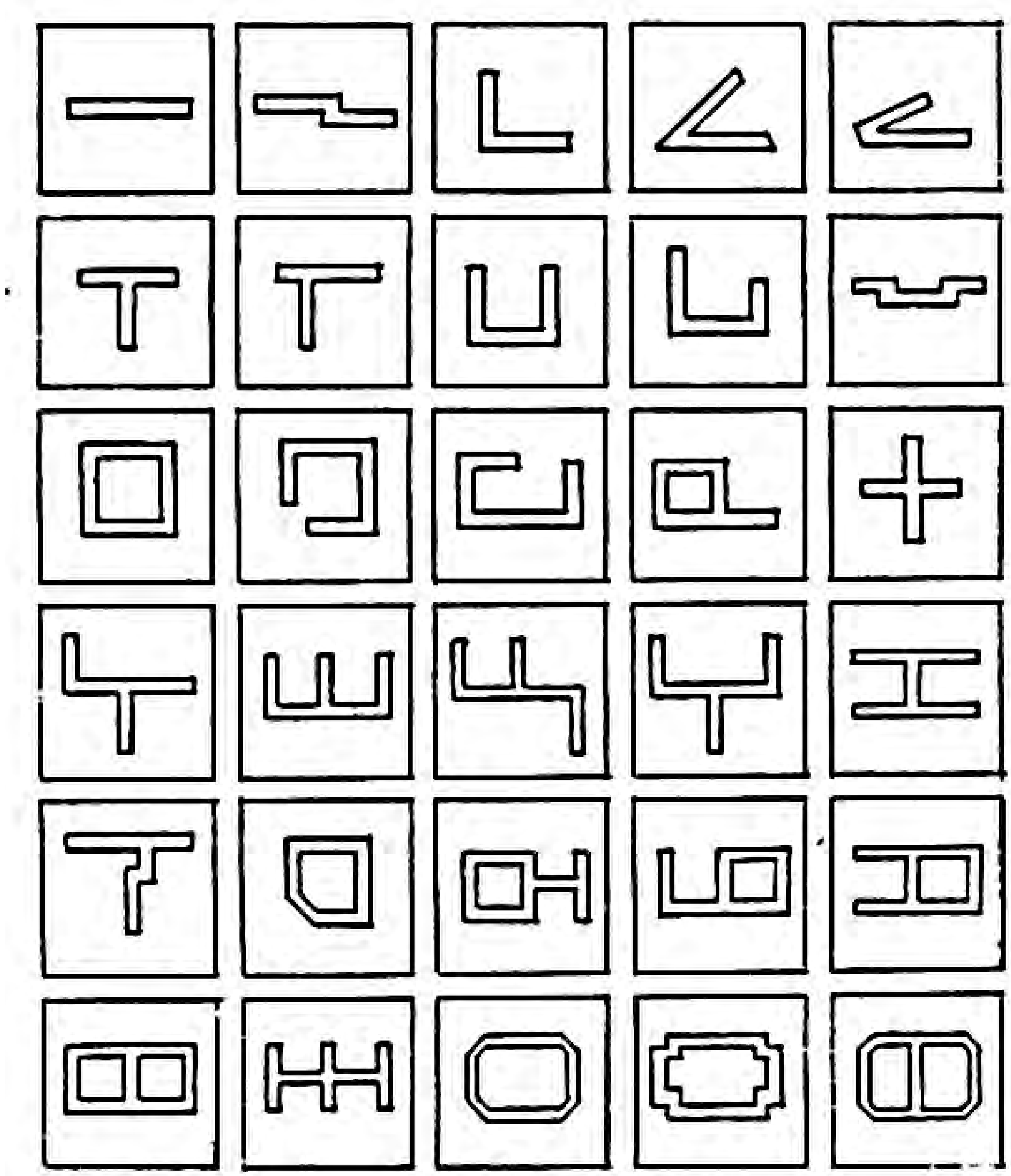


Figure 2.5 Sample of layouts used by Weisman (1981) for understanding the effect of configuration in wayfinding. Inter-subjective ratings provided the researcher with 'good form' of plan configuration.

Chapter III

Environmental Cognition

1 INTRODUCTION

The similarity between environmental form and cognitive understanding is a common assumption of a number of researchers. For example, Kevin Lynch (1960) hypothesized a correspondence between environmental elements and mental images. Similarly, other researchers have sought to identify significant environmental units and properties that may have cognitive consequences.

Since topological and visual properties of the environment were taken as independent variables in this research, an important aspect was to inquire into their significance in environmental cognition. Some significant questions were: do the topological and visual relationships within the environment 'map' into those of the cognitive map? What are the structures and the elements of the cognitive map, especially in its beginning stages of development? What are the configurational qualities of cognitive maps?

Regarding configurational qualities, the research literature does not always make a clear distinction between topological and metric relations. Whereas many argue that the end product of cognitive mapping is metric relations, understood as distance and direction, yet this has been difficult to examine. For example, Montello (1998) put forward theoretical arguments for metric knowledge, but not clear methods about verification. On the other hand, topological relationships i.e., patterns of connections have been found to be prevalent in cognitive mapping; with dominent concepts arising from Piaget and Inhelder's work (1967). However, there is no research that looks at the micro-genetic development of topological understanding. This is an important aim of this study.

This chapter looks into the assumptions and research in cognitive mapping with special emphasis on the environment as was incorporated in various cognitive studies.

2 ENVIRONMENTAL COGNITION

The concepts of cognition, environmental cognition, spatial cognition, cognitive mapping and cognitive maps are interrelated and these interrelationships should be clarified in the beginning of any discussion about them.

"Cognition is apprehending without the necessity of an external stimulus. Imagining, creating, remembering, thinking, learning are all the province of cognition" (Bechtel, 1997, pp. 149). By extension, *environmental cognition* is apprehending the environment. It includes all internal processes with respect to human understanding of the environment. It refers to

> the awareness, impressions, information, images, and belief that people have about environments … It implies not only that individuals and groups have information and images about the existence of these environments and of their constituent elements, but also that they have impressions about their character, function, dynamics, and structural interrelatedness, and that they imbue them with meanings, significance, and mythical-symbolic properties" (Moore & Golledge, 1976, pp. xii).

Although the referent of environmental cognition is not limited to the physical environment only, but also includes human abilities and the total life environment with its socio-cultural, economic and political aspects, it should be pointed out in the very beginning that this thesis is concerned mainly with relevant properties of the physical environment as they relate to its cognition.

Hart and Moore (1973) distinguished *spatial cognition* as a subset of environmental cognition. This is usually considered as “the knowledge and internal or cognitive representation of the structure, entities and relations of space; in other words, the internalized reflection and reconstruction of *space* in thought” (Hart & Moore, 1973, pp. 248, author's italics).

The process of attaining this knowledge or internal representation is known as cognitive mapping and its study is an important part of spatial cognition. Cognitive mapping is defined as “a process composed of a series of psychological transformations by which an individual acquires, stores, recalls, and decodes information about the relative locations and attributes of the phenomena in his everyday spatial environment” (Downs & Stea, 1973, pp.9).

The end product of the cognitive mapping process is a kind of knowledge about the environment. This is termed a ‘cognitive map’. Unlike a real map, this has both physical and non-physical components. In other words, it includes some representation of the environment, some impressions of it *and* some rules or procedures regarding how to act in various environmental conditions.

The term ‘cognitive map’ is widely used in a number of disciplines such as environmental psychology, social psychology, anthropology, geography, cognitive studies, city planning and architecture. It was used as early as 1948 by Edward C.

Tolman to describe maze learning of laboratory rats. He found that experimental rats not only learned about turns and responses to get to their reward, but also gained an *overall idea* of the location of that reward in relationship to their initial position. To describe this overall idea about one's environment, he coined the term 'cognitive map'. About this term, Golledge says, "the memory representation of spatial information in particular has been called a cognitive map" (Golledge, 1987, pp. 143).

Cognitive maps are mental constructs that encompass all the internal processes that enable people to acquire and manipulate information about the nature of their spatial environment (Downs & Stea, 1973, pp. xiv). They are incomplete, segmented and mentally distorted internal representations of the environment. They are constantly being updated and so at any one instance are merely a snapshot of the contemporary state of the physical knowledge. "Cognitive maps are the internal information structures that people use to represent information about everyday physical environment" (Garling, Book, & Lindberg, 1984). Additionally, a cognitive map is also a "...compact orderly collection of knowledge, … it contains more information than one can generally conceive at once, thus permitting one to anticipate, to react, to consider next possible events" (Kaplan & Kaplan, 1982, pp. 63). Furthermore, it provides a satisfactory basis for decisions even when a lot of information is missing. Finally, cognitive maps are considered to be essential components in the adaptive process of spatial decision making. "This mental representation is shaped by the environment within which it evolves and it has at least some impact upon subsequent behavior on that environment" (Rovine & Weisman, 1995, pp. 151). Cognitive maps are used to understand and know the environment, predict the environment and guide behavior (such as wayfinding) in the environment (Kitchin, 1994). Also, they help fulfill certain fundamental human needs such as recognition, prediction, evaluation and taking action (Kaplan, 1973). *Recognition* is knowing where one is, *prediction* is knowing what to expect next, *evaluation* is being able to anticipate weather the outcomes will be favorable or not and *action* is knowing what to do. Therefore, the relationship of cognitive maps to behavior is multifaceted. However, in this research, a focal interest is the relationship of cognitive maps to wayfinding behavior and the physical environment.

In research, a general concept of cognitive maps is used to study how the physical environment is represented in the head. The questions that have always dogged investigators are these: what is the form of the cognitive map?, how is it created?, what are its elements and what are the relationships between them?, how valid are the external representations in conveying the internal information/understanding?, is it influential in human-environment interaction (like wayfinding)?, if so in what manner?, how can this be studied? (see Kitchin, 1994, Golledge, 1987 and Evans, 1980 for general reviews of cognitive mapping research).

Since cognitive maps are built over time, researchers interested in human development have found them to be especially important. Therefore, contributions to cognitive mapping research by developmental psychologists will be considered first. Later, this discussion will concentrate on the *environmental elements* that are thought to be incorporated into cognitive maps and the influential properties of those elements.

3 DEVELOPMENT OF COGNITIVE MAPS

Cognitive maps are internalized knowledge about the environment and are formed by interaction with that environment. They can be shaped either by direct communication with the physical environment or by indirect representations of it through various media such as oral or verbal descriptions, maps, still pictures or moving images. A generally accepted working concept about cognitive mapping is as follows: individuals receive information from complex, uncertain, changing and unpredictable sources which is the world that s/he lives in, via a series of imperfect sensory modalities. From such overwhelming diversity, s/he aggregates information to form a mental structure that contains a representation of the environment. This is also used in future interactions in that environment and so, in the process, the mental structure is constantly being upgraded.

The process of cognitive mapping is a means of structuring, making sense of, and coping with the complexities of environments that are external to mind (Golledge, 1987). Therefore, it is dependent on both environmental and individual factors. Obviously, familiarity with the environment is important and cognitive maps are a function of the length of exposure to it. For example, as a person gets to know an environment more, s/he will generally have a better cognitive map of it. On the other hand, individual characteristics and abilities can also play an important role in this process. Some people seem to keep track of direction and distance almost effortlessly, while others are hopelessly lost from the beginning. Unfortunately, human capabilities and differences are beyond the scope of this discussion. However, one focus will be on the development of cognitive maps in the short period of being introduced to a new environment.

Most studies in the development of spatial understanding in humans have roots in the work of Piaget and his colleagues. (Piaget & Inhelder, 1967; for an extensive review see Hart and Moore, 1973). Perhaps their most basic finding, which also makes the most intuitive sense, is the fact that representations of space are primarily built up by acting-in-space and not by perception-in space. In other words spatial understanding arises from movement within space. The other important aspect of their work is the identification of three kinds of *spatial relations* that form the content of spatial cognition: topological, projective and euclidian. Their work, done with children indicated that the knowledge of basic geometric properties of space is learned sequentially; first, an intuitive understanding is attained which is based on direct experience; second, some spatial thoughts allow systematic reversible operations and finally, spatial thoughts become such that they can be disengaged from action.

In terms of a general theory of the development of environmental knowledge by adults in unfamiliar environments, Hart and Moore (1973) and Moore (1975) suggested that organization of knowledge of large-scale environments passes through three stages; egocentric reference system, a fixed reference system and an abstract or a coordinated reference system. The first is a system of orientation that is based on one's own position in space, the second is based around some fixed elements in the environment and the third is organized around some abstract understanding of space.

Research that deals with the identification of environmental elements considered to have some significance in cognitive maps has roots in the work of Kevin Lynch (1960). He identified 5 environmental elements: paths, nodes, edges, landmarks and districts as being distinct in mental representations. In 1975, development psychologists Siegel and White studied the sequence in which environmental elements are acquired and they proposed that *landmarks* are acquired first, followed by knowledge of *routes*. Finally *survey or configurational* knowledge develops. (Also see Golledge, 1987, Mcdonald and Pellegrino, 1993, Hirtle and Heidorn 1993 and Freundschuh, 1991, for detailed surveys). Landmark knowledge is familiarization of an element or a place in the environment (referred to as landmarks) without knowledge of locations relative to others. Route knowledge is the knowledge of how to go from one location or an element to other one without a definite sense of their relative positions. The third and most comprehensive is the survey type of knowledge. This is the knowledge of relative locations of environmental objects (landmarks) and their interconnections.

Although most researchers agree to these three 'elements' i.e. landmarks, routes and configurations, as the building blocks of cognitive maps, there is some controversy about the sequence in which they are learned. Both Hart & Moore (1973) and Siegel & White (1975) stressed the functional nature of landmarks as initial place markers that facilitates one's knowledge about relative positions in space. Later Golledge (1978) expanded the scope of these landmarks by proposing that they act as 'anchors' around which further knowledge of adjacent areas and paths connecting it to others develop. In this 'anchor point' hypothesis, features of the environment that are more important in a person's cognitive map'anchor' secondary features which in turn serve to anchor features of lower significance. Separate empirical works have supported the notions about the importance of landmarks. For example, Evans, Marrero, & Butler's (1981) study done in Irvine, USA and Bordeaux, France where they studied sketch maps from people who had lived there for less than two weeks and those who lived there for ten months is an important one.

On the other hand, Lindberg and Garling (1983) found evidence that paths are learned before or at least along with landmarks. The authors maintain that connections between 'places' are the foundations of environmental knowledge. As people learn about environments, these mental connections between 'places' strengthen and accumulate. In this manner, a simple 'strip map' representation is developed into an integrated spatial overview that is also known as a survey map.

Research findings vary as to the time necessary for route maps to develop into survey maps. For example, Moeser (1988) found that student nurses who worked in a large irregularly shaped complex hospital building for two years had very poor configurational representations of the building, yet they had good route knowledge. On another level, Appleyard (1969), Garling, Book and Ergezen (1982) and Peponis, Zimring and Choi (1990) have all asserted that configuration is learned relatively quickly in the process of acquisition of environmental knowledge. Needless to say, the configurational complexity of the environment itself is an important variable; some researchers have hinted at this (including Weisman, 1979, Moeser, 1988, Peponis et al, 1990) but few conclusions have been drawn. Of course, this would require handy techniques of categorizing entire environments from the point of view of cognition– a task not easily done with available tools until the recent development of computer based analytic methods.

Although all of these studies question the sequence in which environmental elements are learned, the elements themselves; landmarks, routes and configurations remain ubiquitous in the research literature. These are considered the general contents of the cognitive maps, i.e. its basic units and building blocks. Researchers however, vary in the *description* of these knowledge units, especially regarding their properties with cognitive consequences. This issue will be taken up next.

4 CONTENTS OF COGNITIVE MAPS

Although cognitive maps contain information about the environment, and certain action procedures , it is the knowledge about the environment that is of interest here. A study of the environmental components of cognitive maps should identify environmental elements and discuss their significant properties. One way of studying internalized environmental knowledge is to focus on its external representation. This was done, quite early on, by Kevin Lynch (1960) who argued that certain environmental elements are more 'imageable' than others. From interviewing and studying sketch maps of 36 subjects in three US cities, he identified five environmental elements from the property of 'imageability'. However, later cognitive researchers have generally agreed on three: *landmarks, paths* and *configurations.* (This has been discussed in section 2). Obviously, these three are not derived from ideas of imageability only. Nevertheless all three can have mental images of increased complexity that can be externalized. In other words, the images of landmarks, paths and configurations can be expressed, either through verbal expressions or drawings. Cognitive units that permit such expression will be termed as the *tangible contents* of the cognitive maps.

Other environmental properties that are also relevant to cognitive mapping research may not support a distinct 'images', but they provide some *qualitative* sense of the environment. They usually consist of non-physical entities. For example, an environment may be 'threatening', 'beautiful' or 'mysterious'. Also, one may have a sense of procedures in his/her cognitive maps. These may include action rules and decision strategies. Such qualities are also part of our cognitive maps and have been considered by cognitive researchers. In this thesis, they will be termed the *intangible contents* of the cognitive maps.

The following sections will discuss the tangible and intangible contents of cognitive maps in greater detail.

4.a Tangible contents

As discussed before, the tangible contents of cognitive maps are landmarks, routes and configurations.

4.a.1 Landmarks

The concept of landmarks stems from the pioneering study of Kevin Lynch (1960). In his approach to urban design he hypothesized that the 'mental images' that residents have of their cities are important in understanding their cognitive maps. In a study done in three US cities, Lynch demonstrated that these images are of discrete *physical* elements; the important ones being *paths, edges, districts, nodes,* and *landmarks.*

According to Lynch, these are the building blocks of mental maps. Paths are the channels along which an observer would actually or potentially move; edges are either permeable or impermeable barriers that tend to differentiate one segment of space from another; districts are the areas delineated by the edges and are seen as having some common identifying characteristics; nodes are strategic points in the paths and are essentially the intersections of two or more paths and finally, landmarks are easily identified elements of the physical landscape and could be effortlessly remembered from the entire range of urban functions or structures.

These five categories of Kevin Lynch were quickly accepted and have been used continuously to this day. So widespread is their use that they have almost become a 'paradigm' in cognitive research, with many research designs starting from the elements of Lynch. His influence is made graphically explicit in a published table (Downs & Stea, 1973, pp. 84-85) that summarizes the findings regarding environmental images of different kinds of people in 14 cities of America, Europe and the Middle East by 7 researchers in the 10-year period after Lynch published his book. Much later, Aragones & Arredondo (1985) also found evidence for the five elements following the dissertation work of Magana (1978) in the city of Madrid. In the first of two experiments, 56 subjects organized pictures of urban elements into pertinent groups. In the second one, 250 residents ranging in age from 15 to 64 years freely associated one element of their city, presented as a stimulus, with another. Various analyses of the generated data provided support for the Lynchian categories and also added new dimensions that modulated the groupings of the five categories. Finally, it can be seen that in the widely accepted model of environmental cognition that includes landmarks, routes and configurations, the first two are directly derived from

Lynch's categories. Also, the Lynchian concept of nodes as intersections between paths may be considered a kind of landmark knowledge.

In spite of its success, the most vexing problem which later researchers faced was the fact that many of the Lynchian elements were extremely difficult to describe objectively. This was probably because first, their properties were hard to formulate and second, they held various meanings for different persons (common versus idiosyncratic landmarks). Among the five elements, landmarks are probably the most difficult to define and ironically are the most prevalent of them all. Later, Appleyard (1976) took up this matter and proposed that the three properties: form, visibility and use & symbolic significance were the most important characteristics of an environmental element that contribute to it being considered and memorized as a landmark. Others have looked at this issue from a different points of view and proposed that ease of some mental functions in processing environmental information may help establish certain elements as landmarks. For example, familiarity from past experience and ease of putting a linguistic label on it (Carr & Schissler, 1969) could elevate an environmental element into a cognitive landmark.

An essential difference between Lynch's landmarks and Golledge's anchor points is that while both are cognitively salient cues for the environment, landmarks are considered inter-subjective while anchor-points are not. Therefore a house may not be a landmark for everyone, yet may be an anchor point for the person who lives there. Landmarks afford concrete visual cues while anchor points may be more abstract. Furthermore, Couclelis, Golledge, Gale, & Tobler (1995) made the distinction that while landmarks are treated as a person's factual knowledge of space, anchor points facilitate additional cognitive functions, like the organization of spatial knowledge, navigational tasks and the estimation of distances and directions.

4.a.2 Routes

Route knowledge is the linking together of the various landmarks or other known 'unit' places so that one may travel between them. This is referred to in many ways; strip map, route map, projective knowledge, procedural knowledge and so on. Route knowledge is a kind of spatial knowledge that can be described as a linear representation of space. Kevin Lynch's (1960) category of paths is perhaps the earliest discussion of routes in cognitive mapping. Routes may be the paths in a landscape, streets in an urban environment or corridors in large buildings. The various intersections of routes are also important because these are where a conscious decision regarding direction of travel needs to be made. Nodes may be regarded as part of the route and hence part of route knowledge. Alternatively, they can be thought of as independent landmarks. This distinction is rarely made in the research literature.

In cognitive mapping literature a distinction is sometimes made between route knowledge as physical elements and route knowledge as a procedure of going from one point to another. For example, to turn left/right at a certain point, go straight and so on. Route knowledge theoretically requires both metric and topological information, yet in most research only the topological aspect is considered. The idea of metric knowledge is usually linked to configurational or survey knowledge. This distinction between topological and metric relationships merits a separate discussion and is taken up in section 5a.

4.a.3 Configurational or Survey Knowledge

Configurational or survey knowledge is considered to be the ultimate goal in spatial learning. It is thought to provide the most complete information about the environment. This not only incorporates both route and landmark information but also the relations between them (McDonald and Pellegrino, 1993). Generally, it is considered to be a two dimensional representation of space which threads together many route and landmark information to form a 'network' between several places. It is acquired most easily through map reading or through overviews of the environment from elevated positions. Researchers also believe that it is built up by more and more experience with an environment.

Approaches to configurational or survey knowledge have differed. It has been referred to as egocentric knowledge, comprehensive knowledge, configurational knowledge, survey map, Euclidian map, and the more general term cognitive map. In this study it will be referred to as *configurational knowledge.*

In the study of configurational knowledge, a basic distinction may be discerned between researchers who assume that it is a system of routes and landmarks that incorporate both direction and distance i.e. *topology and metric* information and others who assume that actual distance may or may not be understood, i.e. they consider *topology* only. For example, empirical researchers in the former group ask their subjects to both point to familiar destinations as well as to estimate distances between them while those in the latter group only require the pointing task. The former group (topology and metric) considers configurational knowledge as being almost map-like, while to the latter group it is an understanding of relative locations and directions that are extended to cover the entire area that is being considered. For example, a person may be able to comfortably travel all over his/her city but may not have an accurate sense of the distance between various locations. This would be possible only if one attains a sense of topological configuration. If one has both topological and metric knowledge then s/he would be able to describe distances too. In cognitive mapping literature the distinction between metric and topological relations is perhaps not critically evaluated. For example, some studies have concluded that people's distance estimation abilities are not an adequate test of configurational knowledge (Hirtle and Hudson, 1991, Garling, Book and Lindberg, 1981). This is because a knowledge of distance was considered a criteria of configurational knowledge. If topological relationships are considered, then we get a different picture. For example, Sadalla and Magel (1980) found that subjects estimated routes with more turns to be longer than routes with fewer turns. Peponis, Zimring and Choi (1990) found that wayfinders in a new environment prefer areas that are topologically closer, on an average, from all the spaces in the system (Syntax integration). These studies suggest that topological understanding is more prevalent than metric ones. (See section 5a for a longer discussion on topological and metric properties).

4.b Intangible contents

There are other elements in the cognitive map that focus on the qualitative aspects of the environment as it features in its mental representation. Perhaps the most significant in this category is the work of Kaplan and Kaplan (1977) whose approach was through studies on environmental preference. Approaching this topic from an evolutionary point of view, they suggested coherence, complexity, mystery and legibility as important qualities of the environment that feature prominently in cognitive maps.

A second way into the intangible in cognitive maps is looking for information contained in them. It is argued that cognitive maps hold 3 kinds of information: declarative knowledge, procedural knowledge and configurational knowledge (Golledge, 1991). Declarative knowledge is knowledge about what is in the environment. This includes, besides the tangible elements, persons, events and places. Procedural knowledge is the knowledge about the relationships between environmental elements. This embodies knowledge about specific paths through complex environments, the ability to preview and preprocess information to develop a travel plan and the ability to translate those plans into spatial activity. Lastly, configurational knowledge is notions about angularity, direction, continuity and relations.

Another topic in this section is that of schemata. Strictly speaking, this cannot be categorized as an intangible content of cognitive maps. It is a form of the internal understanding itself.

Schemata are active, information seeking structures that accept information and guide action. They direct perceptual exploration that in turn modifies them. Neisser (1976) has suggested that cognitive maps are ‘orienting schemata’. This term is proposed to convey the dynamism of schemata that is an important quality of cognitive maps.

Just as the schema of an object accepts new information and directs new exploration, so does the orienting schema of the entire area (see figure 3.1). The object schema is part of the larger orienting schema. However, knowledge from object schema to orienting schema is not attained successively. Rather, the former is embedded in the latter.

As an example, Neisser (1976) reanalyzed the work of Lynch and has suggested that landmarks, nodes and edges are real elements and have their own schema. They direct perception and pick up information in their own right. Additionally they provide information about things external to themselves and these become part of the larger orienting schema or cognitive map. In this way, the different levels are not related sequentially, but are embedded.

As Neisser acknowledges, his theory fails to account for paths and districts. This is probably because he based his work on the concepts of Gibson (1966). In this ecological manner of visual perception, it is the changes in vistas or the edges of visual fields that carry meaning. Therefore, paths themselves become less important for the formation of schemata.

The most important aspect of this theory, cognitive maps as schemata, is that it acknowledges movement as the means of environmental understanding. This has profound ramifications for experiment design and will be highly meaningful in the empirical work of this research.

5 ENVIRONMENTAL PROPERTIES IN COGNITIVE MAPS

Perhaps the most meaningful question regarding cognitive maps, at least for environmental researchers, is regarding the properties of the tangible environmental elements that constitute them. This is especially important because environmental elements are usually understood or remembered because of some characteristic property. For example, Appleyard (1970) had proposed size and Evans (1980) put forward color as some properties that have cognitive consequences. Properties such as these can be understood by being within a space itself. Alternatively, another kind of property can be those that are discerned not by being within one space, but by moving from one to the other or by having views from one to another. The properties understood in this case would obviously be from the relationships that each space has with all others. Since cognitive maps are built up through movement, these properties can be expected to be an important components of the cognitive maps. In this research, the former will be termed *discrete* properties and the latter as *relational* properties. Hillier (1999) refers to these two as non-local and local properties of the environment. These non-local/relational properties bring up both the issue of configuration and the distinction between metric and topological properties. These are discussed below.

5.a Topological and metric relations

A very important discussion in the cognitive mapping literature and one that is perhaps the most underdeveloped is that regarding the various relationships that exist between environmental elements. This is crucial especially in the consideration of configurational knowledge. As mentioned before, researchers usually discuss configurational knowledge as topological or metric.

Topological relations are the ordering of places and their association with one another. They indicate the connections between places, whether it is possible to travel from one location to another; and ultimately what places one would pass through enroute to a distant destination. On the other hand, metrical relations indicate the direction and distance between places.

In everyday life the importance of topological information regarding the environment is not too difficult to comprehend. In this regard, a common act of giving wayfinding directions to complete strangers is a popular example that is widely used to emphasize the importance of spatial relationships: topological rather than metric ones (Hillier, 1999, Hamer, 1999). It is easier to describe a long route with fewer turns than a short one that has many branches and connections.

As knowledge of the connections between places is developed, a sense of configuration is attained. Many researchers have supported the notion that such topological information is acquired first and is a precursor of a more detailed cognitive map (Evans, 1980, Kuipers, 1983). Kaplan and Kaplan have noted that topological information is a natural by-product of the human learning process and allows humans to assemble a usable representation of the environment from many small and incomplete pieces or views (Kaplan and Kaplan, 1982).

In research, the distinctions between topological and metric properties are often not clarified when configurational knowledge is studied. The following quote from Golledge should suffice to make this point:

> "… configurations are considered to have more formal geometric (usually Euclidean) properties: they have the necessary robustness to allow trigonometric functions to be used to explain the spatial relations

> embedded in the configuration; they can be described by metric and non metric geometries and topologies; and they form a convenient form of summarization or generalizations about experienced features, places and connections. Whereas routes may be adequately described by using only ordinal information, configurations are usually best described using metric information" (Golledge, 1999, pp. 21)

On the other hand, some researchers like Siegel (1981) and Sholl (1996) have concluded that if pointing tasks are correctly carried out i.e. topological properties understood, then configurational learning has been achieved.

Although the concept of topological connections between various spaces is relatively straightforward, there may be various levels of its acquisition by humans. For example, understanding simple connectivities of any one space or a route to adjacent ones, comprises basic topological knowledge. This may be considered 'local' level understanding. On the other hand a total comprehension of how all the spaces in a system are connected to each other is a much higher-level topological understanding of that layout. This may be considered a 'global' level knowledge. Similarly one may consider various in-between levels of configurational learning that range between the local and global levels of comprehension.

Those kinds of spatial knowledge are not metric in character. However higher levels of topological knowledge do incorporate a sense of global relationships, and hence become configurational knowledge. Unfortunately, there is almost no indication in the research literature of probes into acquisition of finer details of the topological relationships. On the other hand, Space Syntax theories have tried to be precise in distinguishing between the topological kinds of environmental properties and its methods aim to be objective in their description. Therefore, this would seem to be a very appropriate tool to study the acquisition and comprehension of topological properties in cognitive maps. Space Syntax is described in chapter IV.

6 DISCUSSION

In the discussion presented here, the complexities in studying cognitive maps and cognitive mapping have been pointed out. On one hand it deals with the physical environment and on the other with its representation in the mind. Since the latter is the most illusive part, research approaches to cognitive mappings have been varied; some of these have been mentioned here.

The previous sections focused on the environmental elements that play a role in the formation of cognitive maps. The elements have been categorized into tangible and intangible kinds. Tangible contents of the cognitive maps were further distinguished by their elements and properties (see table 3.1). Although many researchers have supported the environmental elements of landmarks, routes and configurations, slightly deviating models have been proposed also.

For example, David Stea (1969) had put forward the ideas of points, boundaries, paths and barriers; Appleyard (1969) supported paths, nodes & points, districts, landmarks and edges, Norberg-Schulz (1971) suggested paths, places and domains; Siegel and White (1975) opted for routes, nodes and configurations; Kuipers (1978) discussed paths, places and relative locations; Garling, Book and Lindberg (1984) suggested places, spatial relations between places and travel plans and Rovine and Weisman (1995) mentioned landmarks (see table 3.2). These researchers come from various backgrounds and have different agendas, but one can easily see that they almost unanimously suggest that paths/routes and nodes/points of the environment are featured prominently in the cognitive maps of people.

Seigel & White, (1975) were two of the early researchers from psychology who discussed the importance of configuration. This was also an important focus for geographers who argue thatcognitive maps are spatial data assembled in working memory and can be externally represented in a map form. (see Tobler, 1976, Golledge, 1976). Regarding configuration, the topological and metric properties have been distinguished, but no clear argument has been developed. In this regard, perhaps the most significant one that has been reported is that subjects are less accurate with distance estimates than direction, which leads to the assumption that topological characteristics get more cognitive mileage.

Also, in the design of experiments, the layout is usually controlled through its quality of being grid-like or not, or whether the intersections are at right angles or not. Gopal (1995) developed a robotic wayfinder that operated on a grid layout and Evans (1995) found in an experiment with 128 subjects that rectangular intersections enhance route accuracy.

In environmental studies, Weisman (1981) took up the concept of configuration and proposed an intersubjective ‘good form’ quality. O’Neill (1991) proposed the methodological construct of inter-connection density (ICD) as ways to both understand and quantify configuration. In a more theoretical approach to this subject, Tommy Garling suggested that along with information and travel plans, cognitive maps also contain different kinds of spatial relations between places -- for example, topological, ordinal and metric (Garling, 1995, pp. 02). Also, Peponis, Zimring and Choi (1990), Willham (1992) and Haq (1999) have used Syntax methods to investigate the role of configuration in wayfinding.

Regarding the development of configuration in cognitive mapping research, a careful look at table 3.2 brings out a very important pattern. It shows that research in the 1960's was mainly concerned with the discrete elements of the environment and in the cognitive maps. The decades of the 1970's and 1980's were characterized by an increasing awareness of the configurational properties, in other words, the properties of various spatial elements that were derived from their relationship to one another. This period is further characterized by theoretical calls for the above, undoubtedly because of a lack of tools and techniques by which these relational variables could be measured. It was only in the 1990's that new methods and computerized tools became available to cognitive researchers, which makes this a very important juncture in the field of cognitive research.

One significant theory regarding relations among environmental units is Space Syntax. This permits the consideration of environmental relations or configurational variables as predictors. It has proved to be a useful theory in predicting natural movement in urban areas, and has a high potential in wayfinding and cognition research. It is also an important tool for this research.

The next chapter will present a short discussion of Space Syntax. This will complete the three important theoretical pieces of this dissertation. After that, all the three will be brought together in the discussion of the empirical work and its results.

Table 3.1 *Contents of Cognitive Maps as found in literature*

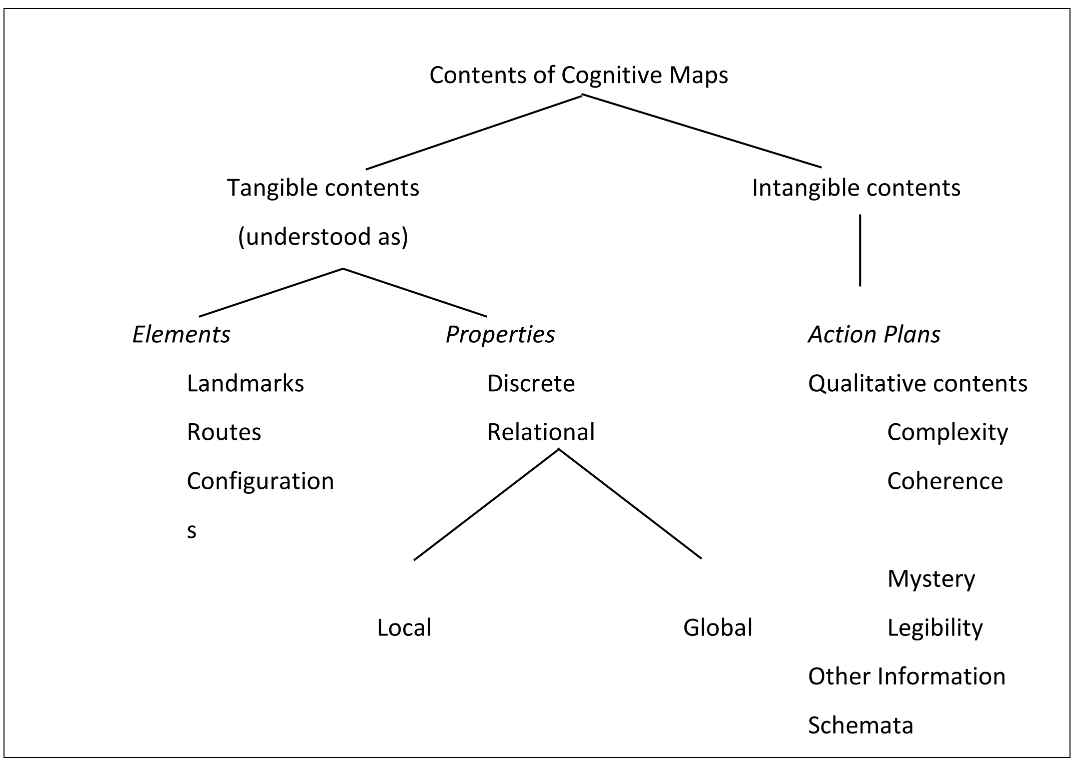
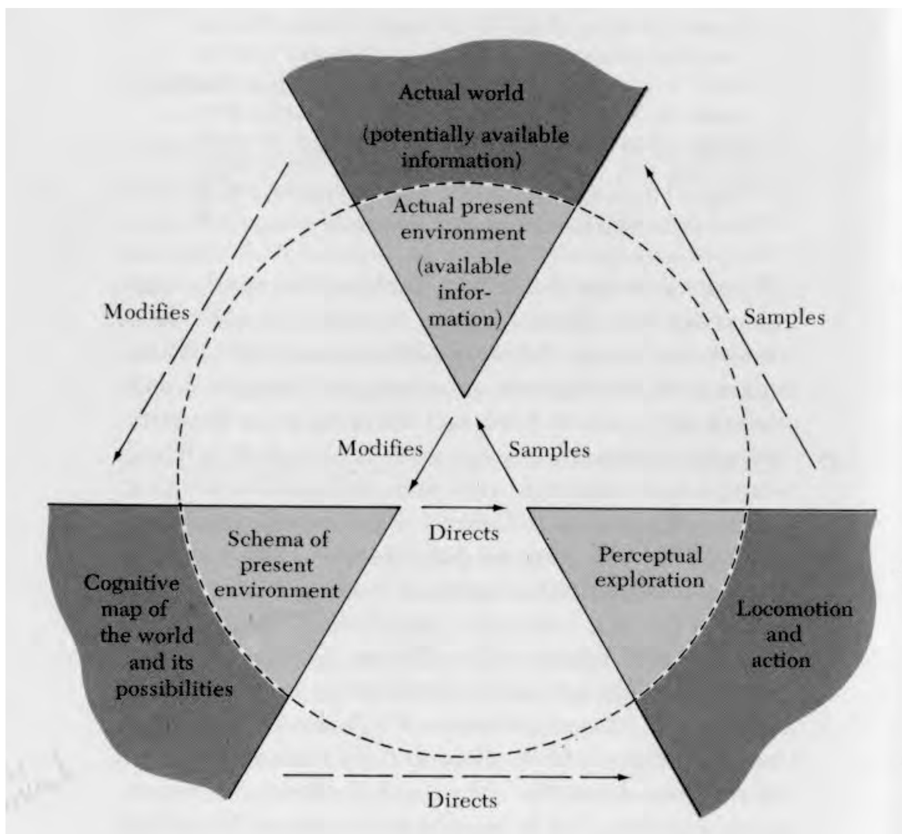


Table: 3.2 The Environment in Environment Cognition research.

Yr	Author	Environmental Elements that are reflected in Cognitive Maps						
		Local order Environmental Measures					**Global order Environmental Measures**	**Other**
		Lines	**Points**	**Areas**	**Elements**	**Edges**		
60	Lynch	Paths	Nodes	Districts	Landmarks	Edges		
69	Stea	Paths	Points			Boundaries and Barriers		
69	Appleyard	Paths	Nodes & Points	Districts	landmarks	Edges		
71	Norberg-Schulz	Paths	Places	Domains				
75	Siegel and White	Routes	Nodes				Configuration	
76	Tobler						Configuration	
78	Kuipers	Paths	Places				Relative Locations	Travel Instruc-tions
78	Golledge		Anchor points					
84	Garling et.al.		Places				Spatial relations between places.	Travel Plans
89	Rovine and Weisman				Landmarks			
91	O'Neill						ICD	
95	Evans et. al.				Landmarks		Pathway Configuration	
95	Gopal						Configuration (Neural Network Model)	
99	Haq						Configuration (Syntax Integration)	



Figure; 3.1 Neisser's orienting schema

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 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=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 = 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)[1].

[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.

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 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.

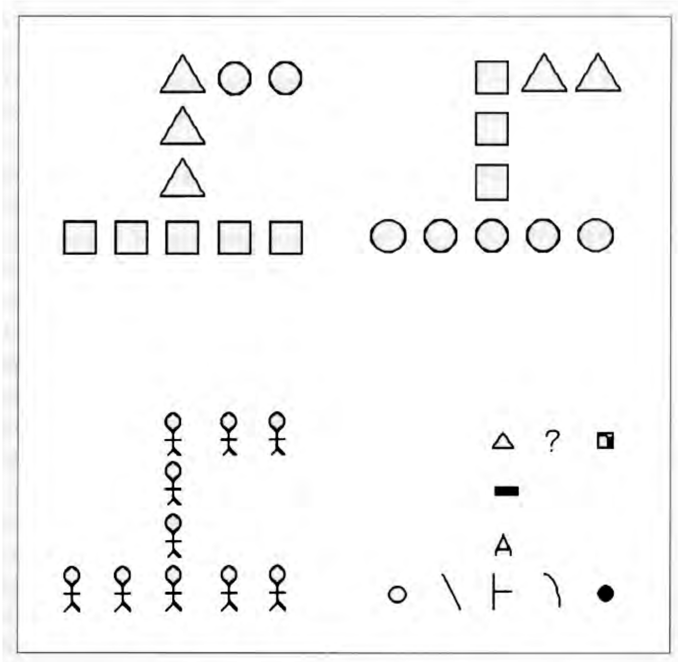


Figure 4.1 *Configuration is independent of constituent units.*

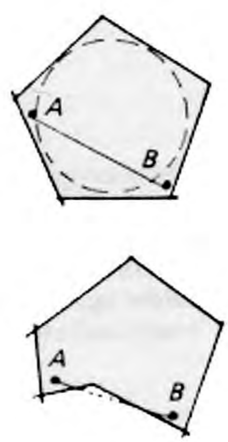


Figure 4.2 *Convex Spaces. All points are visible from all other points in each space.*

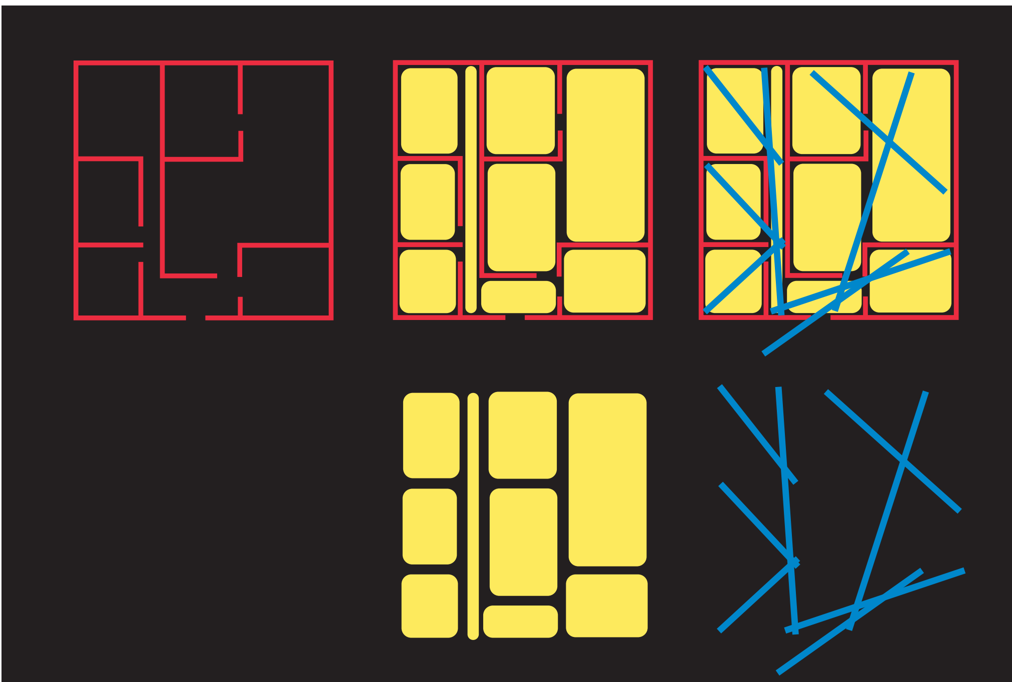


Figure 4.3 Deconstruction of a layout into convex spaces and axial lines

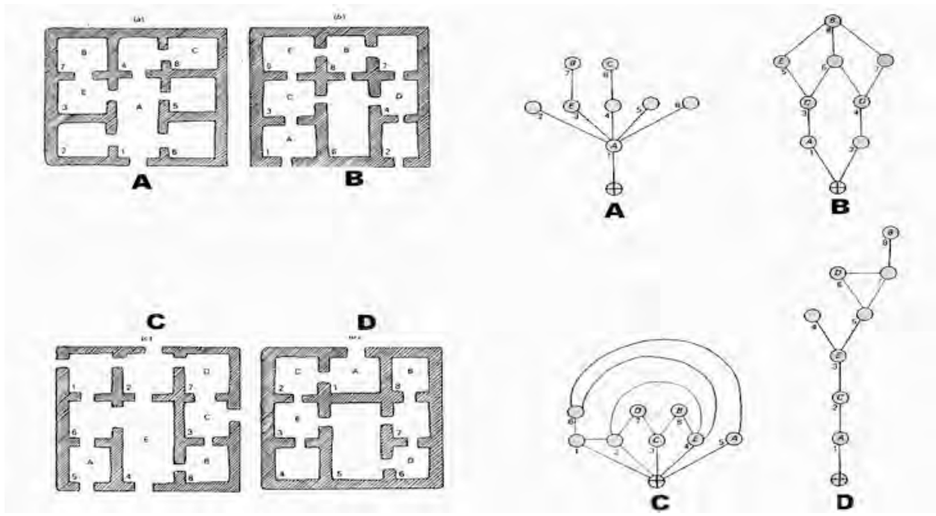


Figure 4.4 Depth can vary even if shapes do not.

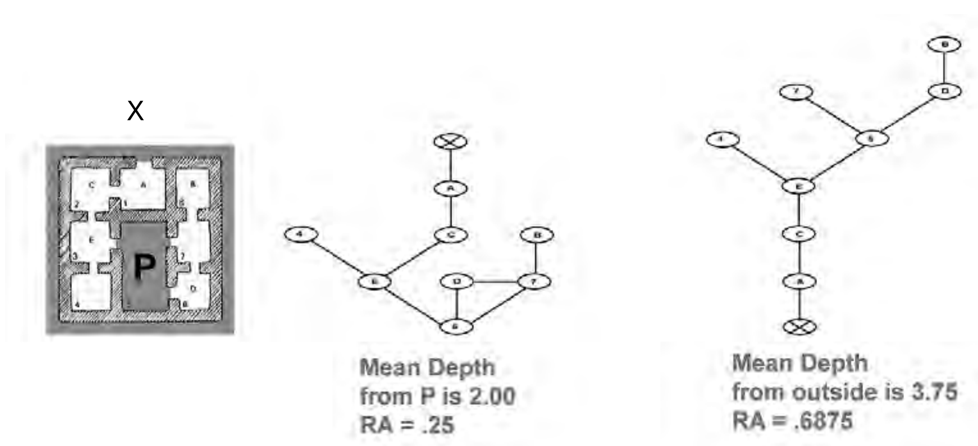


Figure 4.5 Mean depth is different from different spaces in a configuration.

Section 2

Chapter V

Hypothesis

The literature on wayfinding and cognitive mapping is detailed and diverse. As discussed in chapters II and III, wayfinding has been considered both as a direct reaction to the environment and as an activity that is mediated by cognition. In the process, both environmental qualities and human abilities have been studied. Perhaps due to research limitations, this has been done separately. Reality dictates that both the environment and human factors interact together and simultaneously influence wayfinding and cognitive mapping. For example, the task of travelling from one place to another requires a cognitive understanding of the environment, some aspects of travel planning, some procedural or action rules and certain aspects of the environment that are important at the moment of action.

It has been argued that although laboratory research is suitable for controlling for exogenous variables, it tends to miscalculate people's true navigational competence and configurational knowledge (Garling, Lindberg, Carreiras and Book, 1986, pp. 75). On the other hand, a less controlled naturalistic environment permits more regular behavior. Whereas the former prefers 'pure' settings to control all extraneous variables, the latter needs to take all the actual world 'clutter' as interacting phenomena. In this regard, this work supports an 'in-between' position. The research was set up in three real world settings with all their elements intact. These are places in which people interact everyday. On the other hand, attempts were made to control the experiment.

For example, the volunteers were not allowed to ask for directions, a very common wayfinding task, nor were they given a lot of time to perform their tasks as in instances of real wayfinding. Their paths were tracked very carefully and this was taken as an indication of their environmental knowledge. Other methods were also used to extract a similar kind of knowledge; these were: pointing, distance estimation and sketch mapping; all of which were used to validate the data. In this experiment, real world data are taken to be more suited to research in wayfinding and environmental cognition.

Time is another important factor in wayfinding. No two wayfinding tasks can be exactly the same because every action updates the cognitive knowledge of a person, which then affects the next wayfinding task – either the entire one or a subsection of it. Taking this argument to an extreme, one may even debate that as more and more wayfinding tasks are carried out, the internal representation of the environment becomes richer and richer; eventually some important properties and elements of the environment may not even have any effect. For example, as a person gets to know his/her neighborhood, its landmarks, signs etc. may gradually become unnecessary for his/her wayfinding within it. In this experiment the reliance on the environment is expected to lessen as people spend more time in the setting.

Learning about an environment by walking through it is a natural act. In this process, bits of the environment are revealed sequentially and from this series of events, a complete understanding is achieved. Therefore, it is assumed that along with discrete properties of the environment, the relational properties between various discrete spaces are also important. Relational properties are those that consider how an individual space is related to other spaces. Although many kinds of relationships between spaces can be listed, this research only takes into account those that are revealed by movement through the environment. Such relationships are topological and visual. At this point, a distinction should be made between topological and visual relationships. In figure 5.1, space A is three steps away from B, but there is no visual relationship between them. This study hopes to demonstrate that considerations of such relational properties are more important in the research on wayfinding and environmental cognition.

The need for environmental knowledge for wayfinding varies according to the state of wayfinding itself. As mentioned in chapter II, the environmental properties that are important in exploration may not be so in a search condition. Also, a different set may be influential in a different wayfinding condition, such as navigation. With increasing environmental experience, reliance on its various properties is expected to shift from one kind to another. Previous research that considered such a changing emphasis on various environmental properties is quite rare. This work will attempt to explore such micro genetic development and expects a shift from reliance on local properties to more relational ones.

In terms of environmental knowledge, the questions that have been asked most frequently are these: what are the elements of the cognitive map? and what real life relations among those elements are understood and stored in the mental representations? Prevalent theories include discrete elements like landmarks and routes, suggestions of topological relationships and perhaps survey knowledge of the setting. In some of these, topological relationships are considered to be precursors to the ultimate survey knowledge. Unfortunately, the relationship between topological knowledge and survey knowledge or the development from one to the other is far from being clarified. This is another important aspect that this study aims to explore. It is expected that rather than survey knowledge, or before survey knowledge, topological configurations will be understood that considers larger and larger systems.

Obviously such a hypothesis cannot be devoid of Space Syntax theory. First, Syntax describes and deals with those aspects of the environment that are perceivable; second, it provides a complete theory of topological relationships; and third, it has a computer-based program that can be used to investigate such relational properties. A basic assumption of this thesis is that relations among various environmental elements are important and development of environmental knowledge entails better and better understanding of these relations. On the other hand Space Syntax provides a well-established method of investigating relationships in the environment. Thus it promises to be a good match and a useful tool. Conversely, environmental cognition and wayfinding promises to be a valuable addition to Space Syntax literature.

An interesting aspect of topological relations is that each space can have many values depending on the radius of the relationships that is used for calculation. Therefore it allows the modeling of various levels of configuration and Space Syntax accommodates this need. This should be important specifically with the hypothesis adopted here, which is that environmental learning of relationships develop by considering both deeper and deeper relationships as well as larger and larger configurations.

Since Space Syntax essentially deals with topological relationships, it is a very important aspect of this study. Earlier experiments on wayfinding that used this theory were by Peponis, Zimring and Choi (1990) and Willham (1992). Haq (1999a) used Syntax to study wayfinding and to comment on environmental cognition. Perhaps encouraged by the tradition of Syntax researchers that had ascertained the significance of Integration in various movement researches, these wayfinding studies also found Integration to be important. All of these studies reported significant correlations between Integration and wayfinding use of spaces. However, the novice explorer who cannot have any sense of the overall layout is not expected to understand Integration because it is a global measure that takes into account all the spaces in the configuration. Instead s/he may be more influenced by the local characteristics. The fact that Integration was found to be important in wayfinding, perhaps implied that a sense of configuration is very quickly picked up. This idea was advanced by Garling (1982) and supported by both Peponis et al. (1990) and Haq (1999a). On the other hand, an alternative explanation that could be forwarded is that since all these studies were carried out in highly intelligible settings where Integration and Connectivity values correlated, the results could have simply reflected a preference for local characteristics; one that is understood as connectivities. This study recognizes that a person new to an environment cannot have a sense of the total layout. Instead, in the beginning stage, local properties are expected to be more influential. Thus, it is expected that in the early stages of immersion in a new environment, locally available information i.e. those that can be discerned from a person's station point will be more important. Gradually, as a person's environmental learning increases; s/he will depend on non-local properties. For this reason the environment is categorized by local and global properties. An important task of this research is to focus on the shift from topological to metric properties that is thought to take place with increasing environmental understanding. It is underscored here that global levels of topological information gradually builds up from local measures of connections. This global level knowledge is but topological considerations that incorporate larger and larger systems and deeper and deeper depths.

Thus one hypothesis in this experiment is that Syntax connectivity will be more important in Open Exploration, which operationalizes initial contact with the environment, but this will change to better knowledge of Space Syntax Integration when the environment is known, operationalized here as Directed Searches.

In 1982, Kaplan and Kaplan identified a human preference for landscape scenes that contained a certain element of 'mystery' in them. Approaching this finding from an evolutionary point of view, the researchers have argued that it is an expression of man's natural tendency to explore the unknown. If this argument is accepted then it can be assumed that many people will be drawn to areas that offer more exploration possibilities. Specifically for this study, areas that have high exploration potential will be expected to have a higher use in Open Exploration. The Syntax concept of Connectivity is one property that captures the possibilities of exploration. Additionally other values for decision points or nodes, called DP degree are developed.

Analyzing spaces from the point of view of depth allows each unit space in a layout to have a different value depending on how it is connected to all the other spaces. This seems to be particularly important for entries to the complexes. This is because entries with lower Mean Depth will be closely related to all other constituent spaces and this closeness should be apparent to the walking observer. Thus another hypothesis here is that the Mean Depth of an entry space will have some influence on how explorers in an environment will be spatially distributed within it. In other words, does the property of the mean depth of an entry point have any role to play in the way an environment is explored and understood?

The next chapter will explain the research in more detail.

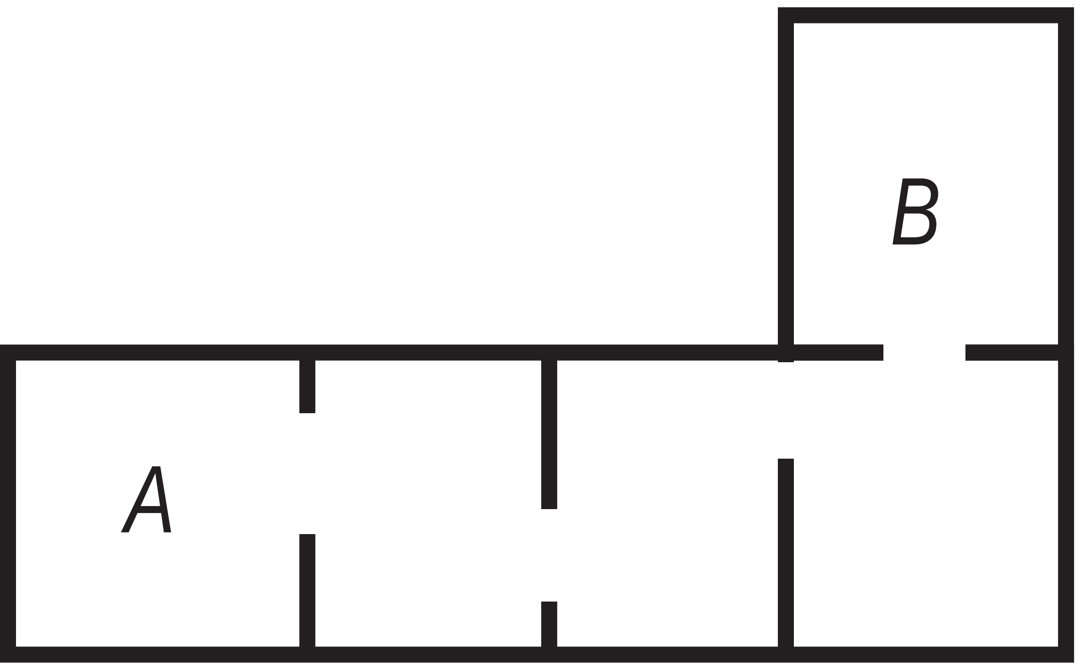


Figure 5.1 *Topological and Visual Connections.*
A is 4 steps away from B, but A and B are not visually connected.

Chapter VI

The Research

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1 INTRODUCTION

Discussing the built environment from the point of view of wayfinding, Arthur and Passini (1992) remarked, “it may be of interest to know which buildings people remember best, but more important … is an understanding of the physical and non-physical characteristics that make buildings memorable”. This thesis will be concerned with the physical characteristics of buildings, in particular, the configuration of its spaces with respect to wayfinding and environmental cognition. It is assumed that people learn about their environment as they *move* through it. In this diachronic process, the spatial information that is obtained is of a sequential nature and therefore a certain kind of mental activity is required to process this successive input into a comprehensive understanding of the environment. From such a position, it follows that movement can be taken as one indicator of cognitive activity. This idea perhaps originated with the empirical work of Lynch. Although not expressed as such, he had tapped into the knowledge of cities by considering everyday movement of his subjects (Lynch, 1960).

This chapter describes the empirical experiment that was undertaken to investigate the relationships between environmental understanding of situated humans and the environment itself.

The research uses wayfinding in complex architectural settings as observable behavior that reflects environmental understanding[1]. As developed in the previous sections, relational variables of the environment are taken as important environmental properties.

The work was carried out in three large and typically complicated urban hospitals. The empirical process that was adopted for this research will be discussed next. However, as a prelude, the three hospitals will be introduced.

2 DESCRIPTION OF RESEARCH SETTINGS

Three settings were used in this research and they were all very large urban hospital buildings: Urban Hospital, University Hospital and City Hospital. They were chosen because of the difference in their layouts and complexity, and also because of their proximity to the researcher's operational base.

In all of these hospitals, only one floor was used. The floor that attracts the most visitors was the ideal choice. In all cases this floor had one or more main entries. Since all of the hospitals had more that one entry, the most visible one was chosen or a selection from the most visible was used. Three entry points were chosen for Urban Hospital, one for University Hospital and two for City Hospital. General descriptions of the three hospitals are given below.

[1] This experiment was carried out with the authorization dated 2/17/97 of the Institutional Review Board, Georgia Institute of Technology, Atlanta.

2.a Research setting 1: Urban Hospital

Conceived by a vision of providing health care for the indigent sick of the city, Urban Hospital became a reality in 1892. Its mission was to become the foundation of health care throughout the larger community and, in doing so, provide quality and affordable health care to its disadvantaged members. After more than a century of operation, and in correspondence to the evolving need of the times, the hospital has transformed and expanded; and in the process, has become a complex physical entity with all associated problems -- including those of wayfinding.

Urban Hospital is large, having 837 beds and 230 outpatient clinics. It is located in a 17-storied structure in a downtown location. It is the largest general hospital in the state and one of the largest in the world (see figure 6.1). Nearly 40,000 inpatients and more than 750,000 outpatients – including approximately 230,000 in emergency clinics – are treated each year at this hospital. It is also the teaching hospital for two important schools of medicine.

A good percentage of its users are poor people belonging to minority communities and many among them cannot speak or read English. Unfortunately, this hospital is also the last resort for people with limited means and this, coupled with its inner city location in Atlanta brings to it a lot of traumatized emergency patients. However, Urban Hospital has always enjoyed abundant funding and is now a premier inner city hospital.

Streets surround the tall hospital building. It has three on its east, west and north sides and a fire way on the south. In 1996, this hospital completed a 400 million-dollar architectural renovation and addition that streamlined its services and increased its patient accommodation. An entire new clinic building was constructed to the south that was connected to the main hospital building by a high atrium. This atrium also provided two new entrances from the eastern and western streets. The western facade of the main 17-story hospital was added to and this created a new 'face' towards the city. It has brand new finish materials that give it a contemporary look. The eastern side was not part of the renovation and so retains the look of the older brickwork. Imposing porches that come out to the sidewalk mark the old entrances in this side. In contrast, there are no porches in the new eastern entrances, but these have high doors to correspond to the high lobbies to which they lead. The polished finish materials, the entrance arcade and the inspiring high entry portals give the renovated part a very imposing character.

Finally, duplication of services was eliminated and functions were reorganized and relocated in the interior to correspond to the new and extended layout. All these efforts brought a contemporary image to the 34-year-old building. However, as administrators were quick to realize, it also created a major wayfinding concern. Some of the reasons are outlined below.

First, the differentiation of renovated and unfinished areas is apparent in the corridors and public areas. This is shown in figure 6.1. A person walking through the halls might be in an old unrenovated corridor in one moment and in a contemporary, gleaming and highly finished area the next. Undoubtedly, such an experience has an effect on anyone wayfinding within the hallways.

Second, the extended hospital was designed to open to the western Street. Unfortunately, after the renovations and extensions were complete, that street was closed off to vehicular traffic and was made into a pedestrian zone. As a result, signs sprung up in the approach streets pointing to the old drop off in the rear (eastern street) and an uniformed officer was seen every day directing confused drivers. In this way, the natural flow of the incoming vehicles was hampered and disorientation started with concerns of parking and finding the entrance.

Third, the building, as completed, has 6 public entrances; it can be entered through two new entrances to the west, two old and a new one to the east and the new emergency entrance on the northern connector street. Naturally people enter from the doorway that is nearest to where they have parked or were dropped off. Therefore, there is constant confusion inside by people who travel the length of the hospital to reach a destination at the far end from their entry point.

Fourth, the proposed remodeling job could not be completed. Therefore, certain departments were not relocated to their designated areas. On top of that, temporary construction detours were made permanent, all of which further aggravates wayfinding difficulties.

Fifth, there is an undesirable situation in terms of signage. Some of the old signs were still in the hospital, and the new signs were confusing because they reflected the proposed but unfinished design. On top of that, there were numerous computer prints of various sizes taped to the wall. All of these together create a complicated and confusing wayfinding environment within the hospital.

The final element of complexity was provided by security concerns in the emergency room that had prompted the authority to install manned metal detectors in the corridor leading to it from the hospital and in the emergency entrance. Although a necessity, these act to further discourage people in their wayfinding. They also affected some experimental subjects who were hesitant to cross the metal detectors and did so only after being assured by the researcher. Out of the 31 subjects who were asked to carry out the experiment, only 10 ventured into the emergency room.

The ground floor of this hospital and the 3 entrances marked A, B and C in figure 6.1 were used for the experiment.

2.b Research setting 2: University Hospital

University Hospital is a 587-bed adult, tertiary care facility staffed by 663 University School of Medicine faculties who are members of the Clinic. The Hospital includes a 47-bed psychiatric facility, a 56-bed rehabilitation center, and a nine-bed clinical research center that is supported by the NIH. The hospital had 19,807 inpatient and 92,978 outpatient visits in 1998. Long known for cardiology, cardiac surgery, oncology, and neuroscience, University Hospital has become one of the region's largest multiple organ and tissue transplant centers. It has the highest level of treatment for acute and chronic illnesses, as well as the most sophisticated and advanced procedures in transplantation. In fact, more than 20,000 patients from around the world come each year to University Hospital, one of the preeminent specialty referral centers in the nation. In 1998, this Hospital was named in 12 of the 16 specialties ranked by U.S. News & World Report in its publication of Best Hospitals in America.

Physically, this hospital is composed of a number of different-sized buildings that are connected to one another in a linear fashion such that a very long central corridor is formed in the middle (see figure 6.2). These buildings are of various heights and on some upper floors one cannot go from one building to the other. Therefore, in the case of overall wayfinding, one needs to be very careful about choosing appropriate elevators from the main level. However, in the experiment only this floor was used and so the particular factor of choosing elevators did not become a wayfinding issue.

Pedestrians coming to this hospital have two alternatives. They can walk from the parking structure, through the outpatient clinic buildings, cross a bridge and reach the southeast corner of the second floor. Alternatively they may choose to be 'on ground' and bravely cross a very busy street and come to the main entrance, also on the second floor. This entry is architecturally defined and is highly recognizable. There are two other options for pedestrians, but mainly staff and others who are acquainted with the larger environment use those. One is through an underground tunnel system that connects adjacent buildings and the other is through what is often considered the 'rear entrance' – on the western side of the building on the first floor. People who get dropped off from vehicles arrive in the first floor directly below the bridge. However, they can choose various routes to climb to the second floor and so there is some amount of disorientation. Overall, the central 'spine' creates a strong sense of location that helps in the orientation of the visitor.

The experiment was conducted on the second floor of this hospital and used the entrance marked A in figure 6.2.

2.c Research setting 3: City Hospital

Established in 1908 as 26-bed sanatorium, City Hospital is now a 583-bed community-based, tertiary care center that is staffed by 561 community physicians and 483 University School of Medicine faculties who are members of the Clinic. Medical services include four 12-bed acute intensive care units, a level III neonatal intensive care unit, and a two-chamber hyperbaric oxygen unit. Women's services include prenatal and postnatal education, bone density testing, mammography, menopause management, and maternity services with a specialization in high-risk obstetrics. This hospital had 19,040 inpatient and 89,193 outpatient visits in 1998.

City hospital grew over time and is now made up of four connected buildings that were built in different periods. Of these, three are clustered together. The second floor of this group was considered in this study (see figure 6.3). The northwestern block of the cluster is the original building in which this hospital was started and now contains the laboratories and associated spaces. The southwestern block houses the administrative offices. A cafeteria is sandwiched between the north western and southwestern block, with the office of the CEO just east of it. Together they act as a continuous sequence of corridors with a dull institutional look. There is very little distinction made by the finishing and furnishings. However, an observant visitor may be able to pick out the differences due to the functions of the various spaces, i.e., between the laboratories and office spaces.

The third block is the eastern wing which is the most recent addition to the complex. It houses all the patient rooms and is therefore distinct both by the series of similar rooms lined one after the other and also by the interior finishes and furnishings that are more recent and include the use of cheery colors and more contemporary finishes.

Since this hospital is built on a sloped terrain, a visitor coming in may enter either on the first or on the second floor, depending on which entry s/he chooses. The first floor has the main entrance lobby in the eastern block and is entered from the north. The rest of the areas on this floor are mostly offices and services and so most of the visitors have to take an elevator immediately after passing through the lobby to go to their destinations. There are two additional entrances from the south, which are on the second floor. The first leads to the southwestern block and the second to the connecting area between the eastern and the southwestern blocks. Both of these entrances however, are from the same external plaza/drop-off area. However, as soon as they enter, the experiences of the two groups are completely different.

As the first floor is mainly services and a few offices, the experiment was conducted in the second floor; and the participants entered from either of the two southern entrances marked A and B in figure 6.3.

3 ENVIRONMENTAL VARIABLES

This section begins with the identification of those environmental units that were thought to be consequential in environmental understanding. It then proceeds to the analysis of the three hospitals and their environmental variables.

From the point of view of the environment, movement brings attention to such properties of spaces as are derived from various *relationships*. This is in contrast to the properties of individual spaces when considered as discrete units. These *discrete* properties of the environment are more apparent to the static observer. Since environmental learning is a product of movement, it is hypothesized that *relational* variables are extremely important in the formation of cognitive maps and thus are an important factor in the study of human movement.

Two questions then arise: 1. what are the *units* of the environment whose relational properties are important? and 2. what kind of *relationships* should be considered? These are discussed next.

3.a <u>Environmental Units</u>

A rigorous description of any environment must commence with the specification of environmental 'units'. Once that is done, then properties of those 'units' can be investigated and quantified. Two kinds of environmental units were considered in this study. They were: *Uninterrupted Visibility Lines* and *Decision Points*.

3.a.1 Uninterrupted Visibility Lines

Firstly, it is fairly easy to understand that visibility is an important issue in movement. Therefore the extent to which one has an uninterrupted view is important. Secondly, an area in which one needs to make a decision regarding direction is consequential because those spaces are usually areas for pause and the taking in of new information. Hence, one may expect a particular property of it to yield a clue about the decision of direction. This is also important from the point of view of the ecological model of wayfinding that was discussed earlier.

Peponis, Zimring and Choi (1990) pioneered the use of Space Syntax axial lines as environmental units in a study of wayfinding. Methodologically, axial lines are particular instances of uninterrupted visibility lines. This was discussed in detail in chapter IV entitled Space Syntax. In this study too, Space Syntax axial lines were taken as representatives of uninterrupted visibility lines.

3.a.2 Decision Points

Decision points were simply intersections of corridors. For many of the variables that were considered in this experiment, they were further operationalized as intersections of Syntax axial lines.

3.b Relations between Environmental Units

When relational properties of unit spaces are being sought, then not only is one unit's relationship to others is considered, but also, how the others are related to that unit. For example, in a *Node* or *Decision Point*, one is aware of other visually related points, or nodes, but at the same time a person also gets a sense of the many possibilities of coming back. It is this two-way relationship that needs to be recognized.

Once the environmental units were defined, then they could easily be plotted on a computer over a plan of the setting. From this, some discrete variables could be measured.

Relational variables obviously, were slightly different and more complicated. For example, one space may be related in a certain way, to its adjacent spaces, to spaces at some specified distance/depth, or to all the spaces in the system. In this manner, three kinds of relationships are possible: locally related, related at a certain depth and globally related (see table 6.1). Unfortunately this description remains incomplete without answering the following questions: 1. what kinds of relationships should be considered? 2. to what extent or depth should these relations go up to? and

3. what constitutes a complete environmental system? or what are the limits of an environment?

These are discussed below.

3.b.1 Spatial relationships

Two kinds of relationships were considered in this study: *visual* and *topological*. Visual relationships were established by simple visual connections. Mostly they were concerned with connections between adjacent spaces and were therefore *locally* relational. Topological relationships considered how each space was *connected/related* to the other spaces, whether one could go directly or had to go through others to reach a destination space. Kuipers (1983) and Hillier (1984), among other researchers, have stressed on the importance of topological relations. This kind of relations deals with access to each space and also involves the concept of depth. These are discussed in the next section.

3.b.2 Depth

The concept of depth is an important one in Space Syntax. It is best explained by referring to figure 6.4. Topologically speaking, space A is 1 depth away from B, 2 from C and E, 3 from D and so on. In other words, it has a different relationship with the different spaces in the system. The relationship that a space has with all other spaces in a system is *global*. The relationship that it has with its adjacent spaces only, i.e. depth 1, is *local*. Any other *intermediate depth* can also be counted. For example, Space Syntax theorists routinely use relationships of depth 3. Depth 3 will also be used in this study.

3.b.3 Limits of the Environment

Any architectural environment is made up of many spaces. In a publicly functioning complex building, such as a hospital, an airport or an office, there are some spaces that are restricted and unavailable to the visitor. Therefore the environmental experience can be quite different between the staff and the visitors – mainly because one group has access to some spaces that the other group does not have. From this point of view, any environmental setting may be considered as separate systems. Two such systems were considered in this study: a *public system* that is made up of all the spaces through which a visitor may go unchallenged, and a *complete system* that takes into account all the spaces in a setting. Thus each relational unit that was considered in this research actually produced two values. One was computed using the public system and the other from the entire system. (These values are denoted here as 'pub' and 'all'.)

3.c <u>Description and Quantification of the Environment and its Units</u>

As mentioned before, the environmental units considered in this study were Uninterrupted visibility lines or *Axial lines* and Decision Points or *Nodes*. Space Syntax was an important method in this task and its measures of *integration*, *connectivity* and *mean depth* were extensively used along with others described here. In total, 23 different kinds of environmental measures for two kinds of environmental units were considered. These are shown in table 6.2.

3.c.1 Uninterrupted Visibility Lines or Axial Lines

Identification and analysis of uninterrupted visibility lines were done by using Space Syntax methodology. At first, the layout was reduced to a minimum set of convex spaces. Then, the longest lines that could connect the maximum number of these spaces were drawn. Thus, an axial system or an axial map was produced. By definition, these axial lines were also the uninterrupted visibility lines of any person who is situated at any point within the building.

These lines were then analyzed on a computer using the software *Axman PPC* for Urban Hospital and *Spatialist* for the other two. This produced output in two formats: a colored representation of the axial lines that corresponded to the relational values of each line and a table of these values. The lines in the colored representation ranged from bright red to deep blue, with the reds being more integrated and the blues being more segregated (see figures 6.5 to 6.16).

By this procedure values of axial lines from global and depth3 relations were determined. Also, the environment was considered in two levels – the public system and the total system. Figures 6.5 and 6.6 show the colored representation of the global level axial analysis and figure 6.7 and 6.8 show the depth 3 level analysis of Urban Hospital. Figures 6.9 through 6.12 show the same for University Hospital and figures 6.13 through 6.16 show those for City Hospital.

The other axial line measures that were used in the research are described in the following sections (see also table 6.2).

3.c.1.1 Discrete Axial Line values

Connectivity (pub): This is a count of other axial lines in the *public system that intersect* the origin line.

Connectivity (all): This is a count of other axial lines in the *total system* that intersect the origin line.

Although a simple count, values of the above were determined by the computerized Syntax analysis.

3.c.1.2 Axial Line values from intermediate relations

Integration3 (pub): Integration values calculated to depth 3 from *the public system only.*

Integration3 (all): Integration values calculated to depth 3 from the *entire configuration.*

Values of the above were determined by computerized Syntax analysis.

3.c.1.3 Axial Line values from global relations

Integration (pub): This is the integration value that is calculated *from the system of corridors and spaces that are open to the public only.*

Integration (all): This is integration value read from *all the spaces in the hospital.* This is the spatial system that would be accessible to a staff member who had a passkey to open all the doors.

Values of the above were determined by Syntax analysis.

3.c.1.4 Mean Depth of Axial Lines from entry points

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 the purposes here, the entry points were important because one hypothesis was that the entry points make a difference regarding how an environment is explored.

The analysis tool used is called 'justified map' or the 'justified permeability map' (Hillier and Hanson, 1984). This was discussed in Chapter 4. Figures 6.17, 6.18, and 6.19 show the 'justified permeability maps' of Urban Hospital from entrances A, B and C respectively. Figures 6.20 and 6.21 show the values for the two entrances A and B of City Hospital. These give a visual representation of 'depth' from the entries, i.e. how shallow or deep it is in connection to all the other spaces in the 2 hospitals.

Depth can also be mathematically expressed. This is denoted by *mean depth* and was calculated by summing up the products of the number of spaces in any line with their depth and dividing the value by all the spaces less one (Hillier and Hanson, 1984). The mean depths of the entries in the two hospitals are shown in table 6.3. It was hypothesized here that the hospital would be better understood and better searched from entries with a lower mean depth i.e. from areas most 'shallow' to all the spaces. A later section of this thesis will deal with this aspect in relationship to the actual wayfinding behavior.

3.c.2 Decision points or Nodes

Since nodes were considered to be the intersections of axial lines, the average values of these lines, as obtained from line analysis, were used as their values.

However, other variables were also considered. A detailed list is given in table 6.2 and is described below.

3.c.2.1 Discrete Node values

Degree: This is the number of choices available at any node and was easily obtained by examining the plans of the settings. Degree includes the approach segment of any node; i.e. it considers the ability of the way-finder to backtrack. For example, the degree of node A in Fig 6.22 is 4.

3.c.2.2 Node values from Local relations

Connectivity (pub) and **Connectivity (all):** These are the average connectivity values – both for public system and entire system, of the axial lines that form the node.

Note that connectivity for nodes is a relational value while connectivity for axial lines is local. This is because connectivity in nodes is the average connectivity of axial lines that produce it and implies views through adjacent nodes. In axial lines this information is directly available and so it is local.

DP degree (Decision point degree): This is the number of decision points that can be seen from one node, not counting itself. Conversely, DP degree indicates the number of other nodes from which a node can be seen. This therefore evokes the possibility of coming to one node from others. This is either equal or greater to the degree value of the node. For example, the node A in Fig 6.22 has DP degree value 3. This measure is considered relational because it implies views through adjacent nodes. This variable was defined by Willham (1992).

Nodes Recognized: This is a value that expresses the number of other nodes that can be *recognized* from any point. This is contrasted to the number of nodes that lie on an axial line and can theoretically be 'seen'. In reality however, because of distance and/or lack of distinctiveness, some of these nodes cannot be recognized. As the name implies, 'Nodes Recognized' only considers those nodes that may be recognized from any node. This is considered important because it takes human sensibilities into consideration while describing environmental variables.

Calculation of 'Nodes Recognized' was done by having a group of independent judges who physically stand in the nodes of the various hospitals and estimate how may other nodes they could identify. The researcher was the only judge in Urban hospital, whereas in University and City hospitals there were 3 and 13 judges respectively (see table 6.4).

This variable was also expected to be a function of the Node Visibility Area (NV Area) described next.

Node Visibility Area (NV Area): This variable was developed as an attempt to objectively determine nodes recognized. First, the area of a node was measured by extending the surfaces of the corridors. It was assumed that a node would theoretically be visible from other nodes that are located in a straight line from it. If sight lines are drawn from the central point of adjacent nodes, then the extra area that will be visible is called NV area or Node Visibility Area (see figure 6.23). It was measured in unit area, i.e. square foot. Although NV Area will increase as a person approaches a node, yet, for experimental purposes, the NV Area was calculated from adjacent and visible nodes; i.e. intersections of axial lines.

For this experiment, NV area for each node was done for City Hospital only. It was calculated by drawing each one of them in *MicroStation*.

Occluding Edges and Occluding Angles: These variables were calculated as an extension of the Node Visibility (NV) Area. After each NV area was determined, the numbers of occluding edges, in each node, from all adjacent nodes were counted. Also, the occluding angles, in degrees, were noted. The occluding angle value that was assigned to each node was the sum of all the angles from all the adjacent nodes.

Isovist Area, Isovist Perimeter and Isovist area/perimeter ratio: Responding to the fact that the overwhelming bulk of perception research was done in the context of environmental perception, Benedict (1979) proposed the construct called *isovists*. This is a set of all points visible from a given vantage point in space with respect to the environment. It can therefore be used as a tool to describe certain visual aspects of an environment.

Isovists were developed from Gibson's (1966) concept that the visual environment is not a collection of objects, but rather a surrounding layout of surfaces which produces structure to the light that are reflected from them and reaches the human eye. This structured sheaf of rays is the 'optic array' that is responsible for direct human understanding of an environment.

Isovists are important because they can be used to quantify an environment from the various points within it. In this research important environmental areas were intersections of axial lines or nodes; therefore isovists were drawn from all of these nodes. A total of 107 isovists were drawn; among them 46 for Urban Hospital were manually drawn using ClarisCad, but the remaining 61 for University and City Hospital were generated by the software *Spatialist (see figure 6.24 and 6.25).* The area of each isovist in all hospitals was used. Additionally, for University and City Hospitals, the other variables isovist perimeter and isovist area to perimeter ratio was calculated.

3.c.2.3 Node values from Intermediate relations

Integration3 (pub): Average of the integration3 (pub) value of the lines that form the node.

Integration3 (all): Average of the integration3 (all) value of the lines that form the node.

3.c.2.4 Node values from Global relations

Integration (pub): Average of the integration (pub) value of the axial lines that form the node.

Integration (all): Average of the integration (all) value of the lines that form the node.

Actual Node Integration: In contrast to the average value of lines being used as a substitute for node values, this variable is the actual integration of the nodes as they relate to the public system. It was calculated by considering the direct connections of each node to all other nodes in the public system. The calculating formula was the same as proposed in Space Syntax theory. Since the softwares *AxmanPPC* or *Spatialist* only works with axial lines, a separate program was used to calculate the actual node integration. This was written by Sonit Bafna, a doctoral candidate in the College of Architecture, Georgia Institute of Technology. Unlike Syntax programs, this does not produce any colored representation and so they were manually drawn. These are shown in figures 6.26, 6.27 and 6.28.

4 EMPIRICAL METHODS

This research was carried out in two stages, an initial one in Urban Hospital that considered the effect of environmental characteristics on wayfinding as its main focus and an expanded one in the other two hospitals that added cognitive dimensions to the study.

The number of times a unit space was used and how many subjects used that space in an exploration and a search situation quantified Wayfinding behavior. The 2 tasks are denoted here as *total use* and *proportional use* respectively. Cognitive variables were determined through pointing tasks, distance estimation tasks and sketch mapping.

4.a Subjects

In the three settings 128 participants carried out a variety of tasks related to wayfinding behavior and cognitive understanding. The subjects consisted of 62 males and 66 female students mostly aged from 17 to 25 (mean 19.5). They were taken from the Human Subject Research Pool of the School of Psychology, Georgia Institute of Technology, and were carefully screened so that none of them had visited a large hospital complex more than once in the 12 months prior to the study.

4.b Procedures

The various tasks that the subjects performed to get behavioral and cognitive variables are discussed in the following sections.

4.b.1 Behavioral Variables

The subjects were individually met on Georgia Tech campus and driven past one of the hospitals to a nearby parking garage. They were then escorted to a pre-selected entry point. Most of the participants carried out 2 wayfinding tasks. An open exploration of the setting and a directed search for certain destinations within it. Some students did not do the open exploration but upon entry started the directed searches (see table 6.4). These two tasks were previously used by Peponis et al. (1990).

For open exploration the subjects were escorted to one of the pre-selected entry points of the hospital and were asked to freely explore the floor of the complex in which they entered. They were instructed to learn about its layout and locations as best as they could, so that they would be able to carry out specific searches within the environment later. They were instructed not to talk to anyone but to try and fulfill their tasks only from the environmental cues, including signage that they received from the actual setting. They were told that they could go to all the spaces accessible to the public and to stay away from areas marked as staff or treatment zone. If they were confused and tried to go inside restricted areas, the researcher would stop them. Therefore this procedure was not disruptive to the hospital, nor harmful for the participants.

They were then taken to one of the four pre-selected locations within the building and were asked to walk to another one. This was Directed Search. For this they were also given a predetermined amount of time after which that task was abandoned. When they found the destination (or if their time was up they were escorted to that destination) they were asked to go to the next one. This procedure was repeated until each participant had journeyed, or had tried, *to and from* all the selected locations. He four locations were chosen in each setting with respect to the environmental variables that were used in this work.

Tracking as a method of studying pedestrian behavior was first used in the early sixties (Weiss & Boutourline, 1962). The important question in this regard was the possibility of change in behavior when subjects knew that they were being observed by a stranger (Bechtel, 1967). For this experiment, a friendly relationship was established between the subject and the researcher in the very beginning, and the researcher constantly walked quietly a few steps behind the subjects. Since the task was carried out in a cordial atmosphere, there was no reason to assume that the subject's behavior would have been any different if the researcher could unobtrusively observe them. Anyway, the research design did not permit that and also it was not deemed necessary.

The four locations in each hospital that were used are marked 1 to 4 in figures 6.1, 6.2, and 6.3. They were each treated both as an origin and a destination. This resulted in 12 routes in each setting. In total, the 127 research subjects carried out 508 directed searches. The searches were counterbalanced such that each task was done earlier, later, or in between, by all the subjects. In this way, the effect of memory buildup and relevant ease of destination finding in the later tasks was avoided. Table 6.4 shows the number of participants and the various tasks in the 3 hospitals.

The maximum time given to the subjects depended on the size and complexity of the setting. This was determined by running a pilot experiment before the actual subjects were taken to the hospital. Table 6.4 also shows the time allowed in the various hospitals. Only a few subjects used the entire time for open explorations, most of them stopped earlier saying that they had learned the layout.

The researcher followed each subject and recorded their routes by drawing continuous lines in a plan of the building. Whenever a person took more than three steps in any direction, it was noted as using that space/axial line. A different drawing was used for each task so that there could be no confusion in recording the data. Later on, the total use of each space during each task by all the subjects and the number of subjects who used each space (proportional use) were calculated.

This study considered 2 kinds of behavioral variables: use of lines and nodes in the two tasks, i.e. Open Exploration and Directed Search, and Redundant Node use in directed search.

4.b.1.1 Use of axial lines and nodes in open search

Total use and proportional use of both the axial lines and nodes were counted for statistical purposes. Total use is how many times a space was used by all the subjects and proportional use is the number of subjects who used a space. Thus the maximum value for proportional use of a space could only be the number of participants who carried out the particular tasks. Figure 6.29 shows a 'track' of one person in Urban Hospital and figure 6.30 shows the tracks of all the participants there.

4.b.1.2 Redundant node use

Redundant Node Use was calculated from the performance in directed searches. It is the use of nodes when one was *not required* to do so. For each directed search task, the shortest topological route, i.e. the route that has the least number of nodes, was determined. The nodes that lie on such routes were called 'path nodes'.

More than one use of these path nodes and use of other nodes were considered *redundant use.* 'Redundant node use' is important because it gives a measure of wayfinding difficulty. In terms of the environment this provides an index of 'attractiveness' of any node and in cognitive terms this provides a sense of environmental understanding. Redundant Node Use was used earlier by Peponis et. al (1990), Willham (1992) and Haq (1999b) in their study of wayfinding.

Total use and proportional use of redundant nodes was calculated for this study.

4.b.2 Cognitive Variables

Cognitive variables were collected in the second and third hospital used in this experiment generating data for 95 participants. These were collected in association with the wayfinding tasks, after each directed search and at the end of the experiment.

The subjects carried out four tasks: 1. pointing to areas that were known to the subjects but unseen from their locations; 2. estimating distances between them; and 3. sketching the environment in which they had operated and 4. a self-report about their wayfinding skills.

4.b.2.1 Orientation / Pointing

Having subject point to known but unseen destinations has been found to be a successful test of orientation in a number of studies (Siegel, 1981, Sholl, 1996). For this reason it was adopted in this study.

After each directed search, the subjects were asked to point to the location/s that they had come from. These location/s was obviously out of sight and the respondents had to rely on their mental representation to perform this task. It was also done after all the tasks including sketch mapping were completed and just before returning to campus. Therefore each subject performed 13 pointing tasks at different times and with increasing familiarity with the setting. All subjects faced a common direction while performing this task and they were in different locations each time. The pointing was done by using a circular cardboard with angles marked on it in 10-degree intervals and a pointer attached to the center. The subjects pointed with this pointer and its value was read from the graduated perimeter. The angular deviations from the actual location, in degrees, were recorded. In University Hospital and City Hospital the subjects did 377 and 871 pointing tasks (see table 6.4).

4.b.2.2 Distance Estimation

Another test of orientation that has been used is having subjects verbally estimate distances between select locations (see for example, Evans and Pezdek, 1980 and Kirasic, Allen, & Siegel, 1984).

As part of a short questionnaire, the subjects were asked to estimate the actual distance in feet and inches between all the points that they had visited. Since they went to four locations they had to estimate 4 distances. When some students wanted to estimate in meters, they were allowed to do so and their responses were later converted to the experimental units. As a guide, the physical dimensions of the room in which they performed this task were made available to the subjects. The difference between the estimated and the actual distance was recorded as the variables from this task.

4.b.2.3 Sketch Mapping

After distance estimation, each subject was asked to draw the plan of the hospital. Care was taken so that all the subjects faced the same direction while they were drawing. The subjects were sitting down and were provided with a blank letter sized paper and a pencil with an erasure on top. They were given extra paper if they needed it. The verbal instructions regarding sketch mapping was that they should try to draw all the paths that they remembered and to put all the locations beside those paths. Golledge had pointed out that whereas sketch maps contain much useful information, they rarely have metric information (Golledge, 1977, pp. 05). However as collected, these drawings did have the corridors or axial lines, the locations they visited in directed search and some others that they remembered. The maps were quantified by counting the number of times each corridor or line was drawn. Also, a value was given to each of the sketch maps based on a comparison an actual plan of the setting. This considered the overall 'correctness' or configuration of the sketches.

To make sure that the occurrences of lines in the maps were correctly accounted for, two independent raters in each hospital judged a sample of the sketch maps. The researcher judged all of them. In University Hospital two raters and the experimenter rated 10 maps; i.e. each rater had to judge 320 axial lines. They totally agreed 239 times, or 74.69%. Average agreement per map was 23.9 times (out of 32) -- maximum 31 and minimum 15. In City Hospital two raters and the experimenter judged 25 maps, which translated to 600 axial lines. Here they agreed 499 times or 83.16%.

A sample of sketch maps is shown in figures 6.31 and 6.32.

4.b.2.4 Self reported wayfinding ability

The self-report regarding wayfinding capability and employed strategies were collected through a standard instrument developed by Lawton (1996). This is reproduced in figure 6.33.

Table 6.1 Relationships that defined the environmental units.

<table>
<tr><td></td><td colspan="4">Environmental variables</td></tr>
<tr><td rowspan="2">Environmental Units</td><td rowspan="2">Discrete variables</td><td colspan="3">Relational variables</td></tr>
<tr><td>Locally related</td><td>Related to a certain depth</td><td>Globally related</td></tr>
<tr><td>Uninterrupted Visibility Lines
Or
Axial lines</td><td></td><td>Visual relations</td><td>Topological relations</td><td>Topological relations</td></tr>
<tr><td>Decision points
Or
Nodes</td><td></td><td>Visual relations</td><td>Topological relations</td><td>Topological relations</td></tr>
</table>

Table 6.2 The 23 different units of the environment that were considered in this study.

Environmental Properties		Line Units	Node units
Relational	Global	Int. (pub)	Int. (pub)
		Int. (all)	Int. (all)
			Actual Node Int
	Specified	Int.3 (pub)	Int.3 (pub)
		Int.3 (all)	Int.3 (all)
	Local		Conn. (Pub)
			Conn. (all)
			DP degree
			Nodes Recog.
			N.V. Area
			No. Occluding edges
			Occluding Angles
			Isovist Area
			Isovist Perimeter
			Isovist area/perimeter ratio
Discrete		Conn. (Pub)	Degree
		Conn. (All)	Node Area

Note: "pub" = public system and "all" = total system.

Table 6.3 Mean Depth values from different entries of the hospitals

Hospital	Entry	Mean Depth Value
Urban Hospital	A	5.234
	B	2.737
	C	3.658
City hospital	A	3.478
	B	3.261

Table 6. 4 Comparison between the various tasks in the three environmental settings.

	URBAN HOSPITAL	UNIVERSITY HOSPITAL	CITY HOSPITAL	ALL HOSPITALS
no. male students	13	13	36	62
no. female students	19	16	31	66
total students	32	29	67	128
Number of entries used	3	1	2	6
subs doing open exp from A	10		45	
subs doing open exp from B	13		22	
subs doing open exp from C	9			
Time given for open exp.	20 min	15 min	15 min	
Time given for dir seacrh	15 min	10 min	10 min	
no. subs started with open exploration	32	14	42	88
no. subs started with directed search		12	12	24
no. judges 'Nodes Recognized'	1	3	13	17
no. pointing tasks		377	871	1248
av. dist. est error		167.855	152.026	
av. pointing error		23.303	37.854	
No. directed searches	124	116	268	508
No distance estimation tasks		116	268	384

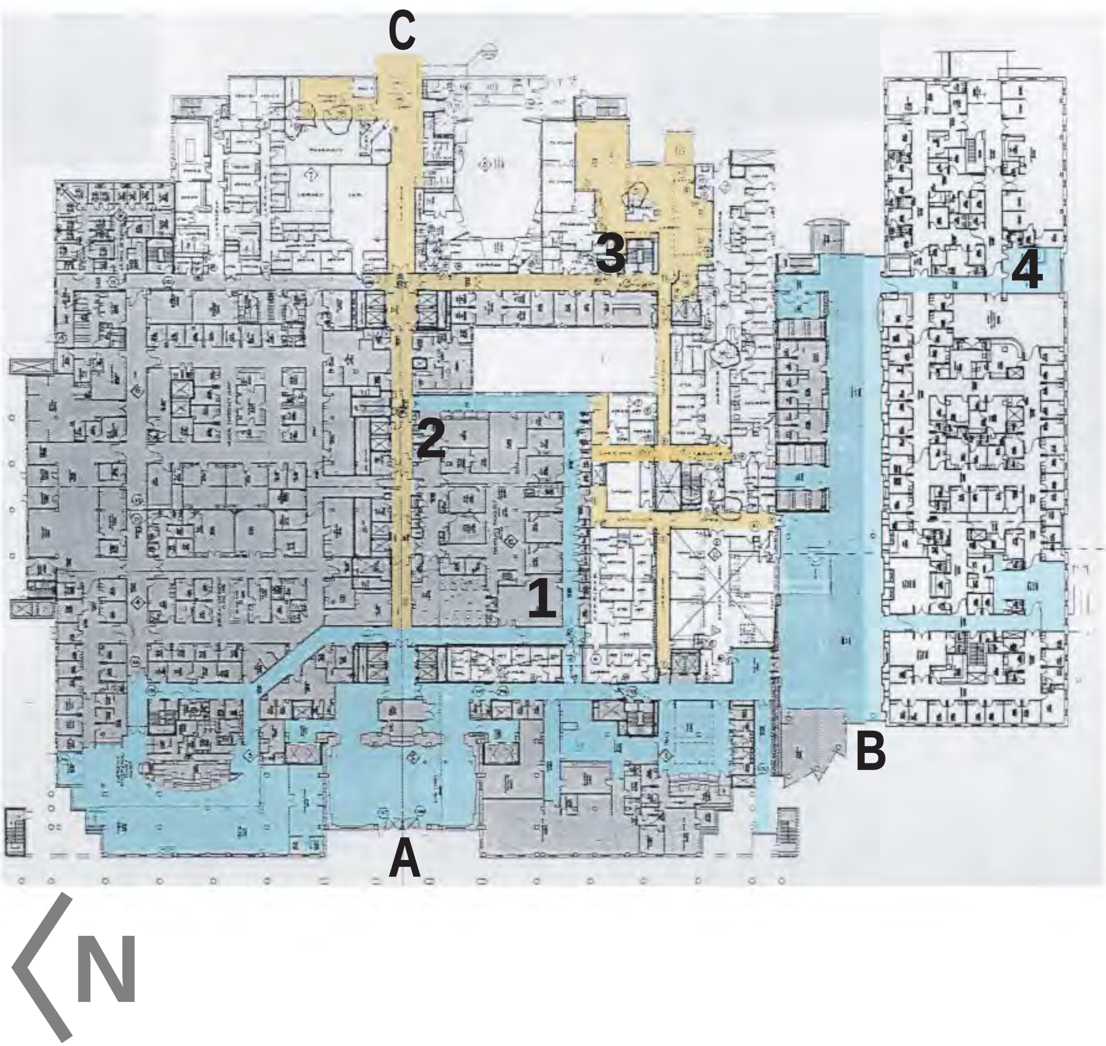


Figure 6.1 *Plan of Urban Hospital.*
The areas marked in blue are renovated while those marked yellow are not. Together they produce a very confusing condition. The entries used are marked A, B and C. The locations used for directed searches are marked 1 to 4.

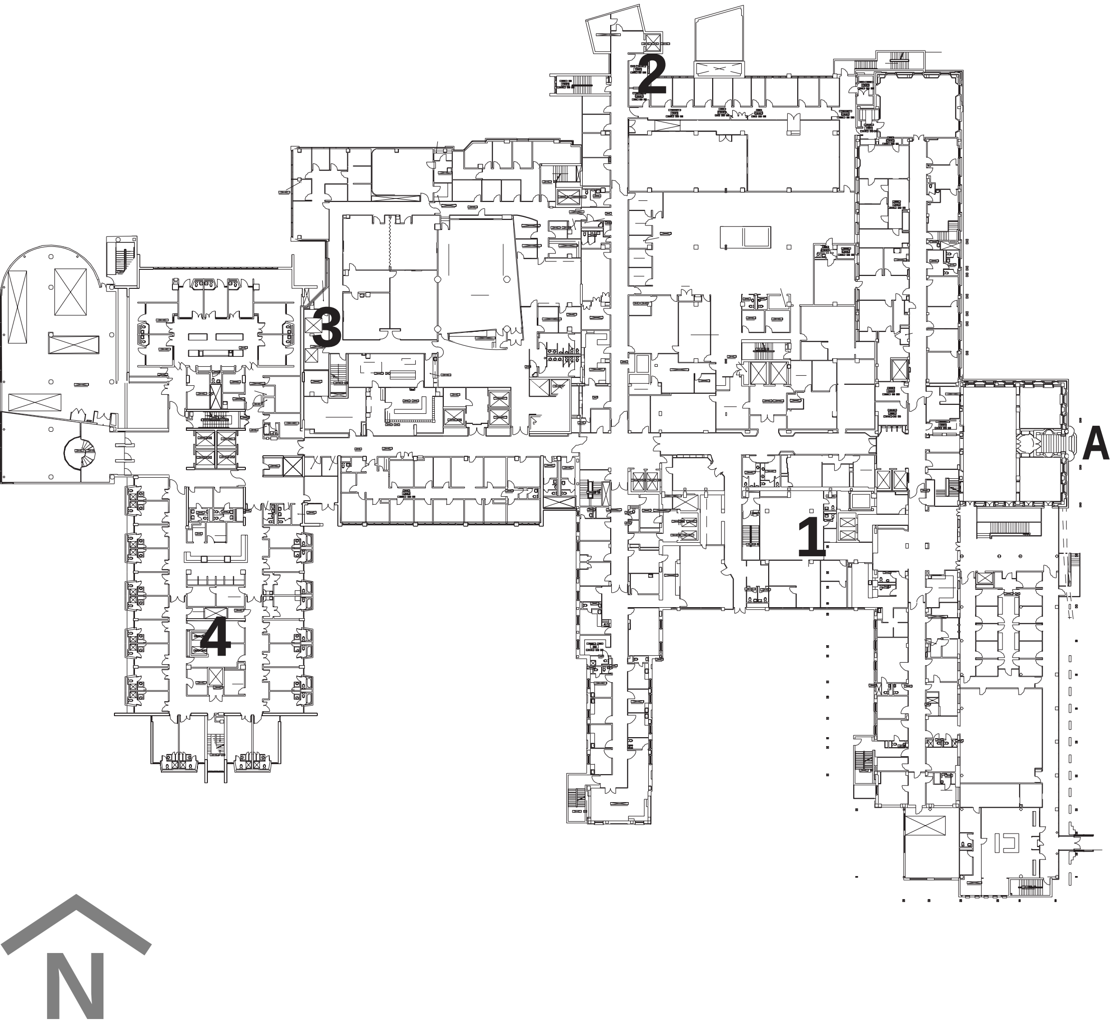


Figure 6.2 Plan of University Hospital.
Although different buildings form an interconnected mass, a central corridor create a strong sense of orientation. The Locations used for directed searches are marked 1 to 4.

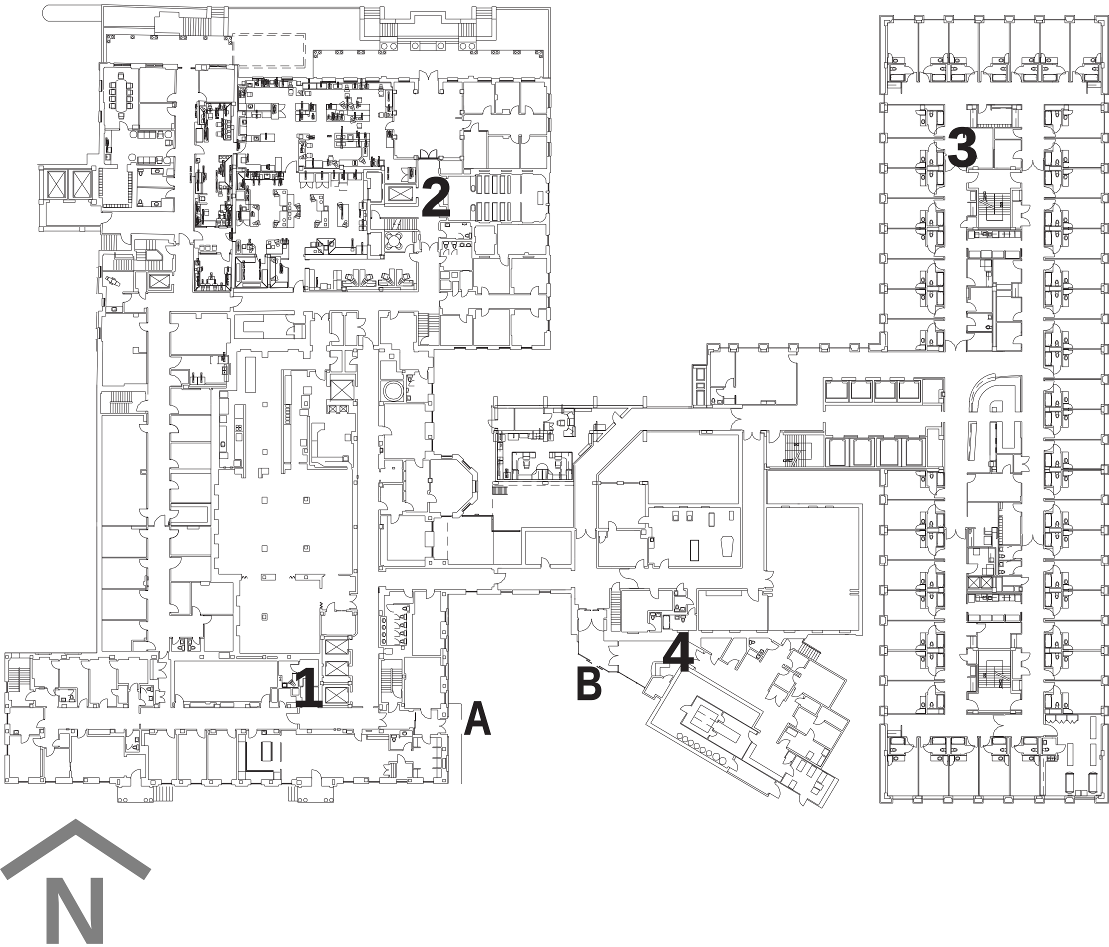


Figure 6.3 Plan of City Hospital.
Three buildings are connected together to form a continuous mass. A north western part, a south western part and an eastern wing. The connecting central part also houses various functions. The entries used are marked A and B. The locations used for directed searches are marked 1 to 4.

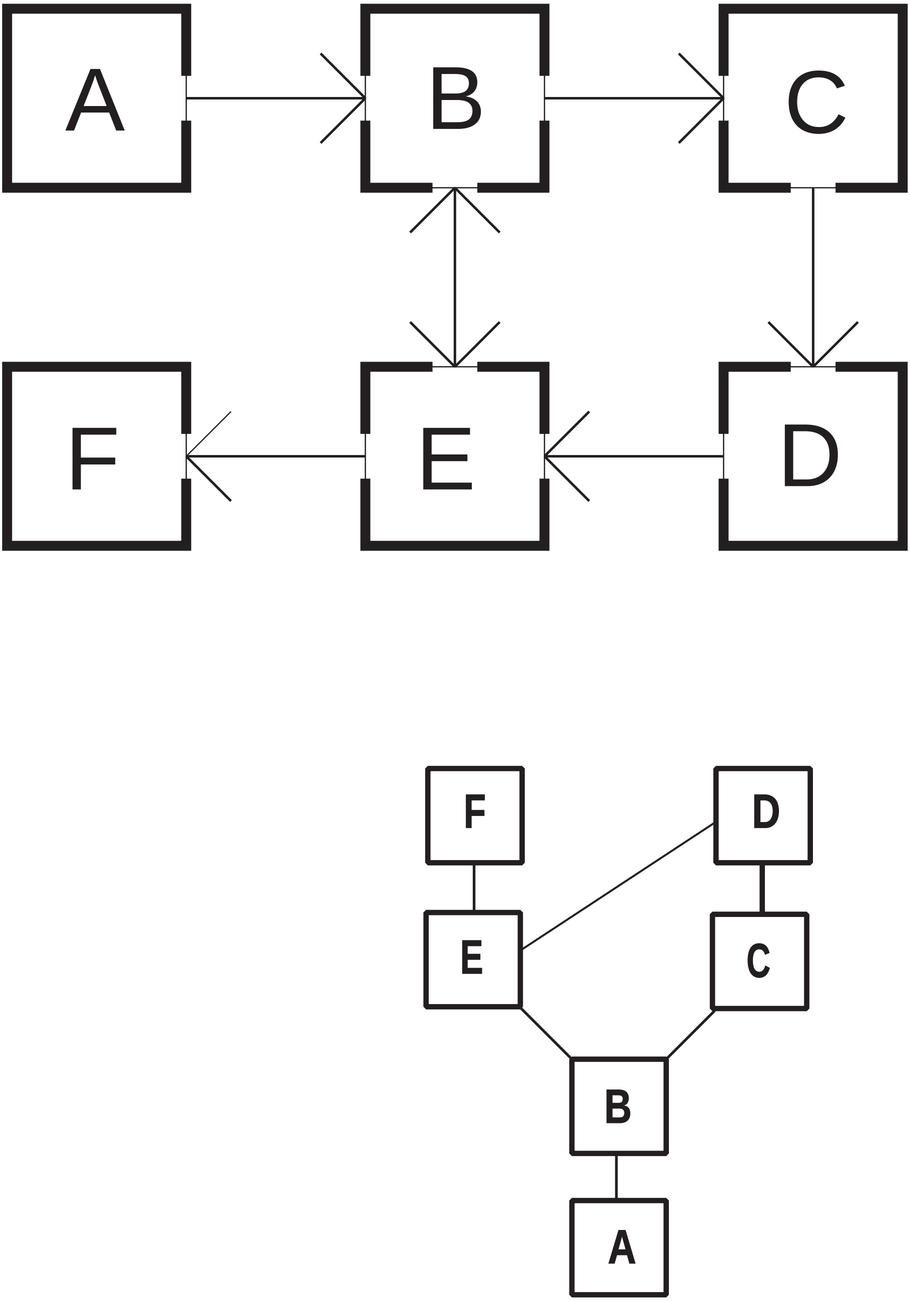


Figure 6.4 *Depth in spatial relationships.*

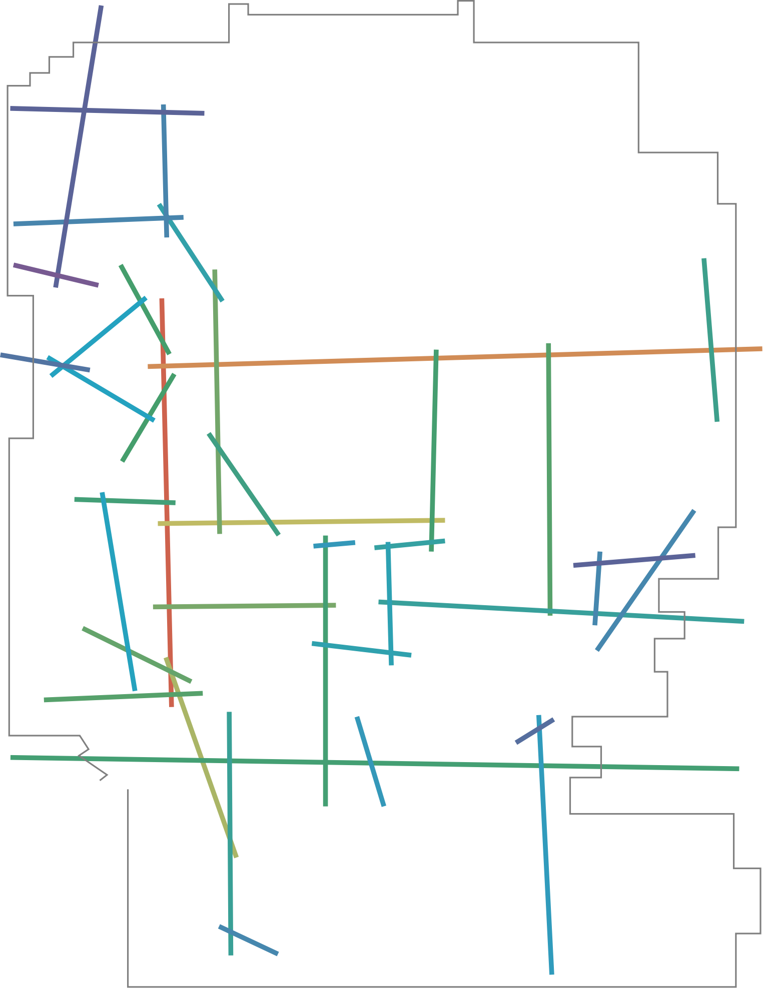


Figure 6.5 *Urban Hospital, Syntax analysis of public lines*

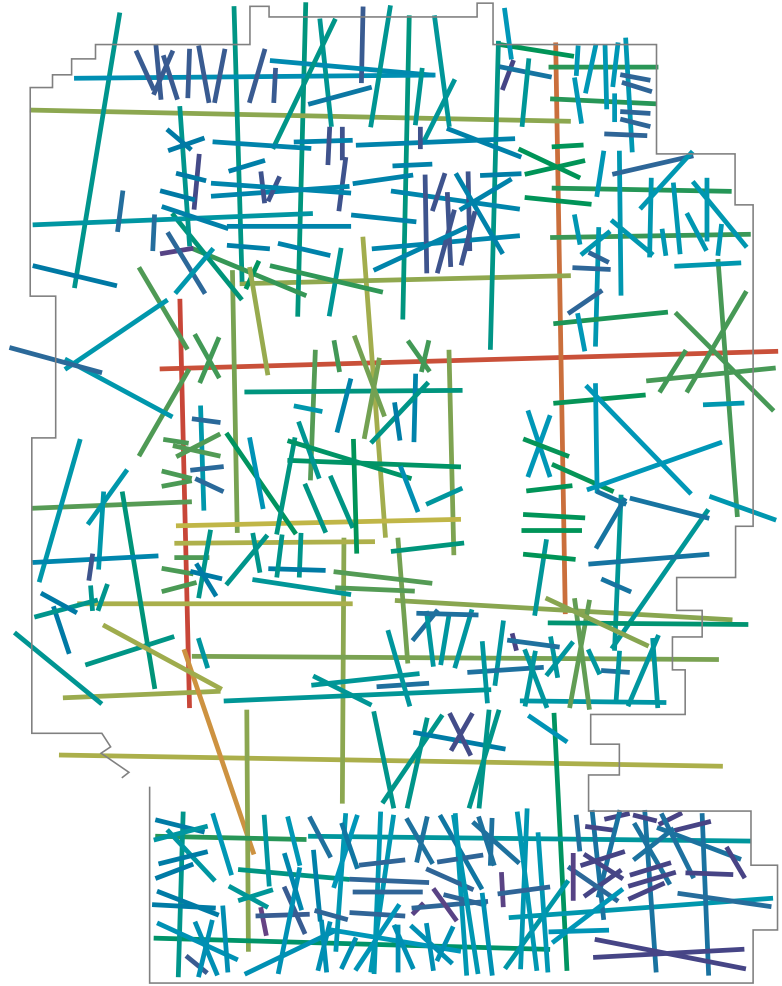


Figure 6.6 *Urban Hospital, Syntax analysis of all lines*

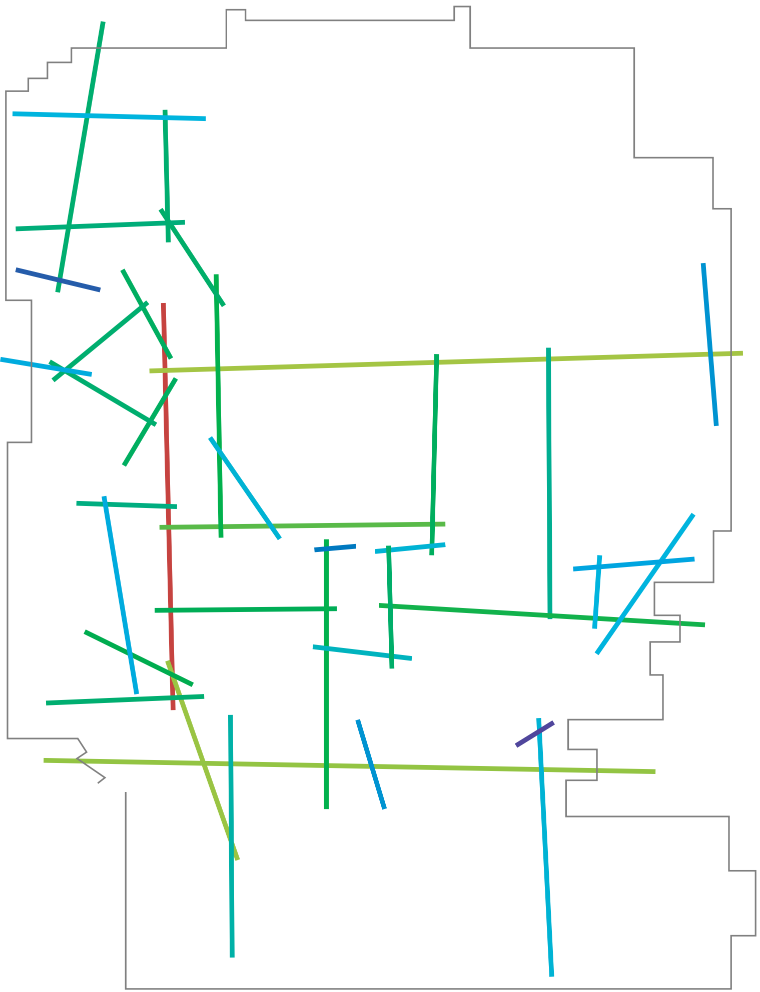


Figure 6.7 *Urban Hospital, Syntax analysis of public lines to depth 3*

Figure 6.8 *Urban Hospital, Syntax analysis of all lines to depth 3*

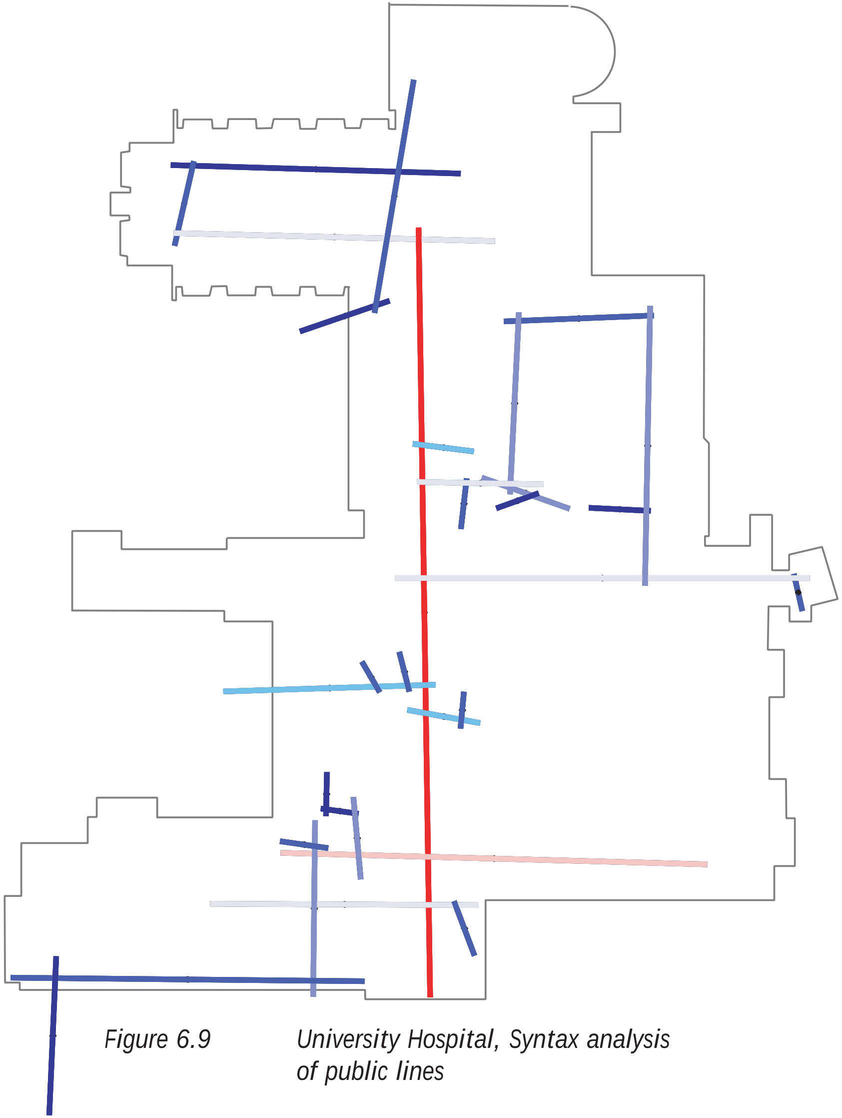


Figure 6.9 *University Hospital, Syntax analysis of public lines*

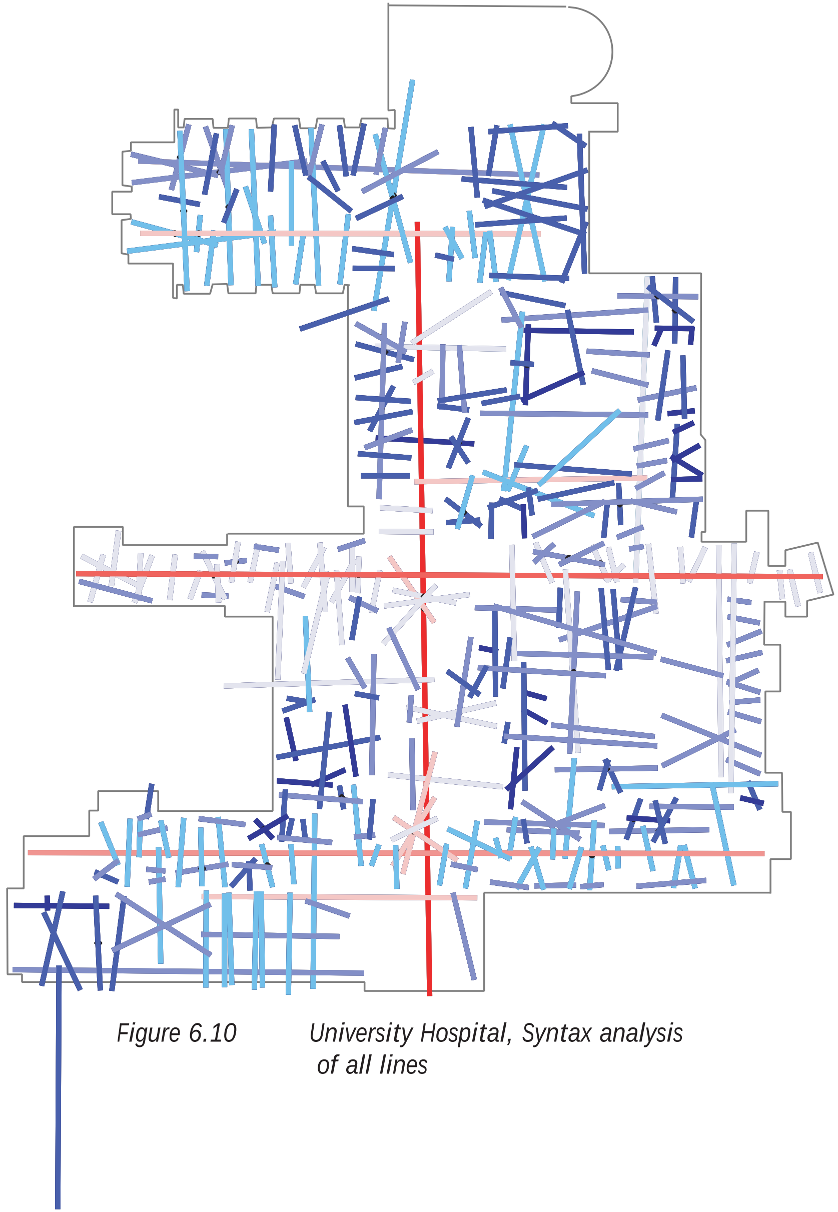


Figure 6.10 *University Hospital, Syntax analysis of all lines*

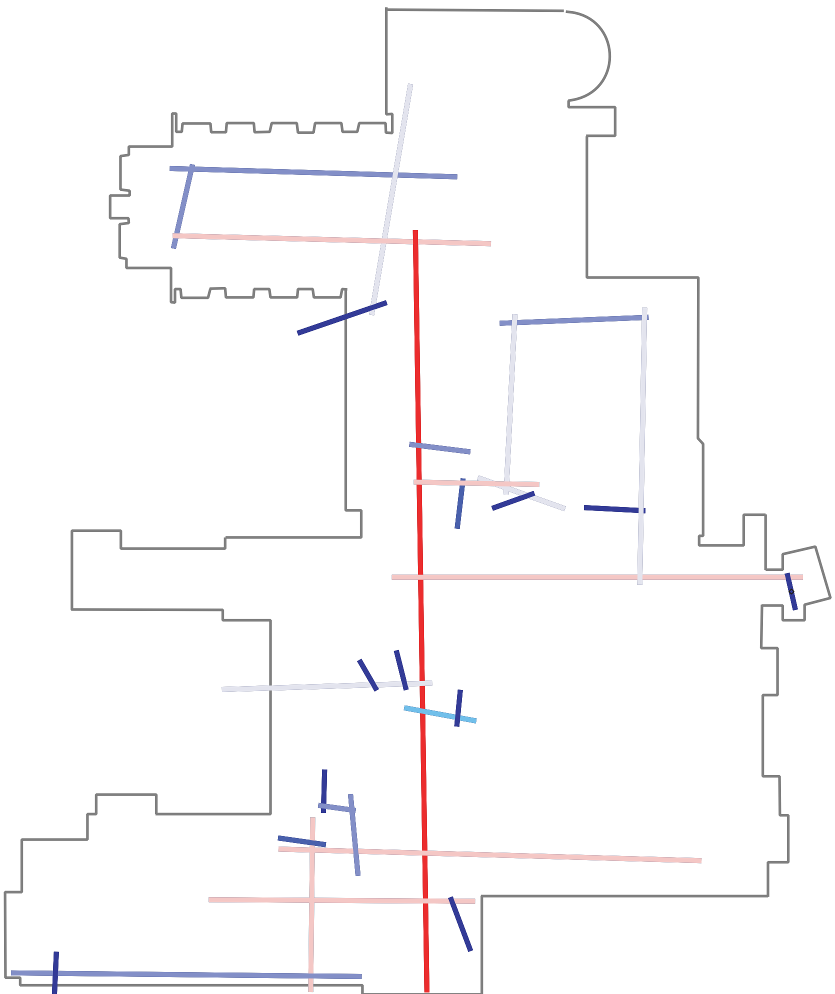


Figure 6.11 *University Hospital, Syntax analysis of public lines to depth 3*

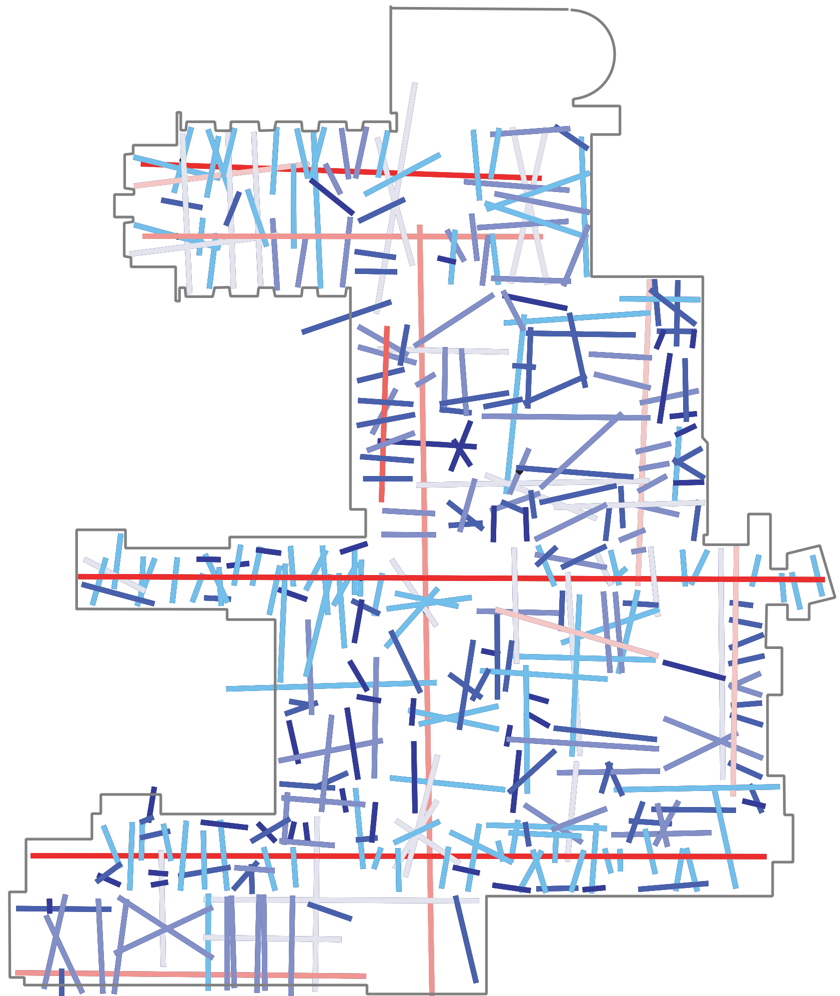


Figure 6.12 *University Hospital, Syntax analysis of all lines to depth 3*

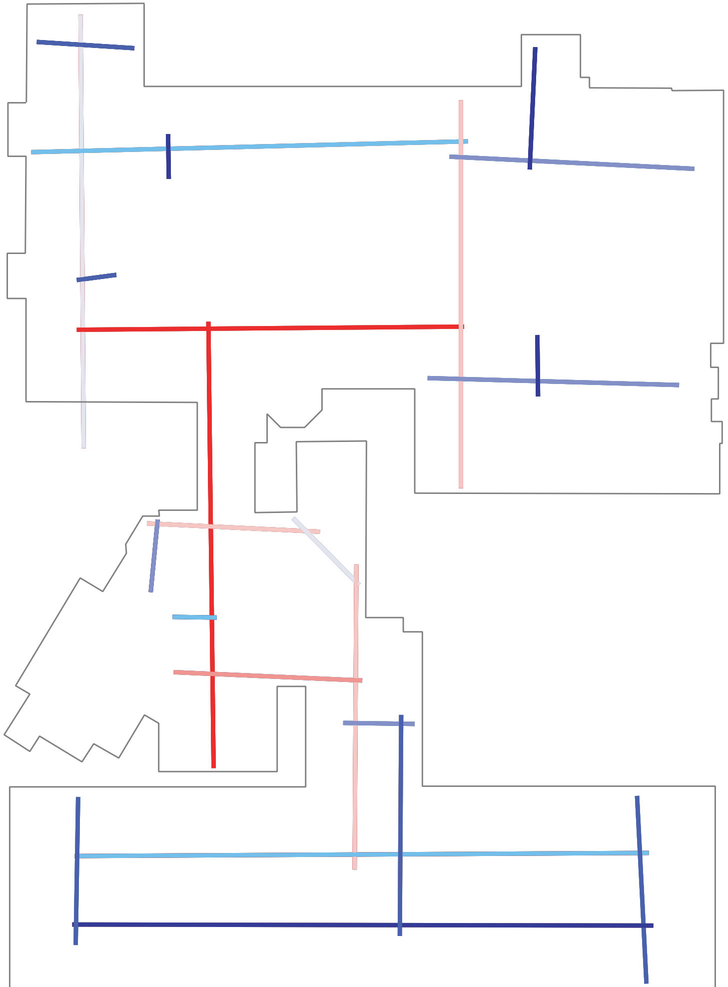


Figure 6.13 City Hospital, Syntax analysis of public lines

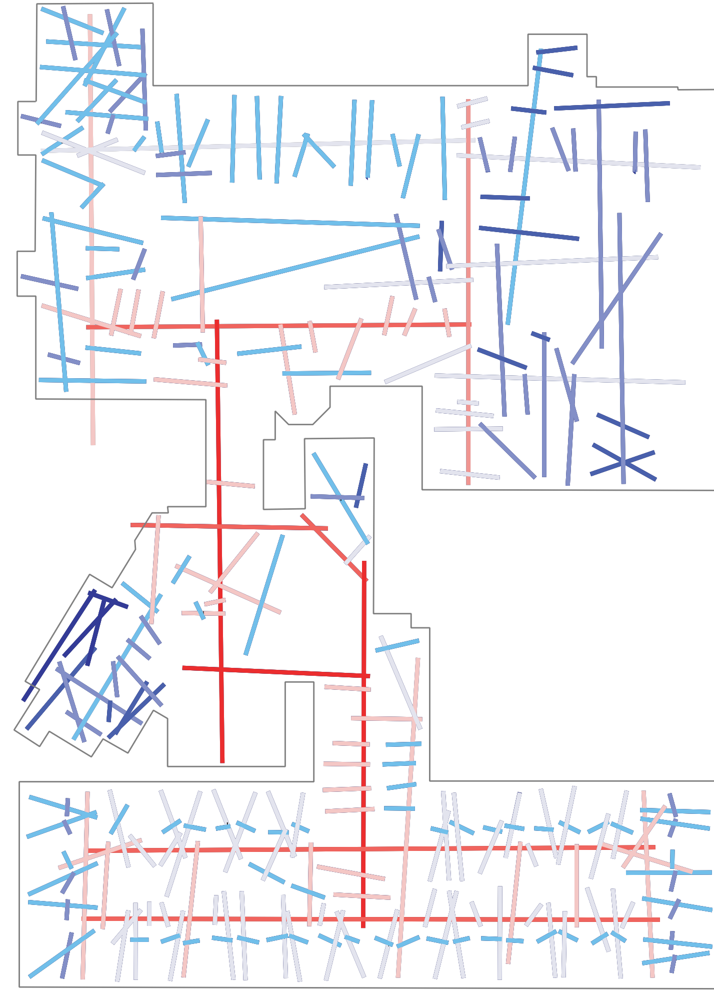


Figure 6.14 City Hospital, Syntax analysis of all lines

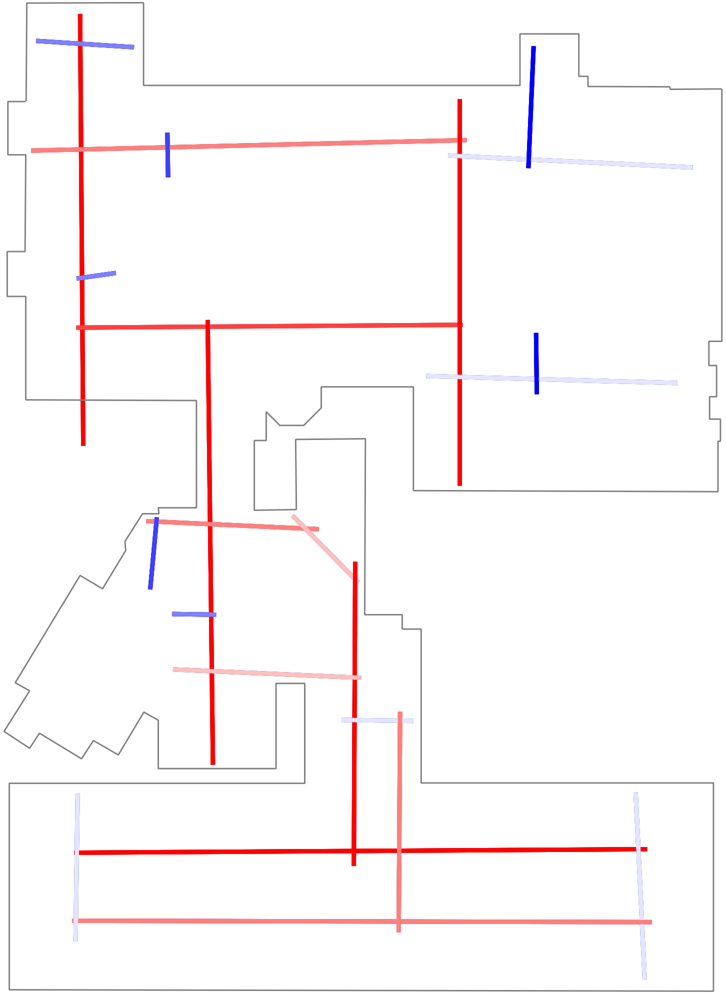


Figure 6.15 *City Hospital, Syntax analysis of public lines to depth 3*

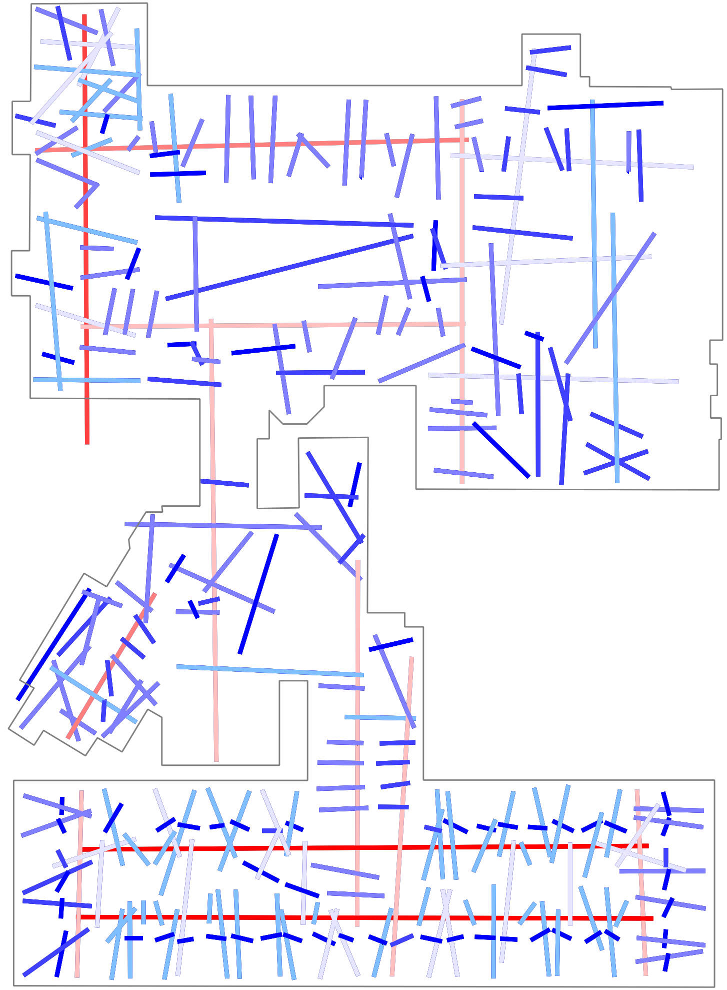


Figure 6.16 *City Hospital, Syntax analysis of all lines to depth 3*

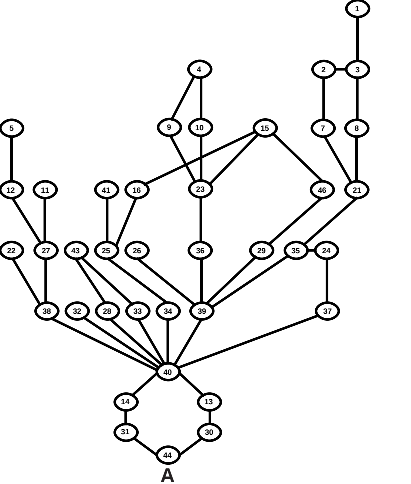


Figure 6.17
Justified Map from entry A, Urban Hospital
Mean Depth 5.234

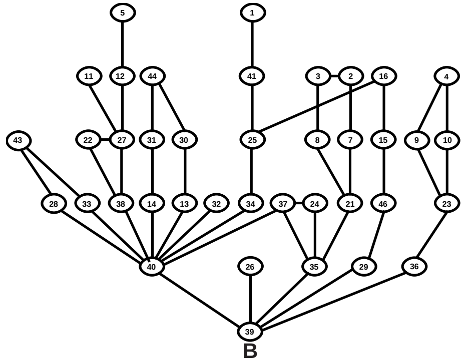


Figure 6.18
Justified Map from entry B, Urban Hospital
Mean Depth 2.737

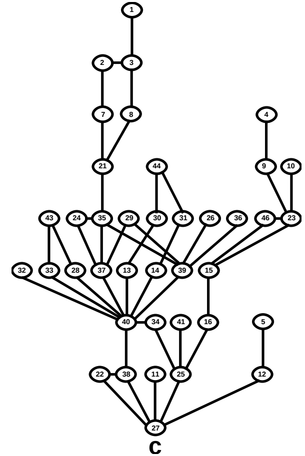


Figure 6.19
Justified Map from entry C, Urban Hospital
Mean Depth 3.658

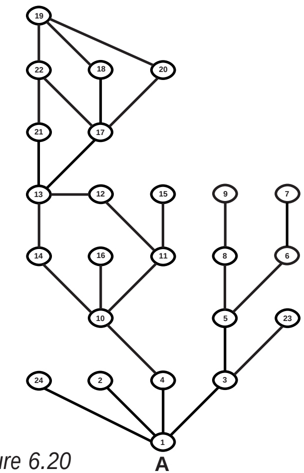


Figure 6.20
Justified Map from entry A, City Hospital
Mean Depth 3.478

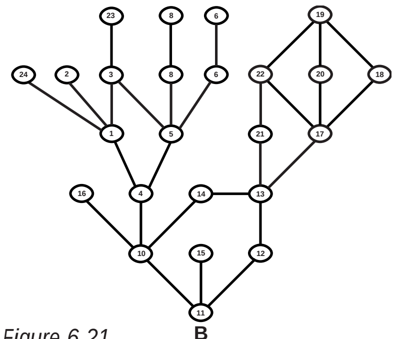


Figure 6.21
Justified Map from entry B, City Hospital
Mean Depth 3.261

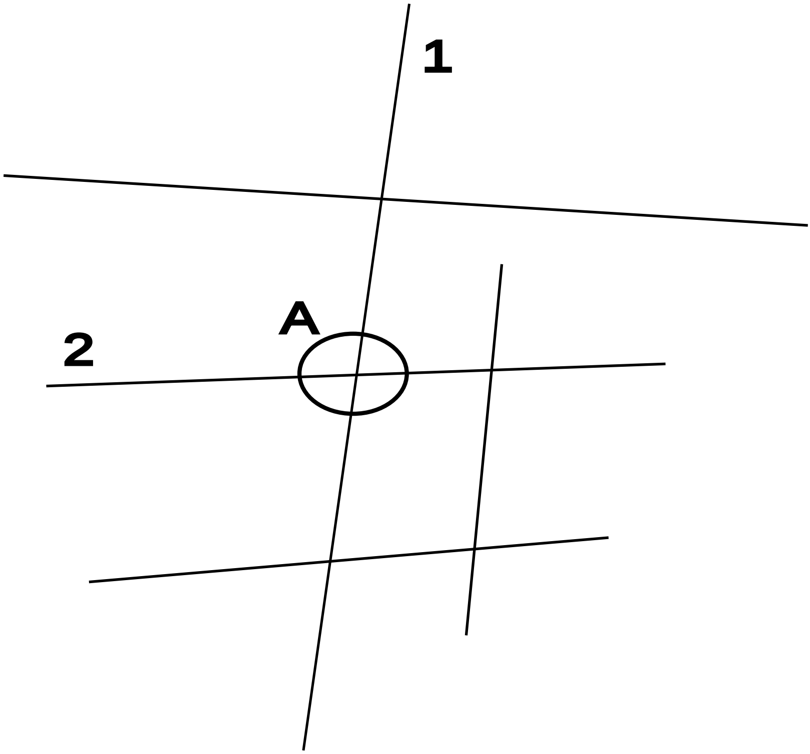


Figure 6.22 Connectivity and DP Degree.
Axial line 1 and 2 has connectivity 3 and 2 respectively. But connectivity of node A is the average connectivity of axial lines 1 and 2 i.e. 2.5. For node A, connectivity is relational because it takes into account visually connected adjacent nodes.
Degree of A is 4, but DP degree is 3.

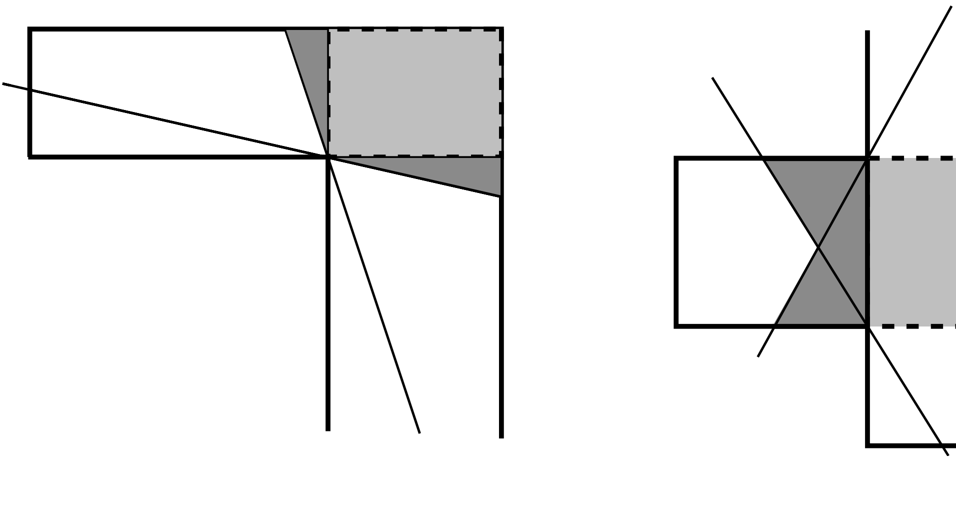
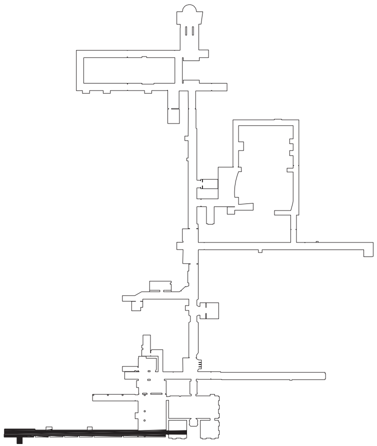
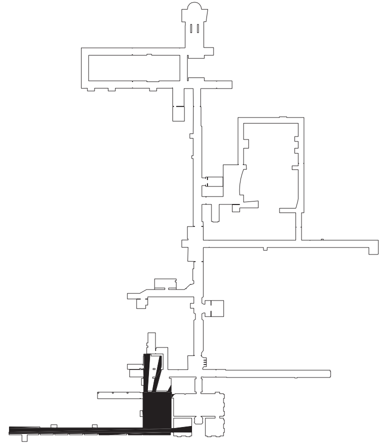


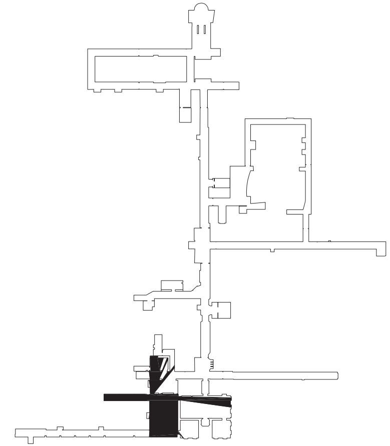
Figure 6.23 Different conditions of Node Visibility Area (NVA)



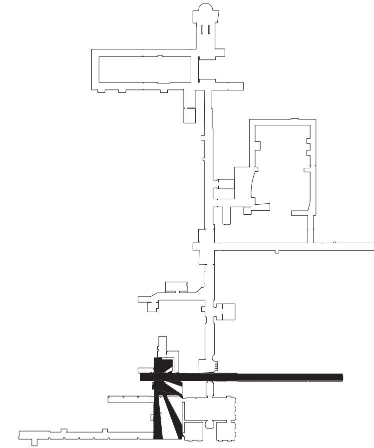
Node 1



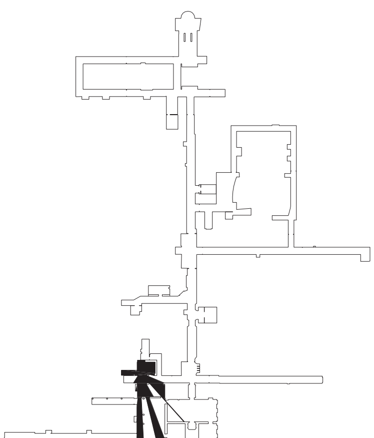
Node 2



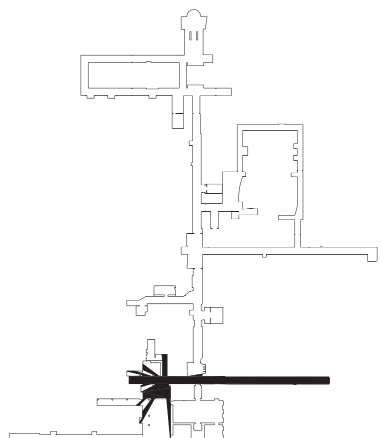
Node 3



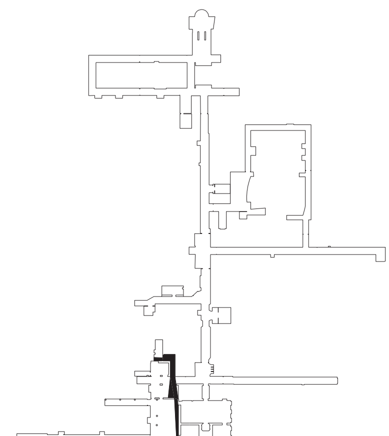
Node 4



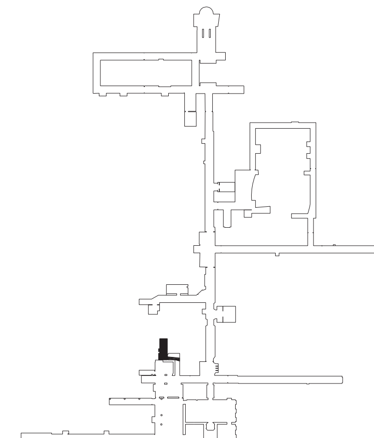
Node 5



Node 6

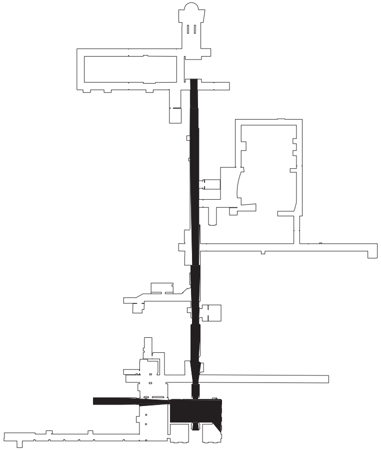


Node 7

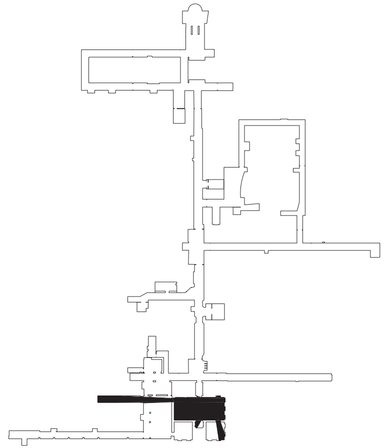


Node 8

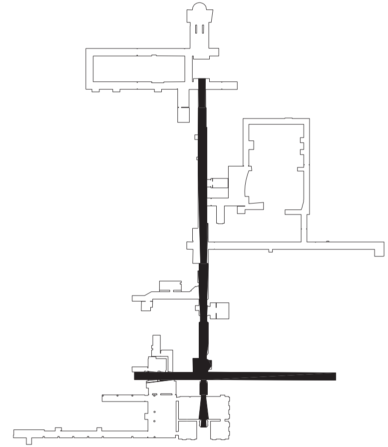
Figure 6.24 Isovists from the various nodes of University Hospital.



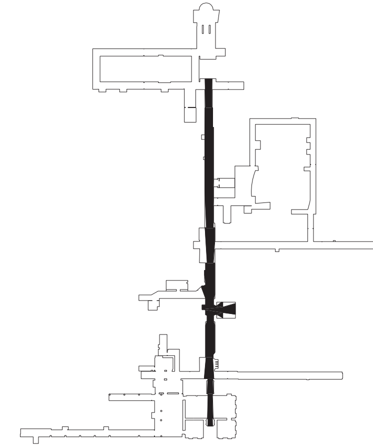
Node 9



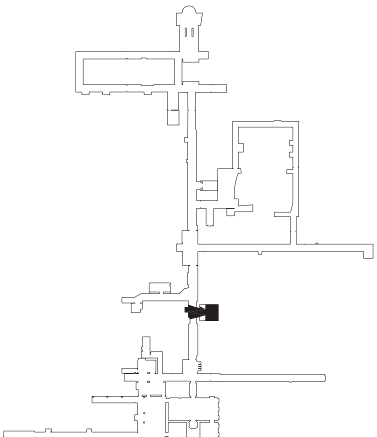
Node 10



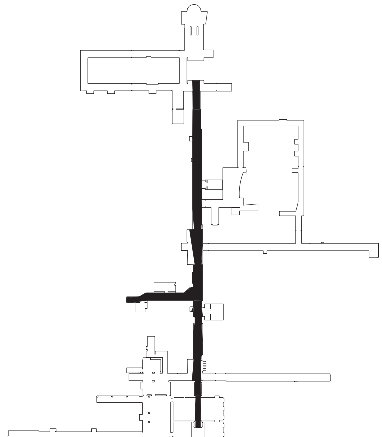
Node 11



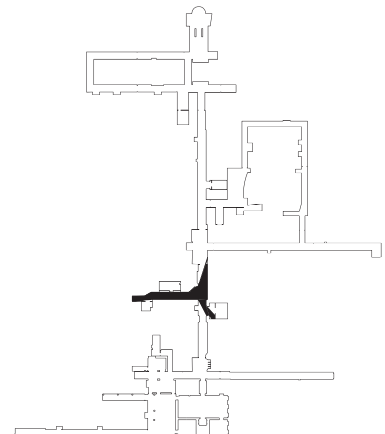
Node 12



Node 13



Node 14



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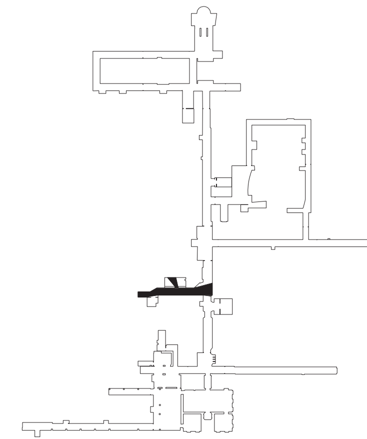
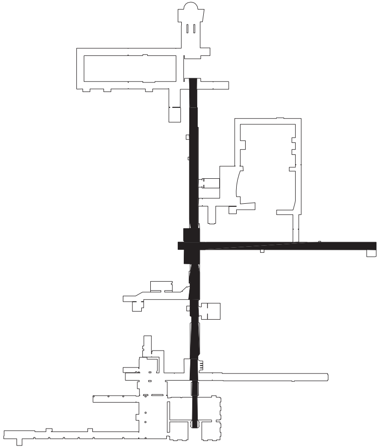


Node 16

Figure 6.24 (Contd.) *Isovists from the various nodes of University Hospital.*



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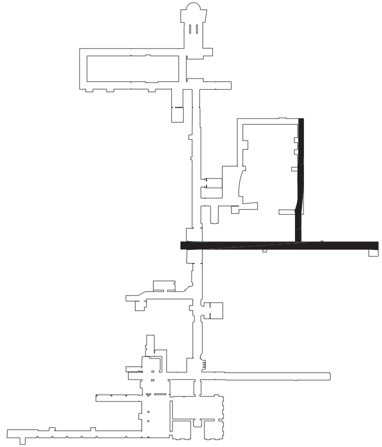

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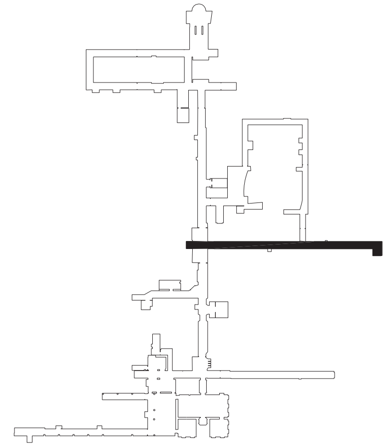
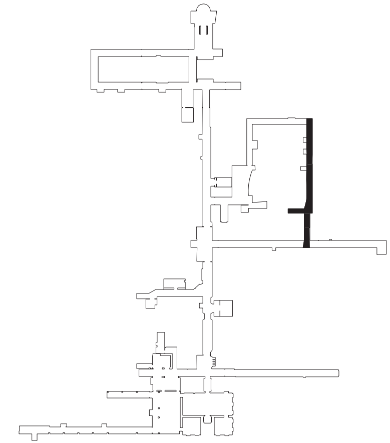
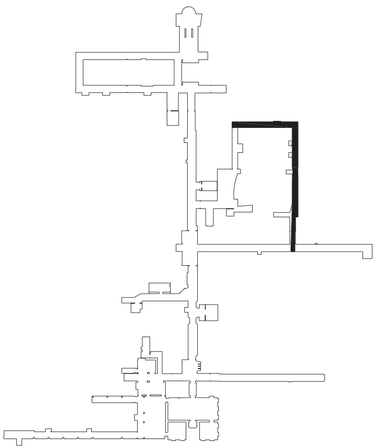


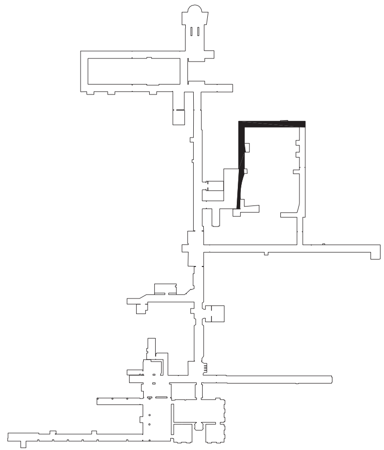
Node 19



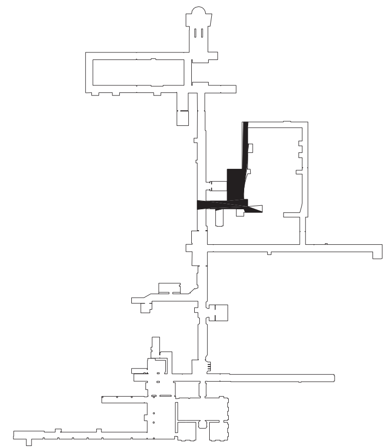
Node 20



Node 21



Node 22



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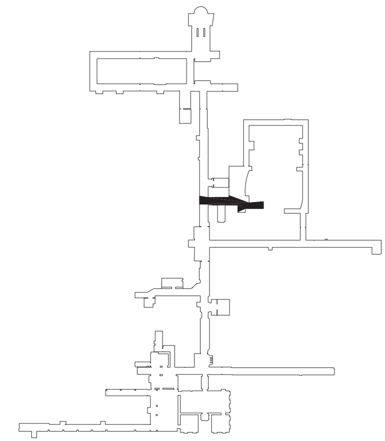
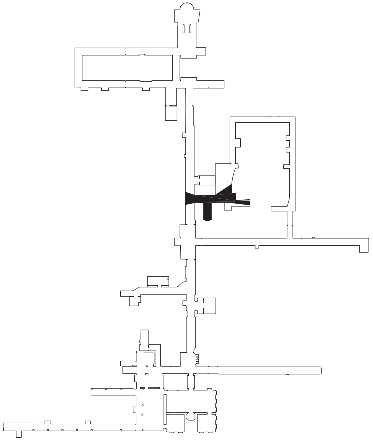
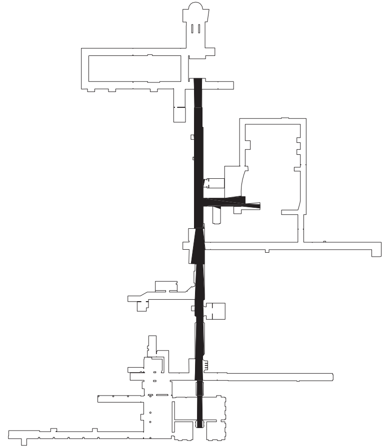


Node 24

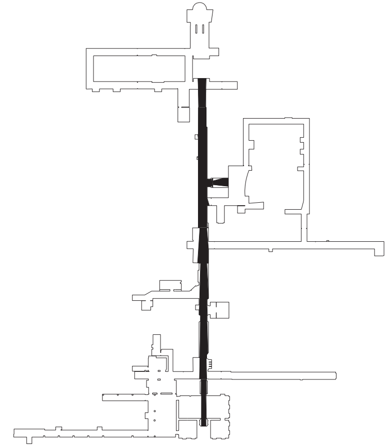
Figure 6.24 (Contd.) *Isovists from the various nodes of University Hospital.*



Node 25



Node 26



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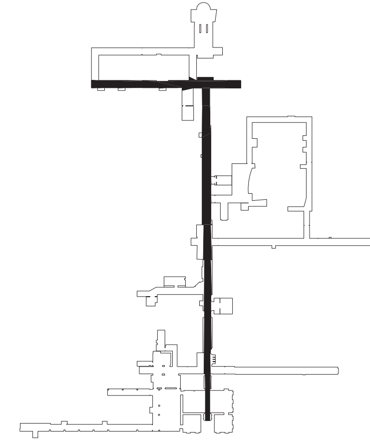
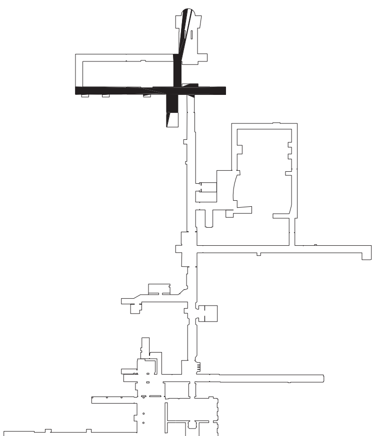


Node 28



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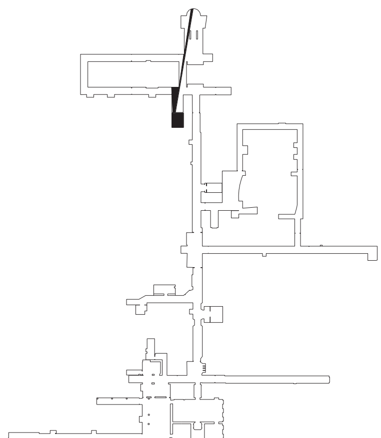
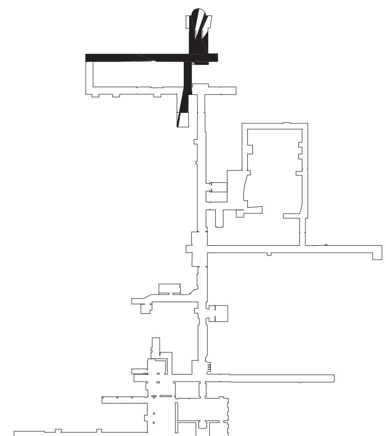


Node 30



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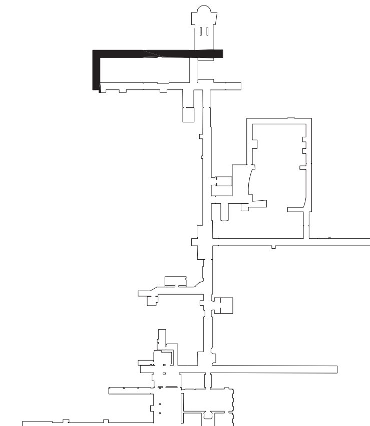
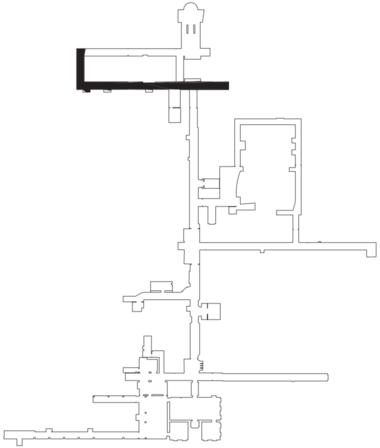


Node 32

Figure 6.24 (Contd.) *Isovists from the various nodes of University Hospital.*



Node 33

Figure 6.24 (Contd.) *Isovists from the various nodes of University Hospital.*

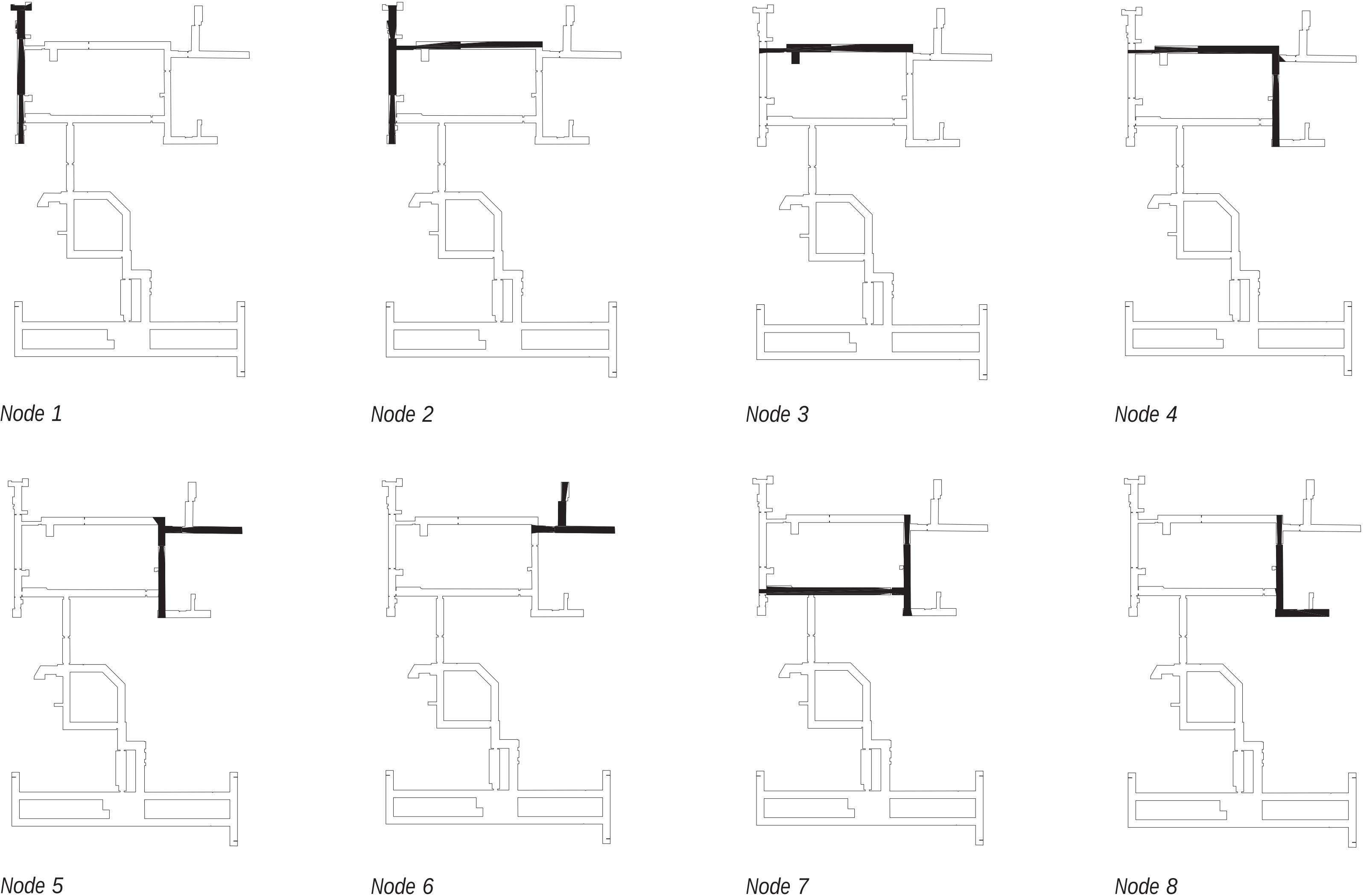
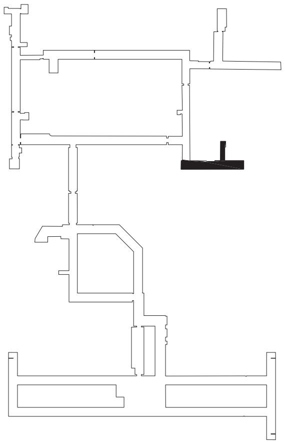
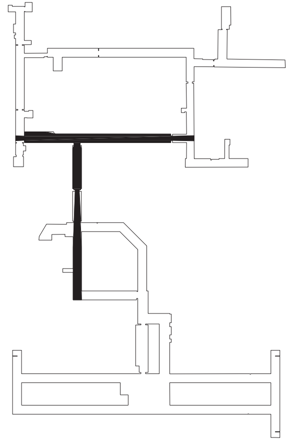


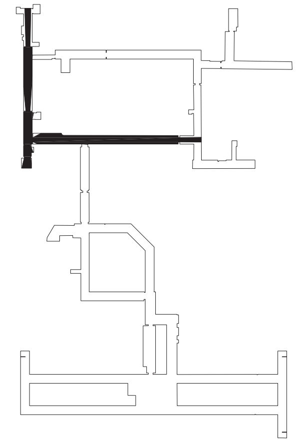
Figure 6.25 Isovists from the various nodes of City Hospital.



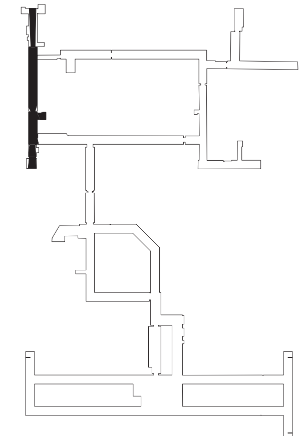
Node 9



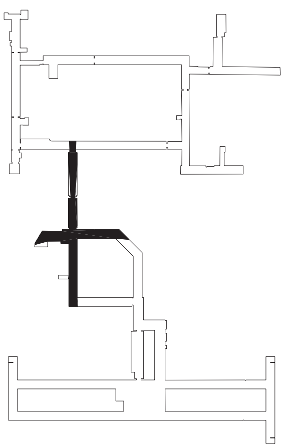
Node 10



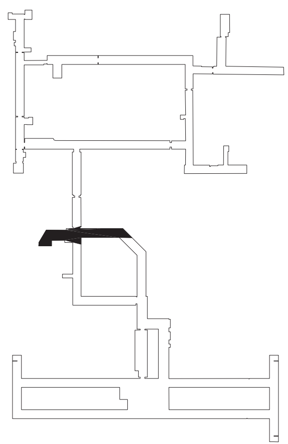
Node 11



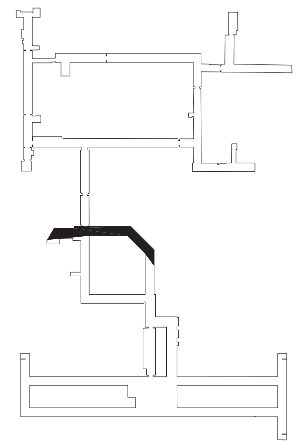
Node 12



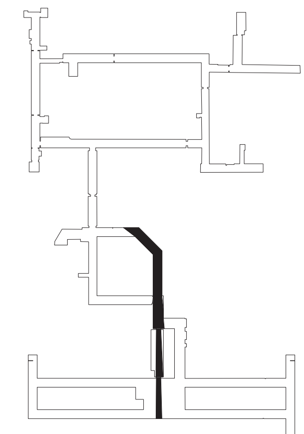
Node 13



Node 14

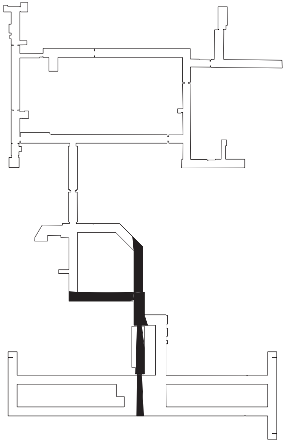


Node 15



Node 16

Figure 6.25 (Contd.) Isovists from the various nodes of City Hospital.



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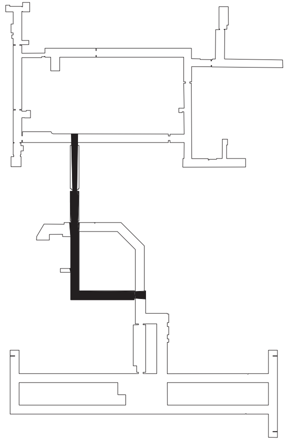
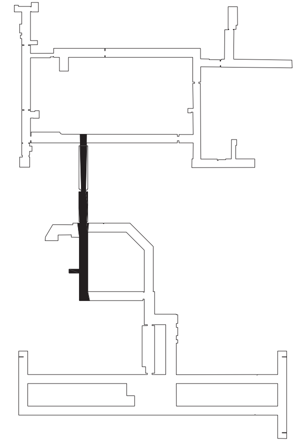
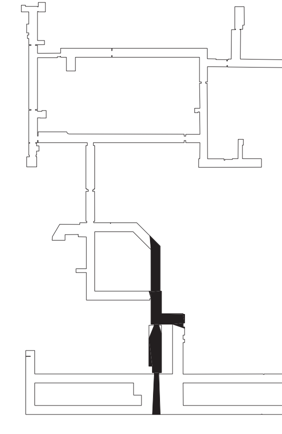


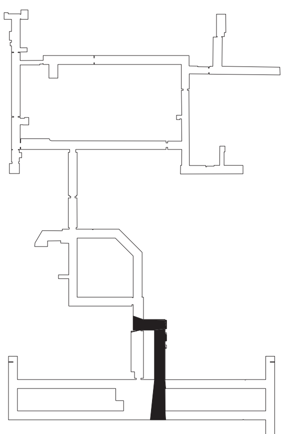
Node 18



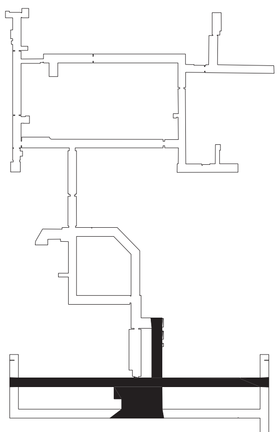
Node 19



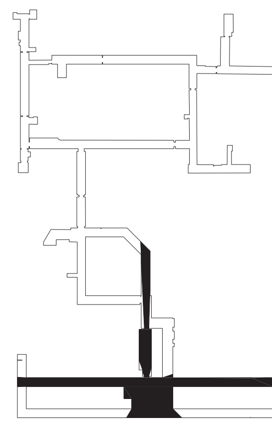
Node 20



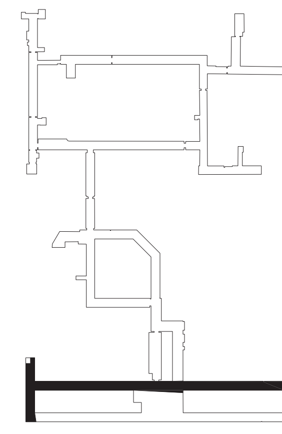
Node 21



Node 22

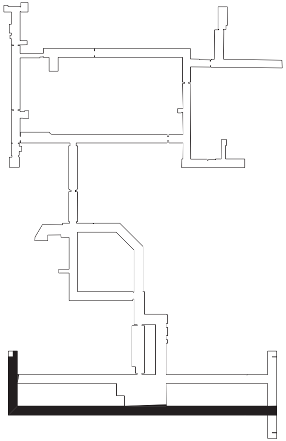


Node 23

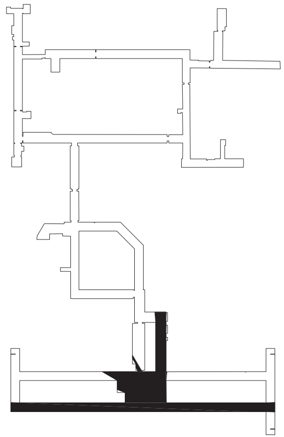


Node 24

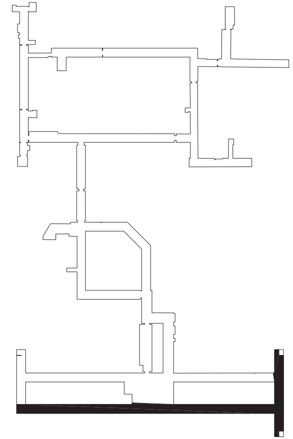
Figure 6.25 (Contd.) *Isovists from the various nodes of City Hospital.*



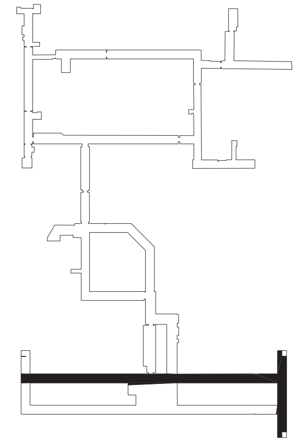
Node 25



Node 26



Node 27



Node 28

Figure 6.25 (Contd.) *Isovists from the various nodes of City Hospital.*

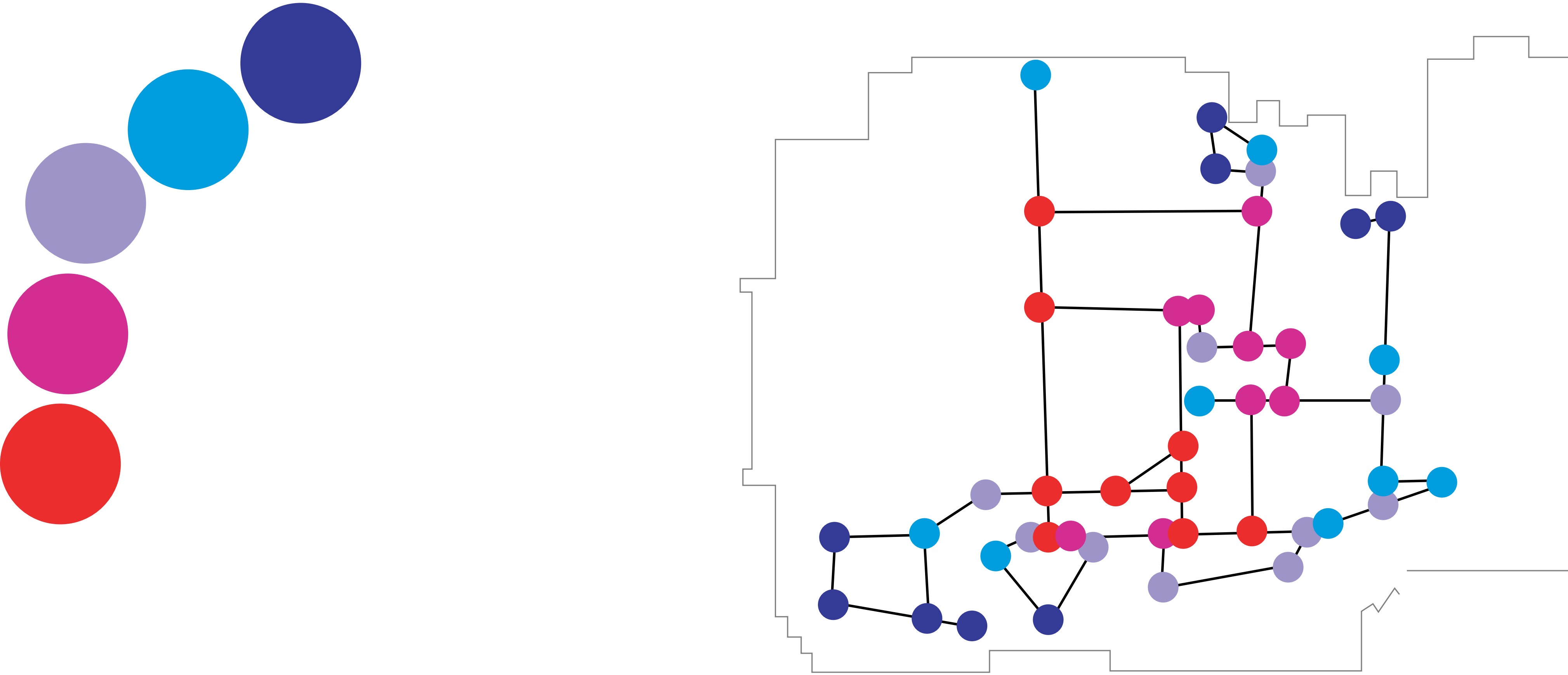


Figure 6.26 Urban Hospital: Actual Node Integration

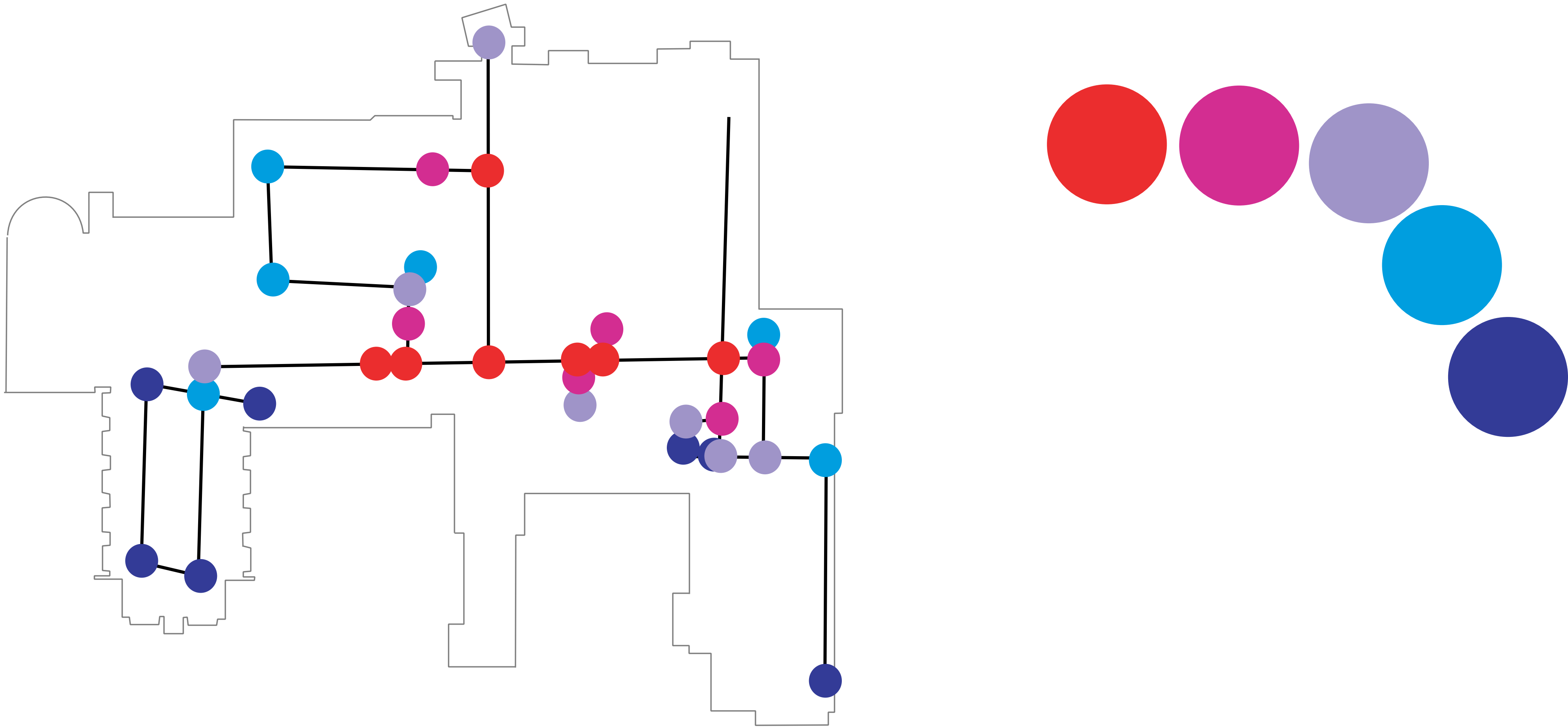


Figure 6.27 *University Hospital: Actual Node Integration*

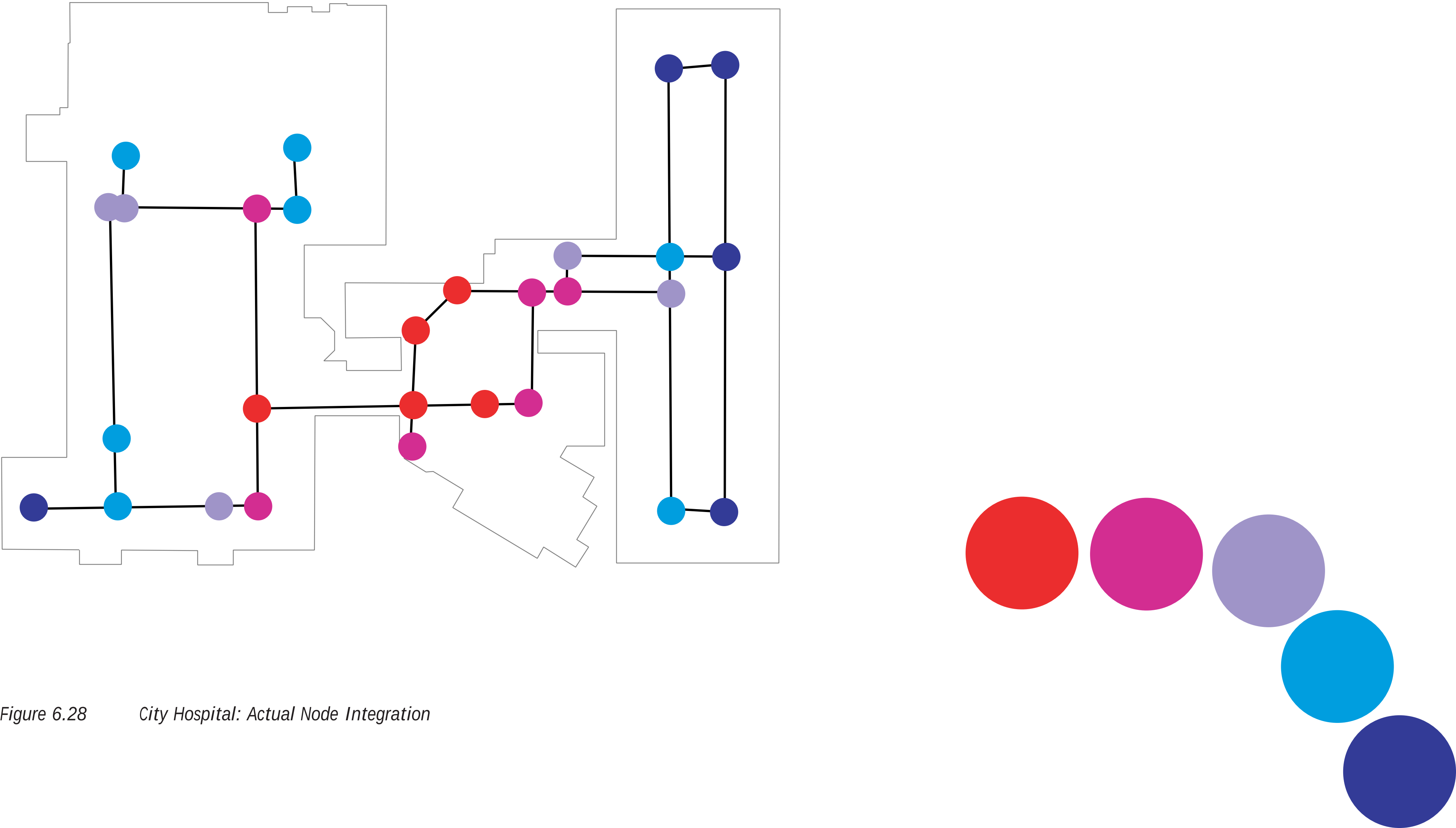


Figure 6.28 City Hospital: Actual Node Integration

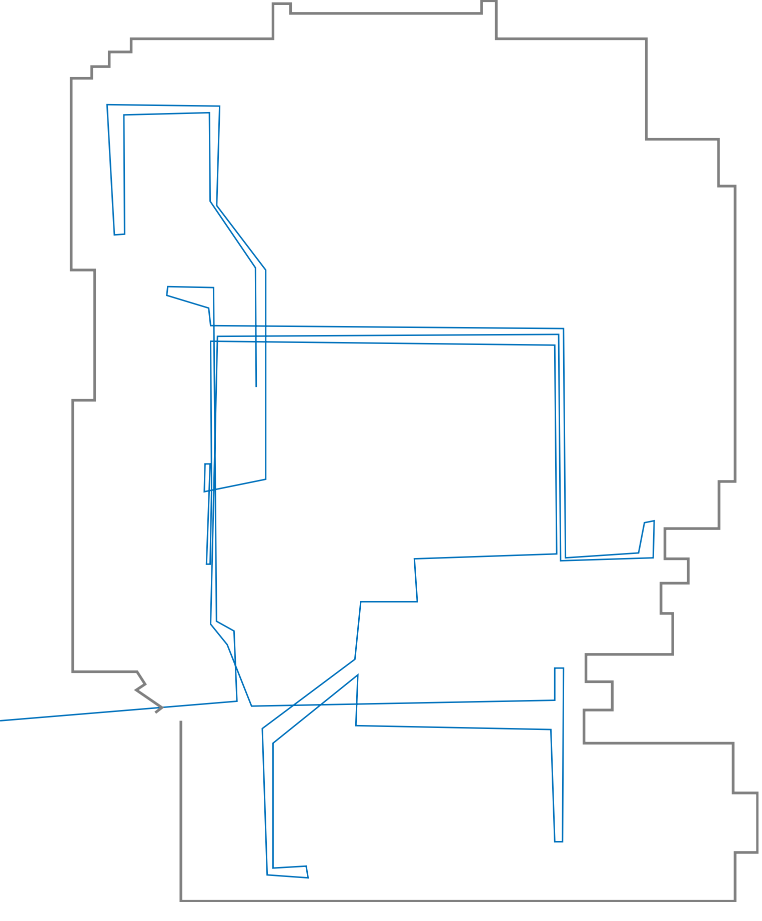


Figure 6.29 A track through the setting. Urban Hospital

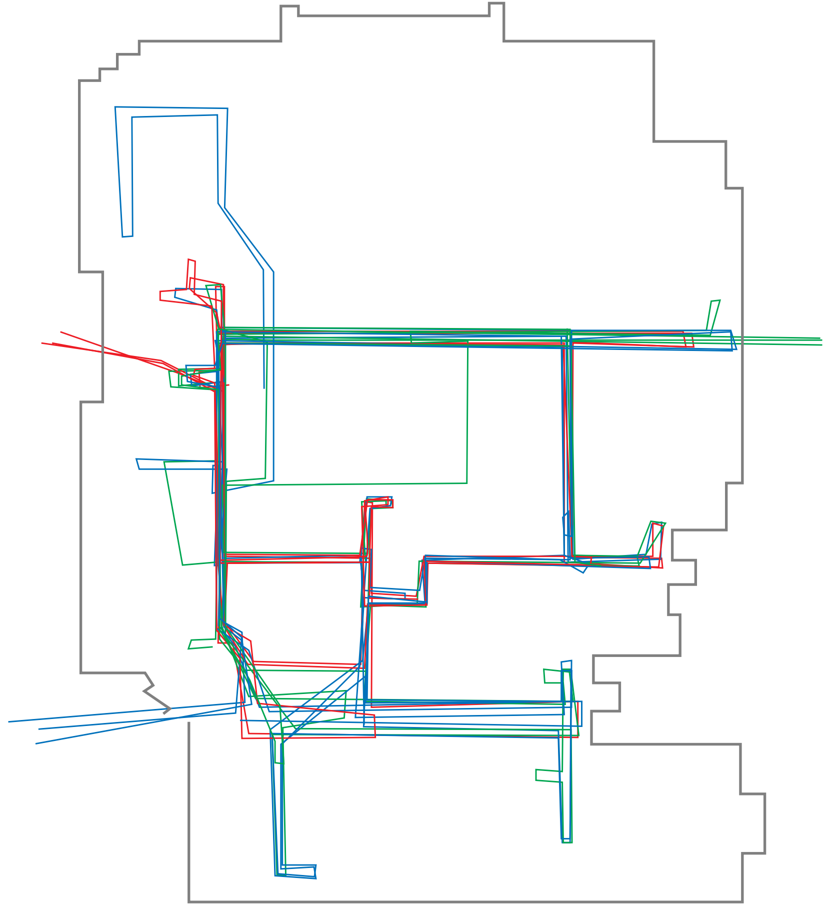
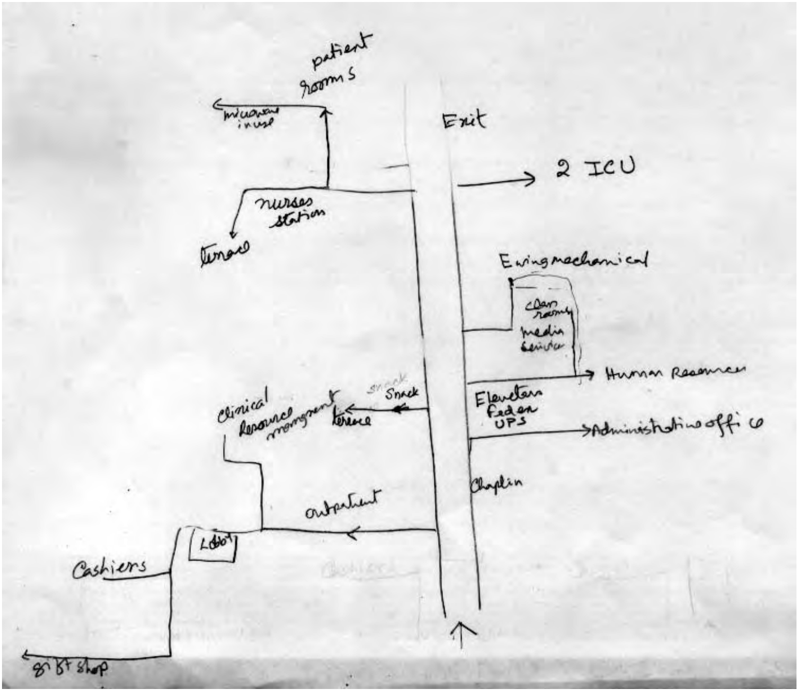


Figure 6.30 The movement pattern: Urban Hospital



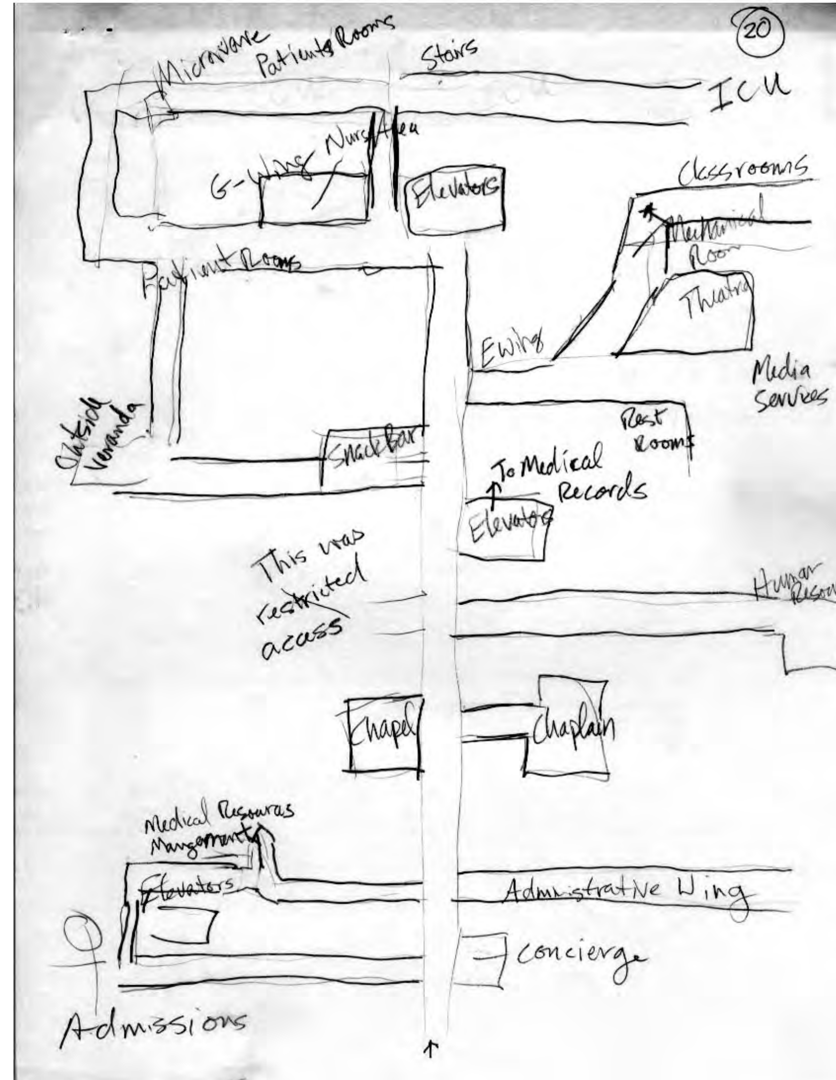
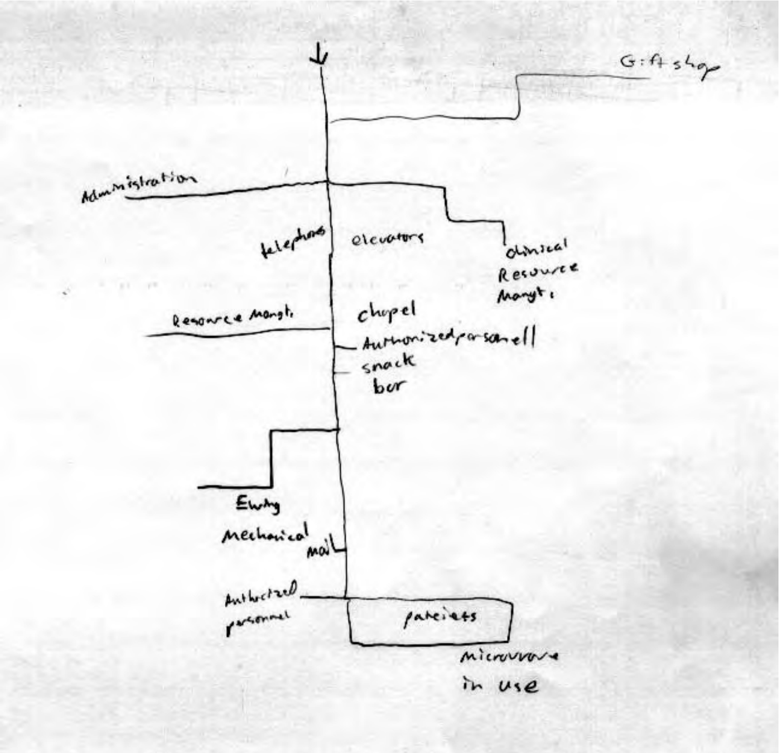


Figure 6.31 Sketch map samples from University Hospital



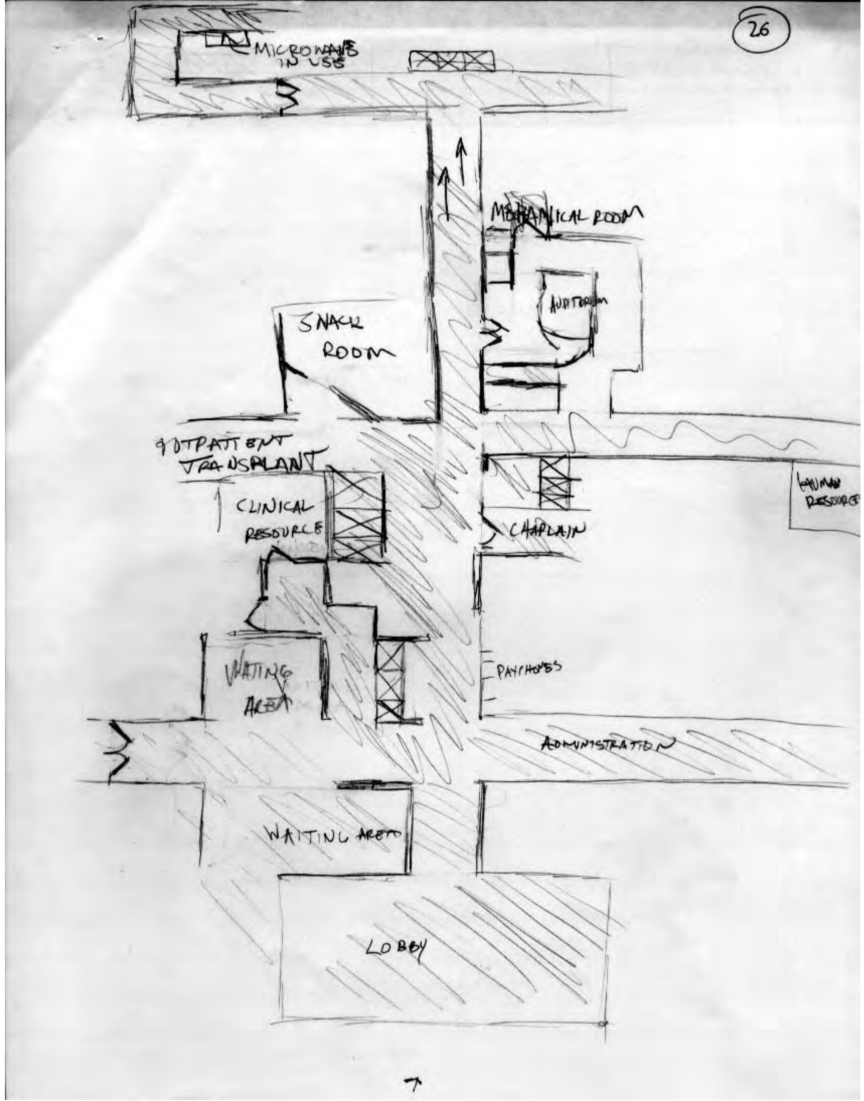
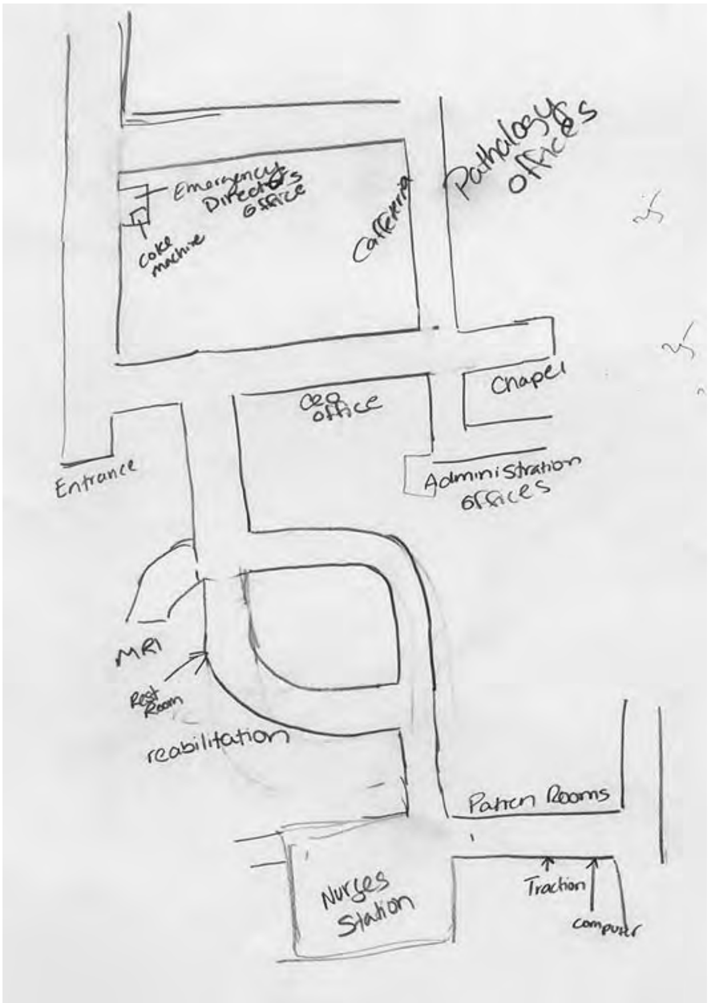


Figure 6.31 (Contd.) *Sketch map samples from University Hospital*



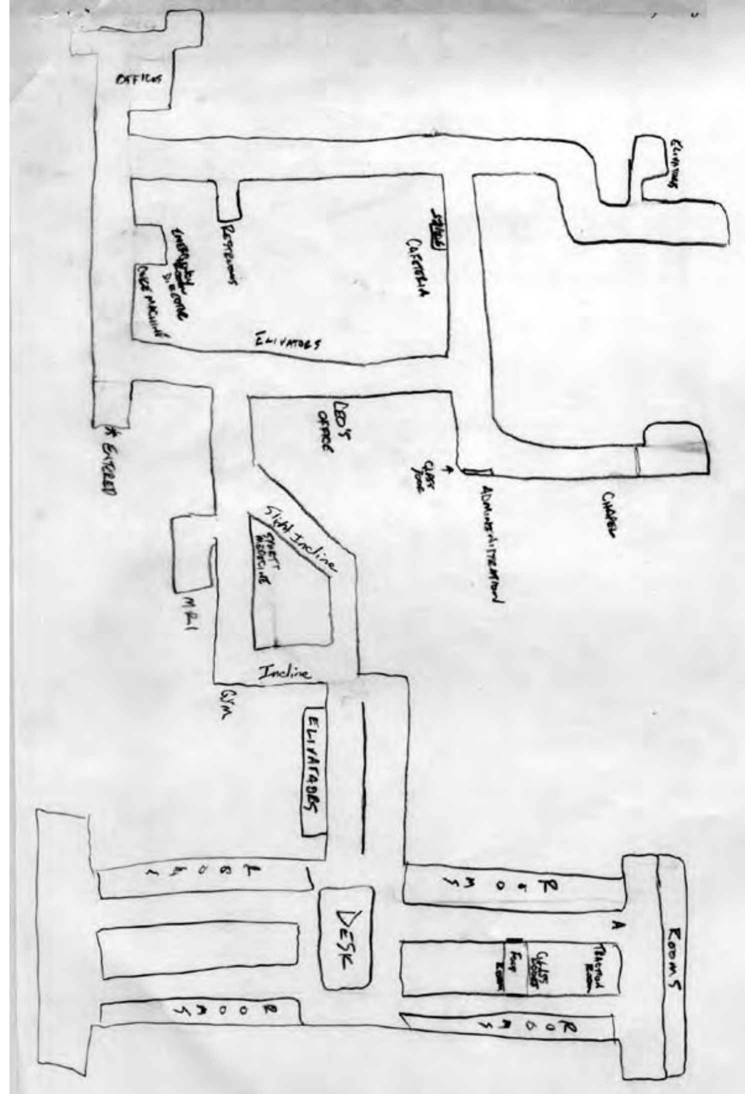
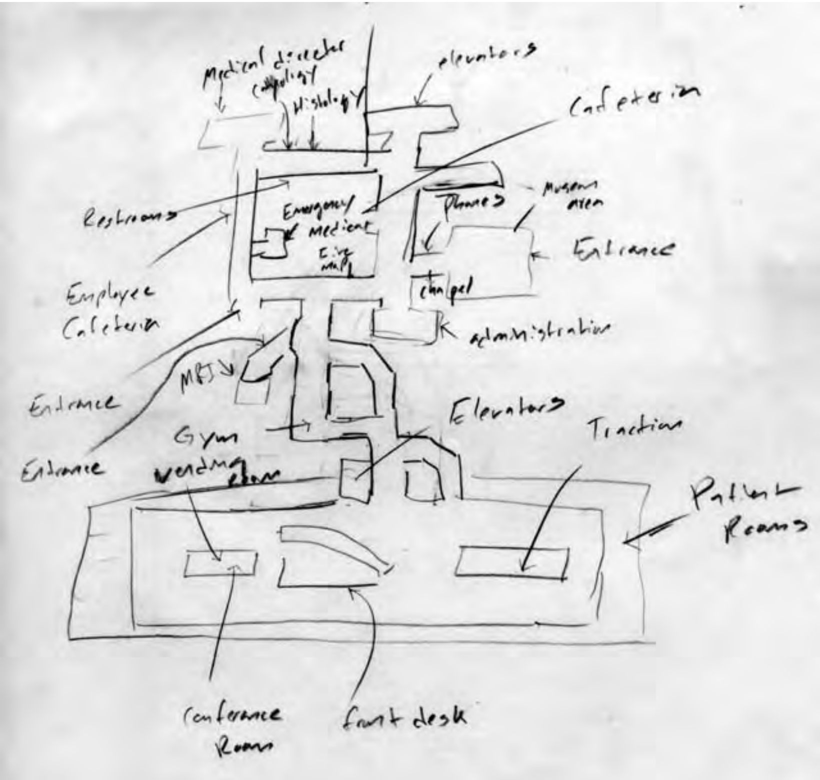


Figure 6.32 Sketch map samples from City Hospital



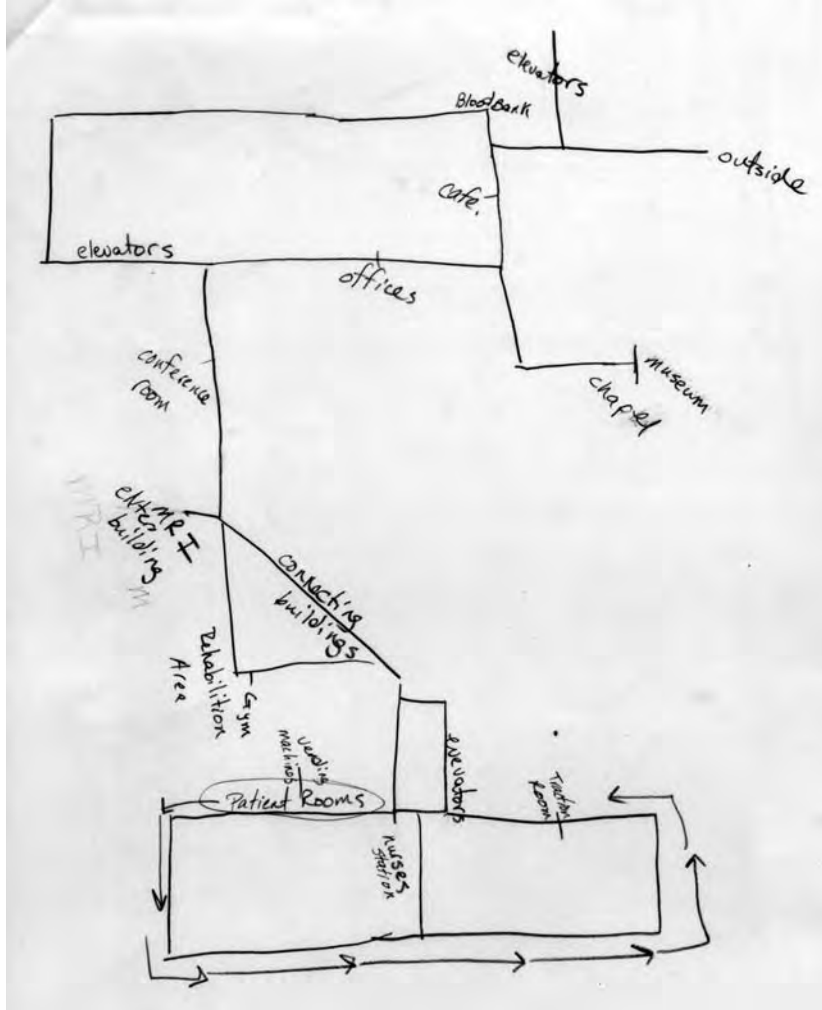


Figure 6.32 (Contd.) *Sketch map samples from City Hospital*

Rating Scale A

Please read each statement carefully. For each statement, select one of the following responses which best represents *how likely you would be to engage in various behaviors while trying to find your way around an unfamiliar building*. Write the number, ranging from 1 to 5, in the space provided next to the statement. Do not hesitate using the entire scale.

1	2	3	4	5
Not at all Typical		**Moderately Typical**		**Extremely Typical**

_____1. Whenever I make a turn, I know which direction I am facing (e.g. north, south, east, or west).

_____2. I know the direction in which I am facing within the building without having to think about it.

_____3. I always keep in mind the direction from which I have entered the building (e.g. north, south, east, or west side of the building).

_____4. I think of my location in the building in terms of north, south, east, and west.

_____5. It takes a lot of mental effort for me to figure out the direction in which I am facing within the building.

_____6. I can visualize what is outside of the building in the direction that I am facing within the building.

Please read each statement carefully. For each statement, select one of the following responses which best represents *how important these items are to you while trying to find your way around an unfamiliar building*. Write the number in the space provided next to the statement.

1	2	3	4	5
Not at all Important		**Moderately Important**		**Extremely Important**

_____1. Clearly visible signs pointing the way to different sections of the building or complex.

_____2. A map of the building or complex, with an arrow pointing to my present location.

_____3. Clearly labeled room numbers and signs identifying parts of the building or complex.

_____4. Availability of someone (e.g. a receptionist) who can give directions.

_____5. Regularity or symmetry in the layout of the building or complex.

_____6. All corridors meeting at right angles.

_____7. Hallways arranged in a uniform grid system.

Do not write in box below.

Page 1 Total _____ (A)

Page 2 Total _____ (B)

Mean =(A+B)/13 = _____

2

Figure 6.33 Lawton's scale for self reported wayfinding ability.

Chapter VII

Analysis of Data

This experiment yielded extensive data in three categories: environmental, behavioral and cognitive. Besides that, basic information about the respondents such as age, sex, race etc. was also collected.

First, the environment, as an independent artifact, was subjected to a thorough analysis. This produced comparative measures for the various environmental units. This was later used to interpret the results from the analysis of behavioral and cognitive data.

The following sections describe the analyses that were undertaken.

1 ENVIRONMENTAL DATA

1.a Comparison between the settings

Data about the various units of the environment, both axial lines and nodes, were generated according to the methods described in the previous chapters. The important subsequent task was an independent analysis of these data to bring out the differences between the three settings. Table 7.1 gives the comparison of the three hospitals according to the different environmental variables.

In terms of line Intelligibility of the public axial system, University Hospital had the highest value, followed by Urban Hospital and then City Hospital. The values were .83, .66 and .56 respectively (see table 7.1). Thus, to the visitor i.e. someone with access to the public system only, University Hospital should be most easily understood, followed by Urban Hospital and then City Hospital. When node intelligibility was calculated from node values taken as ‘average of axial lines’ (node intelligibility pub), a similar hierarchy was seen. University, Urban and City Hospitals have values of .94, .80 and .49 respectively (table 7.1). If however, node values were computed by their own inter-relationships, i.e. the actual relationships of each node to others, then Urban Hospital had intelligibility value of .66, followed by University and City Hospital; .53 and .32 respectively. Therefore, in terms of corridors, University Hospital was most intelligible, but in terms of nodes, Urban Hospital was most intelligible.

Consideration of the total axial system gave a slightly different result. In this case, there was much less variation between the intelligibility of the 3 settings. The line intelligibilities were .44, .43 and .41 for University, Urban and City hospitals respectively. Thus the overall axial complexity of the 3 settings can be said to be similar; but they vary in the manner in which their public spaces are laid out. This of course, attests to the validity of choosing these three hospitals as experimental settings. Also, it demonstrates that settings with similar characteristics in their overall configuration may indeed present different properties to visitors who are restricted to the public system only. In terms of hospitals and other public buildings where there are distinctly separate circulation patterns, this is important to note. Therefore any study should distinguish between separate circulation systems.

Node intelligibility for the entire systems, using average of the line values, was .77, .70 and -.05 for Urban, University and City Hospital respectively.

The very poor node intelligibility for City Hospital was cause for further investigation of its layout. It was noticed that this hospital is actually composed of two spatial 'clumps' that were connected together by a third piece (see figure 6.3, 6.13 and 6.14). These two parts corresponded to one building in the east and two in the west. The two western buildings had merged into one another in a manner such that to the moving observer in the corridors, they seemed to be one unit. These two buildings housed administrative functions and were designed to have a bland institutional look. The eastern building, on the other hand, was exclusively patient rooms, and was a much newer addition to the hospital complex. It had a different internal design that focused on cheery colors and a bright atmosphere. Since there was little functional need to regularly commute between the two zones, there were only a few people in the connecting part. Syntactically however, this connecting corridor had the highest integrating value.

Because of this complexity, City Hospital was later considered as two separate systems. In this case, public line intelligibility increased to .923 and .674, all line intelligibility to .840 and .747, all node intelligibility to .735 and .814 and public node intelligibility to .911 and .711 for segments 1 and 2 respectively. Also, actual node intelligibility became .807 and .556 for the 2 systems (see table 7.1 and figures 7.1 through 7.4).

So, from the point of purely environmental analysis, City Hospital works better when considered as two separate systems.

1.b Comparison between environmental measures within each setting

Since many of the environmental measures were determined by similar theoretical arguments, an important question regarding the calculated values for each of them was: how do they relate to one another? This was deemed necessary in order to get a sense of the statistical relationships between the different variables. For this purpose six correlation matrices for the environmental data in two categories – axial lines and nodes, for all the 3 settings, were created. Additionally 4 more was done for City hospital as a split system. These are shown in tables 7.2 through 7.11. From these tables, certain variables are seen to be significantly correlated to one another. Information about them was used in the interpretation of the various tests that were later performed and will be mentioned where applicable.

2 BEHAVIOR AND THE ENVIRONMENT

The next task was to investigate the effects of the environmental variables: lines and nodes, on behavior. Since this study is exploratory in nature, a detailed task of individual correlational analysis for every variable was carried out. At this point, scatter plots of significant ones were also produced to visually inspect the relationships.

2.a Open Exploration: Axial Line Use and Line Variables

Correlations of axial line use in open exploration to the different environmental variables for the three settings were done first. Tables 7.12 through

7.15 show the values for Urban Hospital, University Hospital, entire City Hospital and separated City Hospital respectively.

2.a.1 Total line use in Open Exploration

A preliminary inspection of all these tables brought out a simple, but very powerful pattern. In the condition of open exploration, and taking the entire hospitals as complete systems, the best prediction for total use of corridors was given by a discrete variable**,** Public Connectivity (r= .77, .88 and .79, for Urban, University and City Hospitals respectively; p=<.0001 for all cases, see tables 7.12, 7.13 and 7.14). Public Connectivity also correlated significantly with open exploration when City hospital was considered as two independent systems (r= .80, p = .002 and r= .79, p=.001 for system 1 and 2 of City Hospital respectively. See table 7.15.). Figures 7.6 through 7.10 show the scatter-grams and regression lines for the relationships between public connectivity and *total* use of corridors for all the three hospitals.

Public Connectivity is the number of publicly accessible connections that are available in a corridor. This is considered a discrete variable because it can be measured from the unit space itself. This value gives a sense of how well a corridor segment is connected to other immediate spaces. From the point of view of the situated observer, it gives a sense of how much further exploration a space will allow. Therefore, it seems reasonable to assume that in the initial stages of exploration, people tend to go to such areas that offer a better sense of other spaces, through visual connections.

2.a.2 Proportional Line Use in Open Exploration

As subjects were walking about during open exploration, certain factors may have influenced repeated use of corridors. These could have been signage, light conditions, color, finish materials, presence of people and so on. Since these variables could not be considered in the experiment, *Proportional Use*, or the number of subjects who used each axial line seemed to be a good variable to explore. This does not take into account the repeat use of spaces, and so controls to some degree, for extraneous factors. Obviously, the maximum value that a line could have was the number of subjects carrying out open exploration.

Proportional Use correlated strongly, in all three cases, with Public Integration3 i.e. integration value of corridors in the *public system*, calculated to depth 3. (r= .69, .86 and .81, for Urban, University and City Hospitals respectively; p=<.0001 in all cases, see tables 7.12, 7.13 and 7.14). When City hospital was considered as two separate systems, Public Integration 3 was also quite significant (see table 7.15, r= .71, p=.010 and r= .81, p=.001 for system 1 and 2 of City Hospital respectively).

This seems to be a potentially important finding. In open exploration, Public Connectivity was the best predictor of total uses of a line, that is when repeat visits to axial lines were counted. However Public Integration (3) was the best predictor of the proportion of people visiting a line. While there was not a statistically significant difference between the correlations, this relationship was obtained in all three settings. This finding has methodological implications—total use and proportional use seem to respond somewhat differently to morphological variables and both should be included in wayfinding studies. While the differences between the correlations are quite small, and the finding needs to be replicated before making too much of it, it points to the potential value of exploring individual differences in wayfinding behavior. The greater predictive power of Connectivity for Total Use suggests that some individuals seem to bias their search behavior strongly toward connected spaces. It would be quite useful to see if these wayfinders differed from others in any ways.

Statistically, as tables 7.2, 7.4, 7.6, 7.8 and 7.9 demonstrate, Public Integration 3 correlates with Public Connectivity at .92, .93, .97, .98 and .98 in all the 5 cases (p=<.0001 in all cases). Such a high collinearity makes it difficult to predict confidently. Additional testing through paired comparisons (z-values) and p-values of intercepts could not produce a definite answer either.

Theoretically, it may be possible to claim that some sense of configuration has developed during the open exploration phase. If so, then it makes more sense that in the beginning stages of configurational learning, as demonstrated through open exploration, Public Integration (3) i.e. that considers Public Integration upto a radius three should become important. This finding has some support from previous research in a different context. Choi (1999) analyzed visitor's paths in eight museum settings and found that while Integration correlated with the number of people that reached each convex space, Connectivity was correlated with the number of times each space was used. Although in the museums there were no appreciable correlations between frequency and total use, in the hospitals used here they were highly correlated (.90, .89, and .86, p=<.0001, in the three settings).

An investigation into such a complexity should perhaps begin with an analysis of the layouts. Indeed, in a previous study on London housing estates it was shown that correlations of movement with configurational variables considered from the boundaries of the estate was low, but it increased when the estates were reanalyzed as part of a larger urban context (Hillier, Burdett, Peponis and Penn, 1987). These studies suggest that there may be some scope for investigating the criteria of the limits of the environment in calculating relational values. Unfortunately, a more detailed environmental analysis was not part of this research.

It was hypothesized in this study, that open exploration will be more biased towards local properties. Furthermore, the influence of Public Connectivity and Public Integration(3) could not be statistically separated. Therefore Public Connectivity was taken as an important predictor of proportional line use in Open Exploration. Figures 7.11 through 7.15 show the scatter-grams and regression lines for the relationships between Public Connectivity and *proportional* use of corridors for all the 5 settings in the 3 hospitals (r= .63, p=<.0001, .81, p=<.0001, 78, p=<.0001, .71, p=010 and .71, p=.007 respectively for the three settings. See tables 7.12, 7.13, 7.14 and 7.15).

2.a.3 Discussion

In this thesis Public Connectivity is taken as an important predictor in the case of open exploration. (see table 7.24). In other words, people tend to use those corridors that give indication of more spaces.

Public Connectivity indicates how many other public corridors are available from a given corridor. Therefore, this is also a measure of how much *potential exploration* one corridor will allow. Hence, in situations of open exploration, people are evidently drawn to those areas that offer more possibilities of exploration.

As demonstrated before, Public Integration 3 had significant relationship with use of corridors. It had the highest correlation with proportional use in Urban

Hospital, University Hospital, City Hospital and City Hospital segment 2. As defined by Space Syntax, the measuring unit of integration, RRA, can be used to compare *between* different settings. Hence, a stacked data set containing the values of all the three settings was produced to investigate the relationship of total and proportional use of lines with Public Integration 3 (RRA 3) values across all the 3 settings. This produced r= .60 and r= .55 (p =<0001 in both cases) for total and proportional use respectively (see figures 7.16 and 7.17).

Public Integration 3 is a lower order measure of configuration. It indicates the extent to which each space is connected, to a depth of three, to all other spaces in the public spatial system. It is tempting to suggest here that while walking through complex architectural settings subjects gain a preliminary understanding of spatial configuration. In the future, one way to investigate this would be to compare the use of spaces in the first few minutes and the last few minutes of the open search. (That was not possible in this study).

2.b <u>Open Exploration: Node Use and Node Variables</u>

Next, correlations of node use in open exploration and the different environmental variables for the three settings were done. Tables 7.16 through 7.18 show the r-values for the three hospitals of this study; Urban Hospital, University Hospital, and City Hospital. Table 7.19 shows the correlation when City Hospital was considered as two separate systems.

2.b.1 Total node use in Open Exploration

The best predictor for total node use in Urban hospital was DP degree (r= .72, p=<.0001; see table 7.16 and figure 7.18). However All Integration and All Connectivity were also highly correlated with total node use (r= .70 and .68, p=<.0001 in both the cases). However, these correlated with DP Degree at .757 and .654 respectively (p=<.0001 in both the cases, see table 7.3).

In the case of University hospital the important predictors were Public Integration (.85, p=<.0001), Public Connectivity (.85, p=<.0001), Public Integration 3 (.84, p=<.0001) and DP degree (.84, p = <.0001, see table 7.17). However, all of these environmental variables correlate with DP degree at r-values .85, p=<.0001, .88, p=<.0001 and .90, p=<.0001 respectively (see table 7.5). Figure 7.19 shows the scattergram and correlation of Total Node Use in Open exploration with DP Degree in University Hospital. In the final case, that of City Hospital, Node use gave very poor correlations when the layout was considered as one system (see table 7.18). The only correlation worth mentioning was with public integration. (r= .49, p=.0084). However, when the layout was considered as two independent systems, Nodes Recognized became important in segment 1 (r= .63, p=.038; see table 7.19 and figure 7.20). In segment 2, Actual Node Integration and Public Integration became important (.66, p=.006 and .59, p=.025 respectively).

2.b.2 Proportional Node Use in Open Exploration

In Urban Hospital, proportional node use most strongly correlated with DP degree (r= .68, p=<.0001; see table 7.16). Other important environmental measures were All Integration (.65, p=<.0001), All Connectivity (.61, p=<.0001) and Nodes

Recognized (.63, p=<.0001). Figure 7.21 shows the scattergram and correlation of Proportional Node Use in Open Exploration with DP Degree in Urban Hospital.

In University Hospital, Public Integration (.84, p=<.0001), Public Integration 3 (.82, p=<.0001), Public Connectivity (.80, p=<.0001), and DP Degree (.72, p=<.0001) were all highly correlated with Proportional Node Use (table 7.17). Here too, the variables correlated with DP Degree at levels .85, .88 and .90, (p=<.0001 in all cases). Since DP degree considers exploration potential, it was taken as being important (see figure 7.22).

As with the condition of total use, proportional use correlated very poorly with node values when City hospital was considered as one complex, with the exception of Public Integration and Actual Node Integration (r= .57, p = .0016 and r= .66, p=.0160; see table 7.18). However, they were correlated with one another at r= .88, p = <.0001 (see table 7.7).

When environmental values were taken from the separated system of City Hospital, Public Integration (.84, p=.001), All Integration (.84, p=.001), Nodes Recognized (.80, p=.003), and DP Degree (.82, p=.002) produced high correlations for segment 1 of the setting (table 7.19). In this case too, they correlated to one another at .90, p=<.0001, .92, p=<.0001 and .79, p=.0022. From this consideration, the locally related measures – DP Degree and Nodes Recognized were taken as important (r= .82, p = .002, and r= .80, p = .003; see figure 7.23 and 7.24).

2.b.3 Discussion

In the settings considered, Decision Point Degree or DP Degree was found to be highly and significantly correlated with total use and proportional use of nodes in open exploration (see table 7.24).

At this point, a comparison should be made between Public Connectivity of axial lines and DP Degree of nodes. Public Connectivity is a measure of how many other public corridors are connected to one and by definition may be seen from any location within one axial line. Similarly, DP Degree is a measure of the other nodes that can be seen from one node. Thus, both of these units are similar because they provide a sense of gaining more information or possibilities for exploration.

It is not surprising that in the case of Open Exploration, i.e. when subjects were trying to understanding an unfamiliar setting by walking within it, those values which provided opportunities for more exploration turned out to be the most significant across the three hospitals and the two kinds of environmental units, lines and nodes. This also makes the most intuitive sense.

2.c <u>Directed Search: Redundant Node use and Node variables</u>

The final task in this section was to look at behavior in a directed wayfinding situation. In this case the dependent variable was 'redundant node use'. These were nodes that were repeatedly used by the subjects despite the fact that they were not required to do so. Peponis, Zimring and Choi (1990) had used this variable previously in their research on wayfinding.

2.c.1 Total Redundant Node Use (Directed Search)

For Urban Hospital, Redundant Node Use had high correlations with Public Connectivity (.72, p=<.0001), DP Degree (.72, p=<.0001) and Public Integration 3 (.71, p=<.0001, see table 7.20). As before, DP Degree correlated with Public Connectivity at .89, p=<.0001, and with Public Integration 3 at .81, p=.0001 (see table 7.3). Figure 7.25 Shows the scattergram and the correlation of Total Redundant Node Use in Directed Search with DP Degree in Urban Hospital.

In this hospital, Actual Node Integration correlated with total Redundant Node Use at r= .56, p=<.0001 (see figure 7.26). This variable only correlates with DP degree at r= .43, p=.0030. Thus Actual Node Integration was also an important predictor of Redundant Node Use.

In University Hospital, Actual Node Integration was highest (.82, p=<.0001), followed by Public Integration (.68, p=<.0001), Public Connectivity (.66, p=<.0001), All Integration (.65, p=<.0001), Public Integration 3 (.64, p=<.0001) and DP Degree (.64, see table 7.21). Unfortunately, all of these variables correlated with DP Degree at .73, .85, .90,.80 and .88 respectively (p=<.0001 in all cases, see table 7.5). Figure 7.27 and 7.28 shows the correlations of Total Redundant Node Use in Directed Search with DP Degree and Actual Node Integration in University Hospital.

In City Hospital Node Variables and their Redundant use produced extremely low correlations with only Isovist area/perimeter ratio being worthy of mention (r= .50, p= .0064; see table 7.22). When the hospital was considered as separate systems, then Actual Node Integration gave the highest and the only significant correlation in segment 1 (r= .66, p= .02; see table 7.23 and figure 7.29).

2.c.2 Proportional Redundant Node Use (Directed Search)

In the cases when instead of total node use, the number of subjects who used a node i.e. Proportional Node Use was considered, the results were similar.

In Urban Hospital, All Integration 3, All Integration and DP Degree became important (r= .73, .72 and .71, p=<.0001 in all cases; see table 7.20). DP Degree correlated with All Integration 3 at levels of .61 and with All Integration at r= .76 (p=<.0001 in both cases; See table 7.3). Figure 7.30 shows the scattergrams and correlation of Proportional Redundant Node Use in Directed Search with DP Degree in Urban Hospital. In this hospital Proportional Redundant Node Use also correlated with Actual Node Integration at r= .61, p=<.0001 (see table 7.20 and figure 7.31).

In the case of University Hospital, Proportional Node Use correlated with Actual Node Integration at .71, p=<.0001, Public Integration at .60, p=.0002, Public Integration 3 at .60, p=.0003, Public Connectivity at .59, p=.0003 and with DP Degree at .54, p=.0013 (see table 7.21 and figures 7.32 and 7.33). These variables correlate with DP degree at .73, .85, .86 and .90, p=<.0001 in all cases (see table 7.5).

Finally, as in the case of total redundant node use, the correlations between proportional redundant use and node values were not significant in the case of City Hospital as a single setting (see table 7.22). But in segment 1, Isovist Perimeter and All Integration 3 became important (r= .63, p= .0269 and r= .61, p= .0308; see table 7.23). Most importantly, Actual Node Integration was also highly correlated with Proportional Redundant Node Use (r= .774 p=.0031; see table 7.23, figure 7.34).

2.c.3 Discussion

In a search situation, when people are looking for unknown destinations, there seems to be a bias for nodes that have a higher value of Decision Point Degree. Recall that this measure is the number of nodes that can be seen from one node, and a higher DP Degree value indicates possibilities of more exploration. This result is similar to the environmental preference found in the case of open search.

What is perhaps more relevant to this study is the fact that Actual Node Integration was consistently found to be a significant predictor of both total use and proportional use of nodes, across all the settings (see table 7.24). Actual Node Integration is a configurational variable that takes into account how the nodes are connected to one another in the public system. In directed search, when subjects had already some experience of their setting, they tended to use nodes with a higher Integration value. This indicates an understanding of the configuration; i.e. a comprehension of global topological properties of the environment.

3 COGNITIVE DATA

3.a Environmental Elements in Cognition

One of the preliminary questions regarding cognitive data was: what properties of the environment are expressed in the cognitive representations? Since this thesis accepts the position of a cognitively mediated model of behavior, the environmental variables that were found to be important in wayfinding can also be expected to be significant in cognitive representations.

It was shown in the prior section of this dissertation that Public Connectivity is an important predictor in line use behavior in both exploration and search situations. Therefore one may expect it to be an important predictor in cognitive maps also.

To test this hypothesis, axial line values were correlated with the corridors that were drawn in the sketch maps by the subjects. As expected, Public Connectivity correlated strongly with the proportion of the sample that drew the lines in all the 3 settings (r= .56, p=.0009 r= .68, p=.0003 and r= .82, p=.0021 respectively in University Hospital, City Hospital and Segment 1 of City Hospital. See figures 7.35, 7.36 and 7.37).

This is a significant result. The environmental variable that correlated strongly with wayfinding behavior was also found to predict 31, 46 and 67 percent of the variance of sketch map lines. This illustrates the connection between cognitive maps and wayfinding behavior. From the point of view of the environment, those units that provide opportunities for more information are more prominent in wayfinding and this feature prominently in cognitive maps too.

Additional correlations of lines in maps were undertaken with Public Integration (3) and those were also significant. The correlations were, .56, p=.0008, .70, p=.0002 and .85, p=.0009 (see figures 7.38, 7.39 and 7.40). These are slightly higher than correlations with connectivity in all three cases. Although not statistically significant, it serves to illustrate the point that configurational variables are an important consideration in cognitive learning. Additionally, it serves to establish the hypothesis that human spatial behavior and an internalized understanding of space are interrelated, and that a knowledge of configuration is an important aspect of cognitive maps.

3.b Overall complexity of layouts

The subjects in University and City Hospitals completed two cognitive tests; pointing to unseen destinations and estimating distances between various known locations. Comparing the results of these 2 tasks should give an indication about the overall complexity of the settings from the point of view of the situated person. It could then be compared to the independent complexity measures derived from Space Syntax analysis, namely intelligibility, to see how they compare.

First of all, an unpaired t-test was performed on pointing errors and distance estimation errors. This produced a somewhat unexpected result. Whereas the difference in pointing was highly significant (p= .0042, t= -2.934) between the two settings, it was less so in distance estimation (p= .4168, t= .816). It would seem that in terms of estimating distances, the two layouts seemed similar, but in terms of pointing to unseen destinations, City Hospital was conceived to be more complex.

This dichotomous result was clarified by literature survey. Although distance estimation is a widely used procedure to study orientation (Golledge, 1977), yet in many cases it is found to be untrustworthy. For example Hirtle and Hudson (1991) found no difference in distance estimation, but a substantial difference in orientation, when they were comparing between a group that studied maps and a group that looked at slides of the same environment. Garling, Book, Ergezen, & Lindberg (1981) also found a similar distinction in their work where distance estimates were less accurate than direction estimates.

In this case then, considering the results of the pointing tasks, City Hospital can be taken to be seen as more complicated than University Hospital. The public intelligibility, of these two, as independently determined for these two hospitals were .557 and .831 (see table 7.1). Therefore there is some cause to believe that intelligibility may reflect the ease or difficulty of learning about a layout.

A correlational study between pointing errors and cognitive map configuration values were also significant ($r= .433$, $p= < .0001$). This is important because it attests to the convergent validity of the two cognitive tasks undertaken.

4 OTHER ANALYSES

4.a The effects of entry points on open exploration

The next level of analysis considered the effect of the entry points on open exploration: does the property of an entry influence the way a building is explored? If so, how and to what extent? In this experiment two settings were explored from more than one entry point. In Urban Hospital, each participant started from 1 of 3 entries and in City hospital from 1 of 2. The different entries of any layout usually vary by the property of mean depth. For example, entry B of Urban hospital has the least mean depth in that setting (2.737), followed by C (3.658) and A (5.234) respectively (See figures 6.17, 6.18 and 6.19). On the other hand, the two entry points of City hospital has values of 3.478 and 3.261 for A and B respectively (see figures 6.20 and 6.21).

As was shown in Section 2 above, Public Connectivity predicts the use of axial lines. To explore the effect of entry points on open exploration, a multiple regression model was proposed with *Public Connectivity* and *Mean Depth* of entry space as predictors of total axial line use. If total line use is y, then the regression equation is

$y=\beta_0+\beta_1$(public connectivity) $+\beta_2$(mean depth)

For Urban Hospital this analysis resulted in the following

y=1.792 + 5.211 (public Connectivity) + (-1.561) (mean depth),

($r=.722$, $p=<.0001$).

For city Hospital it was

y=19.152 + 15.830 (public Connectivity) + (-7.680) (mean depth),

($r= .762$, $p= < .0001$).

Therefore, for Urban Hospital and City Hospital respectively, this model predicts 52% and 58% of the variance. From the same model, it is seen that the co-efficient of Mean Depth was calculated as -1.561 and –7.680 respectively for the two settings. Hence, it can be said that use of an axial line is inversely correlated with Mean Depth of a starting point. In other words, people who entered from spaces with lesser Mean Depth had a better opportunity to explore the layout, given the fact that they all had a fixed amount of time to do so.

From the above, it can be said in general, that if visitors are brought in from entries with lesser Mean Depth, then they will have a better chance of wayfinding success within the configuration. This then becomes an important design consideration, especially in the case of complex architectural settings.

4.b Quantification of Nodes Recognized

As described in Chapter 6, Nodes Recognized was considered important because it takes into account human sensibilities. In this chapter it was shown that it has turned out to be an important predictor. This variable was determined by inter-subjective rating that was obtained by asking various participants to actually judge how many other nodes they could recognize from different origin nodes.

However, in applied situations, it may not be possible to conduct inter-subjective evaluations. Neither will it be possible to do so in buildings yet to be built. Therefore, a different method of considering this variable is important.

In all the hospitals studied here, it was found that values of Nodes Recognized correlated quite highly with DP degree. The correlation r-values are .56, p=<.0001, .66, p=0003, .72, p=<.0001, .80, p=.0022 and .77, p=.0005 respectively for Urban, University, City, City segment 1 and City segment 2 respectively (see tables 7.3, 7.5, 7.7, 7.10 and 7.11). Therefore, in applied situations where ones need to assess nodes that will be heavily used, DP degree can be taken as a substitute for Nodes Recognized. It may also be noted that while this substitution may be valid in architectural settings, i.e. buildings, it may not be so in the case of urban areas.

Table 7. 1 Comparison of environmental variables between the settings.

		ENVIRONMENTAL VARIABLES	URBAN HOSPITAL	UNIVERSITY HOSPITAL	CITY HOSPITAL	CITY HOSPITAL Segment 1	CITY HOSPITAL Segment 2	ALL HOSPITALS
		no. pub lines	39	32	24			95
		no. total lines	377	348	280			1005
		No. public nodes	46	33	28			107
Axial Lines	Public System	intelligibility (pub)	.664	.831	.557	.923	.674	
		max integration (pub)	1.548	2.317	1.263			
		min integration (pub)	.506	.601	.498			
		mean integration (pub)	.93	1.052	.78			
		max pub connectivity	9	8	4			
		min pub connectivity	1	1	1			
		mean pub connectivity	2.844	2.188	2.333			
	All System	intelligibility (all)	.428	.435	.412	.840	.747	
		max integration (all)	1.869	3.177	1.9			
		min integration (all)	.787	.834	.561			
		mean integration (all)	1.16	1.513	1.138			
		max connectivity (all)	28	40	35			
		min connectivity (all)	1	1	1			
		mean connectivity (all)	3.607	3.218	2.586			
Nodes	Public System	Actual node intelligibility	.660	.534	.320	.807	.556	
		node intelligibility pub	.789	.935	.483	.911	.711	
		max node int pub	1.7069	1.954	1.234			
		min node int pub	.5604	.687	.493			
	All system	node intelligibility all	.771	.696	-.045	.735	.814	
		max actual node int	.993	.976	.846	1.1047	1.1098	
		min actual node int	.436	.392	.375	.475	.412	
		max node int all	2.05	2.979	1.881			
		min node int all	1.16	1.289	1.093			

Table 7. 2 *Correlation matrix for axial line measures in Urban Hospital*

	Pub Int	All Int	PUB int(3)	All Int.(3)	PUB Conn	All Conn
Pub Int						
All Int	.833					
PUB int(3)	.797	.677				
All Int.(3)	.474	.760	.495			
PUB Conn	.665	**.552, .0003**	**.922, <.0001**	.437		
All Conn	.428	.681	.412	.911	.429	

Table 7.3 Correlation matrix for node measures in Urban Hospital

	Pub INT	All INT	ACTUAL NODE INT	Pub INT(3)	All INT (3)	Public Connectivity	All Connectivity	DP degree	NODES RECOGNISED	Isovist area	Degree
Pub INT											
All INT	0.886										
ACTUAL NODE INT	0.756	0.681									
Pub INT(3)	0.892	0.822	0.586								
All INT (3)	0.514	0.751	0.44	0.526							
Public Connectivity	0.797	0.742	0.495	0.898	0.457						
All Connectivity	0.565	0.771	0.447	0.532	0.933	0.527					
DP degree	0.711	**0.757, <.0001**	**0.428, .0030**	**0.814, <.0001**	**0.611, <.0001**	**0.884, <.0001**	**0.654, <.0001**				
NODES RECOGNISED	0.284	0.311	0.236	0.437	0.291	0.473	0.245	**0.556, <.0001**			
Isovist area	0.153	0.292	-0.103	0.259	0.233	0.31	0.226	0.381	0.382		
Degree	0.062	0.038	-0.12	0.199	0.136	0.079	0.041	0.111	0.175	0.345	

Table 7. 4 Correlation matrix for axial line measures in University Hospital

	Pub INT	All INT	Pub INT(3)	All INT (3)	Pub CONN	All CONN
Pub INT						
All INT	.942					
Pub INT(3)	.864	.843				
All INT (3)	.498	.608	.655			
Pub CONN	.837	.760	**.927, <.0001**	.559		
All CONN	.519	.650	.576	.905	.480	

Table 7.5 *Correlation matrix for node measures in University Hospital*

	Pub INT	All INT	ACTUAL NODE INT	Pub INT(3)	All INT(3)	Pub CONN	All CONN	DP Degree	Nodes Recog	Isovist Area	Isovist Peri	Isovist A/P	Degree
Pub INT													
All INT	0.956												
ACTUAL NODE INT	0.806	0.847											
Pub INT(3)	0.948	0.895	0.756										
All INT(3)	0.419	0.524	0.282	0.457									
Pub CONN	0.948	0.878	0.761	0.981	0.447								
All CONN	0.537	0.682	0.455	0.516	0.933	0.496							
DP Degree	**.846, <.0001**	**0.801, <.0001**	**0.726, <.0001**	**0.879, <.0001**	0.603	**.897, <.0001**	0.638						
Nodes Recog	0.782	0.7	0.655	0.814	0.458	0.81	0.498	**0.663, .0003**					
Isovist Area	0.874	0.835	0.644	0.893	0.687	0.903	0.703	0.931	0.849				
Isovist Peri	0.847	0.826	0.635	0.862	0.726	0.87	0.75	0.91	0.833	0.982			
Isovist A/P	0.605	0.539	0.379	0.647	0.39	0.619	0.335	0.581	0.578	0.661	0.533		
Degree	0.345	0.248	0.204	0.438	0.202	0.396	0.157	0.36	0.605	0.462	0.422	0.524	

Table 7.6 Correlation matrix for line measures in City Hospital

	PUB INT	All INT	PUB INT(3)	All INT (3)	Pub CONN	All CONN
PUB INT						
All INT	.725					
PUB INT(3)	.629	.768				
All INT (3)	.023	.341	.691			
Pub CONN	.557	.688	**.970, <.0001**	.721		
All CONN	-.026	.306	.607	.945	.646	

Table 7.7 Correlation matrix for node measures in City Hospital

	PubINT	All INT	ACTUAL NODE INT	PubINT(3)	All INT(3)	PubCONN	AllCONN	DP DEGREE	NODES RECOGNIZED	NVA	No.OCCL EDGES	OCC ANGLES	ISOAREA	ISO PERI	ISOVIST A/P	DEGREE
PubINT																
All INT	0.455															
ACTUAL NODE INT	**.874 <.0001**	0.6														
PubINT(3)	0.483	0.55	0.287													
All INT(3)	-0.363	0.011	-0.579	0.53												
PubCONN	0.409	0.492	0.199	0.982	0.591											
AllCONN	-0.431	0.002	-0.616	0.455	0.981	0.523										
DP DEGREE	0.425	0.457	0.196	0.962	0.573	0.976	0.511									
NODES RECOGNIZED	0.093	0.55	0.086	0.735	0.558	0.788	0.512	0.738								
NVA	-0.094	0.397	0.041	0.337	0.235	0.421	0.276	0.421	0.624							
No.OCCL EDGES	0.011	0.51	0.034	0.673	0.49	0.701	0.471	0.633	0.783	0.65						
OCC ANGLES	0.083	0.175	0.063	0.506	0.24	0.568	0.202	0.577	0.523	0.61	0.635					
ISOAREA	-0.257	0.345	-0.302	0.558	0.809	0.629	0.843	0.614	0.772	0.619	0.683	0.352				
ISO PERI	-0.116	0.316	-0.292	0.687	0.912	0.742	0.911	0.727	0.737	0.408	0.612	0.283	0.927			
ISOVIST A/P	-0.389	0.345	-0.187	0.238	0.409	0.293	0.472	0.271	0.611	0.733	0.626	0.367	0.795	0.534		
DEGREE	-0.186	-0.138	-0.306	0.061	0.381	0.113	0.413	0.077	0.177	0.05	0.179	-0.235	0.439	0.401	0.275	

Table 7.8 Correlation matrix for axial line values in City Hospital segment 1

	Pub INT	all INT	Pub INT (3)	all INT (3)	pub CONN	all CONN
Pub INT						
all INT	.993					
Pub INT (3)	.920	.937				
all INT (3)	.824	.869	.900			
pub CONN	**.923, <.0001**	**.933, <.0001**	**.977, <.0001**	**.884, <.0001**		
all CONN	.801	.840	.887	.974	**.896, <.0001**	

Table 7.9 Correlation matrix for axial line values in City Hospital segment 2

	Pub INT	all INT	Pub INT (3)	all INT (3)	pub CONN	all CONN
Pub INT						
all INT	.512					
Pub INT (3)	.724	.726				
all INT (3)	.202	.879	.629			
pub CONN	.674	.702	**.980, <.0001**	.664		
all CONN	.115	.747	.564	.936	.601	

Table 7.10 *Correlation matrix for node measures in City Hospital Segment 1*

	pubINTsep	all INTsep	ACTUAL NODE INTsep	pubINT(3)sep	all INT(3)sep	pubCONNsep	allCONNsep	DP DEGseparate	NODES RECOGNIZED	NVAsep	No.OCCL EDGESsep	OCC ANGLESsep	ISO AREAsep	ISO PERIsep	ISOVIST A/P sep	DEGREEsep
pubINTsep																
all INTsep	0.992															
ACT NODE INTsep	0.747	0.76														
pubINT(3)sep	0.87	0.894	0.525													
all INT(3)sep	0.741	0.794	0.458	0.896												
pubCONNsep	0.898	**0.916, <.0001**	0.538	0.991	0.879											
allCONNsep	0.673	0.726	0.358	0.871	0.981	0.85										
DP DEGseparate	**0.898, <.0001**	**0.916, <.0001**	**0.538 .0714**	0.991	0.879	1	0.85									
NODES RECOG.	0.905	0.919	0.803	0.742	0.625	0.791	0.526	**0.791 .0022**								
NVAsep	0.143	0.142	-0.068	0.116	0.039	0.18	-0.01	0.18	0.317							
No.OCCL EDGEsep	0.636	0.651	0.352	0.709	0.463	0.719	0.424	0.719	0.645	0.494						
OCC ANGLESsep	0.626	0.588	0.464	0.558	0.342	0.596	0.26	0.596	0.575	0.539	0.71					
ISO AREAsep	0.771	0.835	0.682	0.787	0.846	0.786	0.829	0.786	0.772	0.018	0.479	0.22				
ISO PERIsep	0.776	0.836	0.603	0.843	0.92	0.841	0.917	0.841	0.733	0.037	0.484	0.26	0.98			
ISOVIST A/P sep	0.154	0.185	0.581	-0.122	-0.139	-0.114	-0.22	-0.114	0.365	-0.121	0.007	-0.151	0.328	0.139		
DEGREEsep	-0.52	-0.458	-0.329	-0.339	-0.162	-0.387	-0.053	-0.387	-0.45	-0.54	-0.524	-0.898	-0.018	-0.045	0.091	

Table 7.11 *Correlation matrix for node measures in City Hospital segment 2*

	pubINTsep	all INTsep	ACTUAL NODE INTsep	pubINT(3)sep	all INT(3)sep	pubCONNsep	allCONNsep	DP DEGseparate	NODES RECOGNIZED	NVAsep	No.OCCL EDGESsep	OCC ANGLESsep	ISO AREAsep	ISO PERIsep	ISOVIST A/P sep	DEGREEsep
pubINTsep																
all INTsep	0.412															
ACT NODE INTsep	0.796	0.43														
pubINT(3)sep	0.749	0.711	0.637													
all INT(3)sep	0.196	0.833	0.37	0.509												
pubCONNsep	0.691	0.71	0.581	**0.98, <.0001**	0.555											
allCONNsep	-0.067	0.824		0.441	0.794	0.517										
DP DEGseparate	0.577	0.493	0.472	0.855	0.264	0.866	0.393									
NODES RECOG.	0.591	0.692	0.611	0.912	0.609	0.921	0.491	0.77								
NVAsep	0.336	0.427	0.36	0.664	0.298	0.715	0.405	0.727	0.675							
No.OCCL EDGEsep	0.262	0.396	0.369	0.672	0.491	0.712	0.352	0.565	0.783	0.436						
OCC ANGLESsep	0.113	0.077	0.238	0.487	0.089	0.544	0.123	0.574	0.539	0.75	0.706					
ISO AREAsep	0.122	0.758	0.211	0.657	0.699	0.731	0.886	0.695	0.73	0.715	0.544	0.439				
ISO PERIsep	0.151	0.809	0.195	0.63	0.741	0.694	0.921	0.663	0.679	0.52	0.48	0.228	0.957			
ISOVIST A/P sep	-0.023	0.518	0.173	0.516	0.503	0.587	0.638	0.494	0.614	0.835	0.55	0.72	0.811	0.618		
DEGREEsep	0.148	0.38	0.228	0.453	0.494	0.554	0.483	0.477	0.53	0.389	0.697	0.438	0.611	0.583	0.48	

Table 7.12 Correlations (r-values) of Axial line values with their use in Open Exploration. (Urban Hospital)

Environmental Properties		Line units	PROP LINE USE		TOTAL LINE USE	
			r	p	r	p
Relational	Global	Pub Int.	.563	.0002	.620	<.0001
		All Int.	.631	<.0001	.669	<.0001
	Specified	Pub Int. (3)	**.692**	<.0001	**.744**	<.0001
		All Int. (3)	.552	.0003	.590	<.0001
Discrete		Pub Conn.	**.627**	<.0001	**.768**	<.0001
		All Conn.	.550	.0003	.615	<.0001

Table 7.13 Correlations (r-values) of Axial line values with their use in Open Exploration. (University Hospital)

Environmental Properties		Line units	PROP LINE USE		TOTAL LINE USE	
			r	p	r	p
Relationa	Global	Pub Int.	.750	<.0001	.819	<.0001
		All Int.	.762	<.0001	.778	<.0001
	Specified	Pub Int. (3)	**.859**	<.0001	**.829**	<.0001
		All Int. (3)	.644	<.0001	.586	.0004
Discrete		Pub Conn.	**.814**	<.0001	**.884**	<.0001
		All Conn.	.573	.0006	.566	.0007

Table 7.14 *Correlations (r-values) of Axial line values with their use in Open Exploration.*

(City Hospital)

Environmental Properties		Line units	PROP LINE USE		TOTAL LINE USE	
			r	p	r	p
Relational	Global	Pub Int.	.564	.041	.636	.0008
		All Int.	.599	.0020	.450	.0272
	Specified	Pub Int. (3)	**.814**	<.0001	**.775**	<.0001
		All Int. (3)	.488	.0155	.468	.0212
Discrete		Pub Conn.	**.784**	<.0001	**.786**	<.0001
		All Conn.	.360	.0841	.337	.1069

Table 7.15 *Correlations (r-values) of Axial line values with their use in Open Exploration.*

(City hospital as two systems)

Environmental Properties		Line units	SUB SYSTEM 1				SUB SYSTEM 2			
			PROP LINE USE		TOTAL LINE USE		PROP LINE USE		TOTAL LINE USE	
			r	p	r	p	r	p	r	p
Relational	Global	Pub Int.	.708	.010	.776	.003	.686	.010	.774	.002
		All Int.	**.759**	.004	**.818**	.001	.450	.123	.505	.078
	Specified	Pub Int. (3)	**.707**	.010	.780	.003	**.806**	.001	**.832**	.000
		All Int. (3)	.768	.004	.733	.007	.190	.534	.250	.411
Discrete		Pub Conn.	**.711**	.010	**.798**	.002	**.705**	.007	**.792**	.001
		All Conn.	.731	.007	.688	.013	.094	.759	.142	644

Table 7.16 Correlations (r-values) of *<u>Node values</u>* *with their use in* *<u>Open Exploration</u>.*

(Urban Hospital)

Environmental Properties		Node units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	.559	<.0001	.588	<.0001
		All Int.	**.650**	<.0001	**.699**	<.0001
		Act Node Int.	.444	.0020	**.494**	.0005
	Specified	Pub Int. (3)	.603	<.0001	.652	<.0001
		All Int. (3)	.559	.0003	.637	<.0001
	Local	Pub Conn.	.576	<.0001	.605	<.0001
		All Conn.	**.610**	<.0001	**.675**	<.0001
		DP degree	**.678**	<.0001	**.723**	<.0001
		Nodes Recog.	**.625**	<.0001	**.642**	<.0001
		N.V. Area	---	---	---	---
		Isovist area	.463	.0012	.480	.0007
		Isovist area/perimeter	---	---	---	---
		Isovist Perimeter	---	---	---	---
		No. Occluding Edges	---	---	---	---
		Occluding Angles	---	---	---	---
Discrete		Degree	.146	.3328	.142	.3454
		Node area	---	---	---	---

Table 7.17 Correlations (r-values) of <u>Node values</u> with their use in <u>Open Exploration</u>. (University Hospital)

Environmental Properties		Node units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	**.841**	<.0001	**.847**	<.0001
		All Int.	.779	<.0001	.793	<.0001
		Act Node Int.	.737	<.0001	**.788**	<.0001
	Specified	Pub Int. (3)	**.822**	<.0001	**.840**	<.0001
		All Int. (3)	.480	.0047	.552	.0009
	local	Pub Conn.	**.801**	<.0001	**.846**	<.0001
		All Conn.	.538	.0012	.599	.0002
		DP degree	**.724**	<.0001	**.839**	<.0001
		Nodes Recog.	.742	<.0001	**.795**	<.0001
		N.V. Area	---	---	---	---
		Isovist area	.736	<.0001	.791	<.0001
		Isovist area/perimeter	.426	.0134	.436	.0111
		Isovist Perimeter	.730	<.0001	.787	<.0001
Discrete		Degree	.472	.0055	.460	-.393
		Node Area	---	---	---	---

Table 7.18 Correlations (r-values) of <u>Node values</u> with their use in <u>Open Exploration</u>. (City Hospital)

Environmental Properties		Node units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	**.568**	.0016	**.488**	.0084
		All Int.	.009	.9651	.053	.7907
		Act. Node Int	**.675**	.0160	.369	.0531
	Specified	Pub Int. (3)	324	.0925	.253	.1948
		All Int. (3)	-.323	.0939	-.169	.3898
	Local	Pub Conn.	.294	.1291	.273	.1600
		All Conn.	-.422	.0252	-.276	.1551
		DP degree	.330	.0864	.289	.1357
		Nodes Recog.	.088	.6578	.150	.4475
		N.V. Area	-.130	.5094	-.170	.3863
		Isovist area	-.298	.1232	-.205	.2961
		Isovist area/perimeter	-.328	.0879	.324	.0927
		Isovist Perimeter	-.255	.2494	.090	.6499
		No. Occluding edges	.117	.5544	.226	.2474
		Occluding Angles	.296	.1421	.213	.2950
Discrete		Degree	.059		.276	
		Node Area	-.156	.4285	-.332	.0823

Table 7.19 Correlations (r-values) of Node values with their use in Open Exploration. (City hospital as two systems)

Environmental Properties		Node units	SUB SYSTEM 1				SUB SYSTEM 2			
			PROP NODE USE		TOTAL NODE USE		PROP NODE USE		TOTAL NODE USE	
			r	p	r	p	r	p	r	p
Relational	Global	Pub Int.	**.844**	.001	.282	.374	.439	.0893	**.588**	.025
		All Int.	**.842**	.001	.310	.327	-.281	.2923	-.017	.951
		Act. Node Int.	.781	.003	**.478**	.117	.450	.0804	**.656**	.006
	Specified	Pub Int. (3)	.706	.010	.100	.758	.245	.3596	.404	.120
		All Int. (3)	.496	.101	.007	.983	-.363	.1676	-.056	.837
	local	Pub Conn.	**.706**	.010	.144	.656	.159	.5576	.332	.209
		All Conn.	.429	.164	-.059	.856	-.615	.0133	-.403	.122
		DP Degree	**.821**	.002	.144	.656	.226	.3995	.254	.343
		Nodes Recog	**.800**	.003	**.629**	.038	.179	.5244	.388	.153
		N.V. Area	.062	.848	.148	.646	.183	.4987	.193	.473
		Isovist Area	.670	.017	.313	.321	.310	.2433	.152	.575
		Isovist Area/Perimeter	.447	.145	.524	.080	.076	.7810	.045	.868
		Isovist Perimeter	.613	.034	.230	.473	-.438	.0985	-.244	.362
		No. Occuding Edges	.618	.032	.330	.295	.291	.2738	.453	.078
		Occluding angles	.466	.127	.045	.890	.421	.1046	.397	.128
Discrete		Degree	-.393	.206	.024	.117	.090	.7405	.296	.265
		Node Area	.136	.691	-.033	.923	.145	.6068	.013	.965

Table 7.20 Correlations (r-values) of *<u>Node values</u> with <u>Redundant Node Use</u>. (Urban Hospital)*

Environmental Properties		Environmental units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	.606	<.0001	.662	<.0001
		All Int.	**.721**	<.0001	**.704**	<.0001
		Act. Node Int.	**.606**	<.0001	**.561**	<.0001
	Sepcified	Pub Int. (3)	.654	<.0001	**.713**	<.0001
		All Int. (3)	**.725**	<.0001	.588	<.0001
	Local	Pub Conn.	.654	<.0001	**.724**	<.0001
		All Conn.	.694	<.0001	.600	<.0001
		DP degree	**.713**	<.0001	**.719**	<.0001
		Nodes Recog.	.394	.0067	**.317**	.0317
		N.V. Area	---	---	---	---
		Isovist area	.183	.2224	.207	.1685
		Isovist area/perimeter	---	---	---	---
		Isovist Perimeter	---	---	---	---
		No. Occluding Angles	---	---	---	---
		Occluding Edges	---	---	---	---
Discrete		Degree	.088	.5597	.121	.4250
		Node Area	---	---	---	---

Table 7.21 Correlations (r-values) of Node values with Redundant Node Use. (University Hospital)

Environmental Properties		Environmental units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	**.603**	.0002	**.679**	<.0001
		All Int.	.597	.0002	**.654**	<.0001
		Act. Node Int	**.708**	<.0001	**.817**	<.0001
	Specified	Pub Int. (3)	**.595**	.0003	**.638**	<.0001
		All Int. (3)	.365	.0369	.336	.0558
	Local	Pub Conn.	**.594**	.0003	**.658**	<.0001
		All Conn.	.438	.0107	.419	.0152
		DP Degree	**.536**	.0013	**.637**	<.0001
		Nodes Recog.	.400	.0476	**.571**	.0029
		N.V. Area	---	---	---	---
		Isovist area	.422	.0145	.510	.0024
		Isovist area/perimeter	.306	.0828	.321	.0688
		Isovist Perimeter	.422	.0144	.507	.0026
		No. Occluding Edges	---	---	---	---
		Occluding Angles	---	---	---	---
Discrete		Degree	.261	.1417	.257	.1491
		Node Area				

Table 7.22 Correlations (r-values) of <u>Node values</u> with <u>Redundant Node Use</u>. (City Hospital)

Environmental Properties		Environmental units	PROP NODE USE		TOTAL NODE USE	
			r	p	r	p
Relational	Global	Pub Int.	.348	.0699	.354	.0647
		All Int.	-.237	.2239	-.237	.2246
		Act. Node Int	.127	.5134	.148	.4511
	Specified	Pub Int. (3)	.248	.2027	.171	.3843
		All Int. (3)	.059	.7651	.004	.9826
	Local	Pub Conn.	.249	.2021	.195	.3203
		All Conn.	-.048	.8070	-.101	.6106
		DP degree	.275	.1563	.227	.2452
		Nodes Recog. Average	.010	.9587	.010	.9615
		N.V. Area	-.468	.0120	-.379	.0466
		Isovist area	-.214	.2738	-.230	.2400
		Isovist area/perimeter	-.525	.0042	**.502**	.0064
		Isovist Perimeter	.025	.9007	.014	.9440
		No. Occluding Edges	.002	.9935	.020	.9198
		Occluding Angles	.246	.2251	.254	.2103
Discrete		Degree	.160	.4158	.185	3471
		Node Area	-.304	.1162	-.340	.0767

Table 7.23 Correlations (r-values) of Node values with Redundant Node Use. (City hospital as two systems)

Environmental Properties		Node units	SUB SYSTEM 1				SUB SYSTEM 2			
			PROP NODE USE		TOTAL NODE USE		PROP NODE USE		TOTAL NODE USE	
			r	p	r	p	r	p	r	p
Relational	Global	Pub Int.	.570	.053	.363	.247	.401	.124	.517	.042
		All Int.	.598	.04	.401	.196	.046	.867	.088	.747
		Act Node Int.	**.774**	.0031	**.656**	.02	.365	.164	.498	.049
	Specified	Pub Int. (3)	.446	.148	.197	.539	.353	.180	.384	.142
		All Int. (3)	**.611**	.035	.353	.580	.043	.875	.030	.912
	local	Pub Conn.	.430	.163	.222	.489	.253	.345	.285	.284
		All Conn.	.550	.064	.269	397	.278	.296	.306	.249
		DP Degree	.430	.163	.222	.488	.152	.573	.170	.530
		Nodes Recognized	.523	.099	**.553**	.078	.352	.198	.369	.176
		N.V. Area	-.242	.448	.029	.928	.174	.519	.093	.732
		Isovist Area	.623	.031	.447	.145	.178	.509	.182	.450
		Isovist Area/Perimeter	.231	.470	.299	.346	-.210	.435	-.170	.530
		Isovist Perimeter	**.634**	.027	.436	.156	-.144	.595	.169	.533
		No. Occuding Edges	.044	.891	.084	.796	.454	.078	.412	.113
		Occluding Angles	.367	.297	.294	.409	.070	.797	.083	.040
Discrete		Degree	-.152	.636	-.089	.783	.186	.490	.238	.374
		Node Area	.388	.239	.275	.414	.104	.713	.073	.796

Table 7.24 Important environmental measures as determined by the correlational analysis with behavior across three settings.

			URBAN HOSPITAL	UNIVERSITY HOSPITAL	CITY HOSPITAL	CITY HOSPITAL Segment 1	CITY HOSPITAL Segment 2
Open exploration	AxialLines	Total use	Pub Conn.	Pub Conn.	Pub Conn.	Pub Conn.	Pub Conn.
		Proportion of Use	Pub Conn. Pub Int(3)	Pub Conn. Pub Int(3)	Pub Conn. Pub Int(3)	Pub Conn. Pub Int(3)	Pub Conn. Pub Int(3)
	Nodes	Total use	DP Degree	DP Degree		Nodes Recog.	Act. Node Int Public Int.
		Proportion of Use	DP Degree	DP Degree	Actual Nod Int.	DP Degree Nodes Recog.	
Directed search	Nodes	Total use	DP Degree Actual Node Int	DP Degree Actual Node Int	Isovist Area/Per	Actual Node Int.	
		Proportion of Use	DP Degree Actual Node Int	DP Degree Actual Node Int		Isovist Peri All Int 3 Actual Node Int.	

Table 7.25 Correlations of redundant node use with the different environmental variables (paired by the first and the last search task). The effect of the environment has lessened in all the cases. Perhaps wayfinding has gone from being influenced by the environment to being driven by the cognitive understanding.

		ENVIRONMENTAL PROPERTIES						
PAIRS	TASKS	alINTsep	pubINTsep	all INT(3)sep	PubINT(3)	ACTUAL NODE INTsep	allCONNsep	pubCONNsep
1	RNU TOT OE group 1st task	0.574	0.544	0.518	0.422	0.787	0.429	0.452
	RNU TOT OE group last task	0.369	0.339	0.43	0.223	0.543	0.342	0.261
2	RNU PROP OE group 1st task	0.645	0.595	0.733	0.584	0.797	0.684	0.567
	RNU PROP OE group last task	0.573	0.565	0.621	0.428	0.694	0.559	0.449
3	RNU TOT DS group 1st task	0.325	0.306	0.298	0.145	0.457	0.215	0.206
	RNU TOT DS group last task	0.274	0.308	-0.079	0.055	0.377	-0.198	0.118
4	RNU PROP DS group 1st task	0.472	0.468	0.567	0.385	0.413	0.49	0.381
	RNU PROP DS group last task	0.324	0.37	-0.046	0.153	0.291	-0.134	0.177

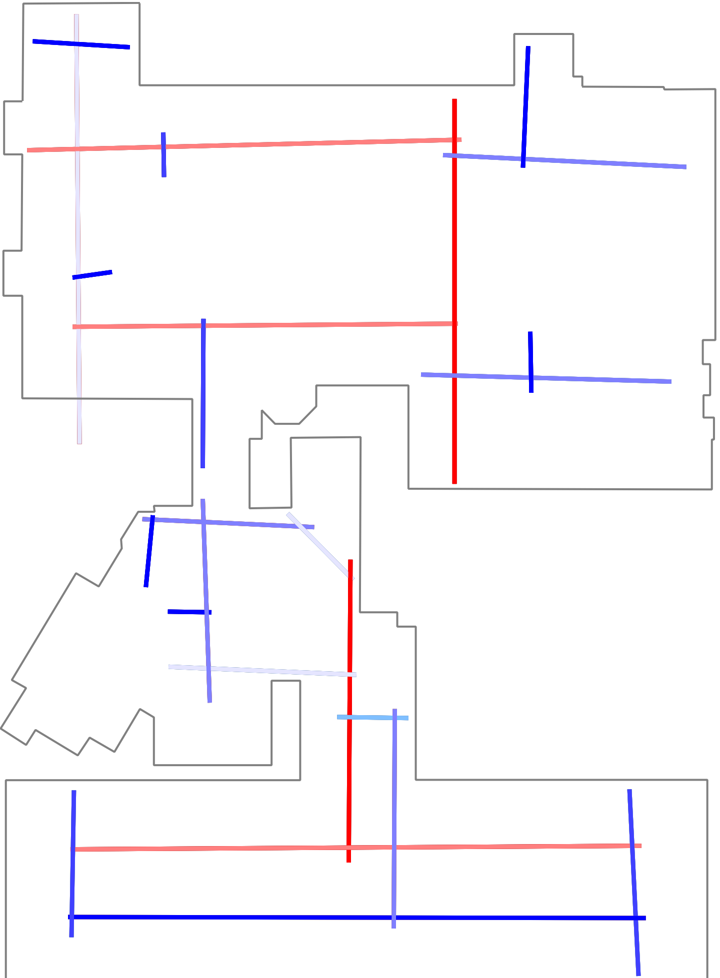


Figure 7.1 *City Hospital as seperate systems*
Syntax analysis of public lines

segment 1

segment 2

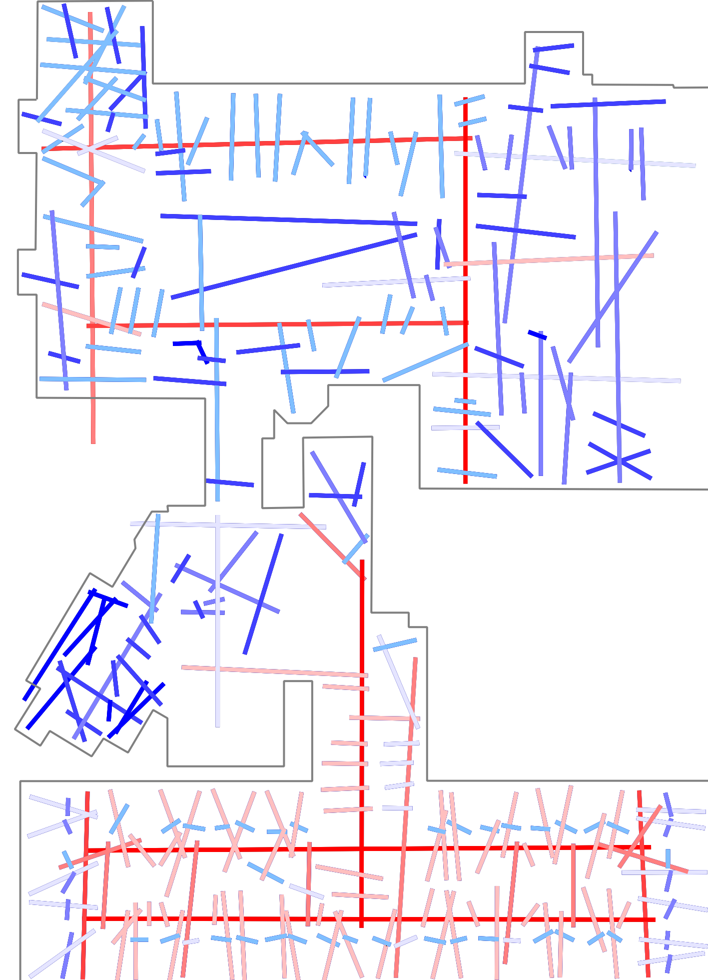


Figure 7.2 *City Hospital as seperate systems,*
Syntax analysis of all lines

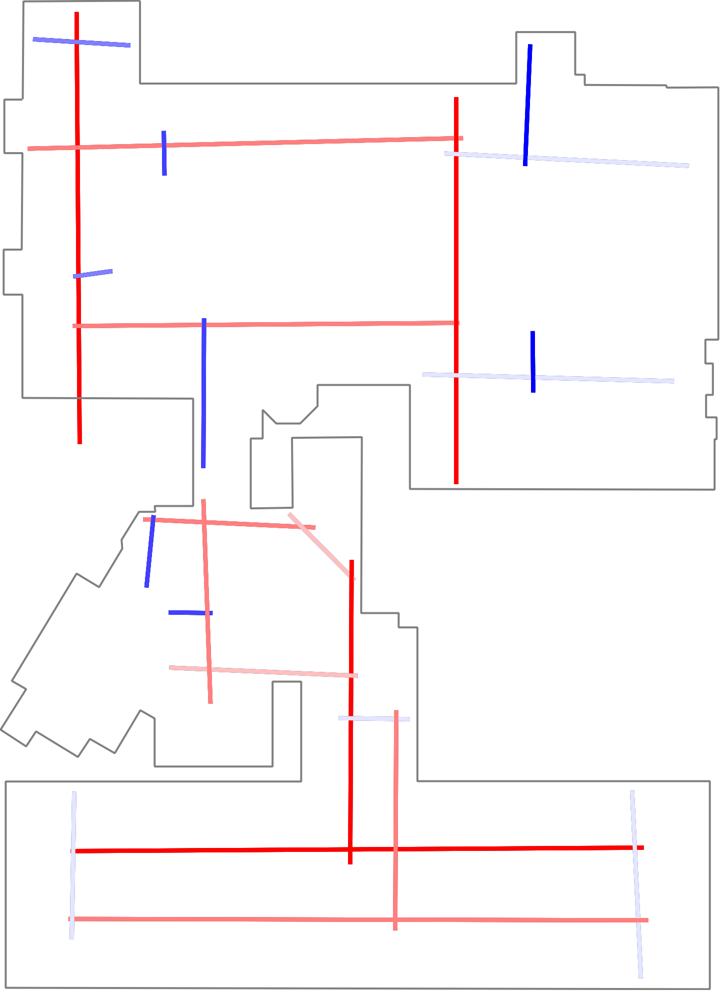


Figure 7.3 *City Hospital as seperate systems*
Syntax analysis of public lines at depth 3

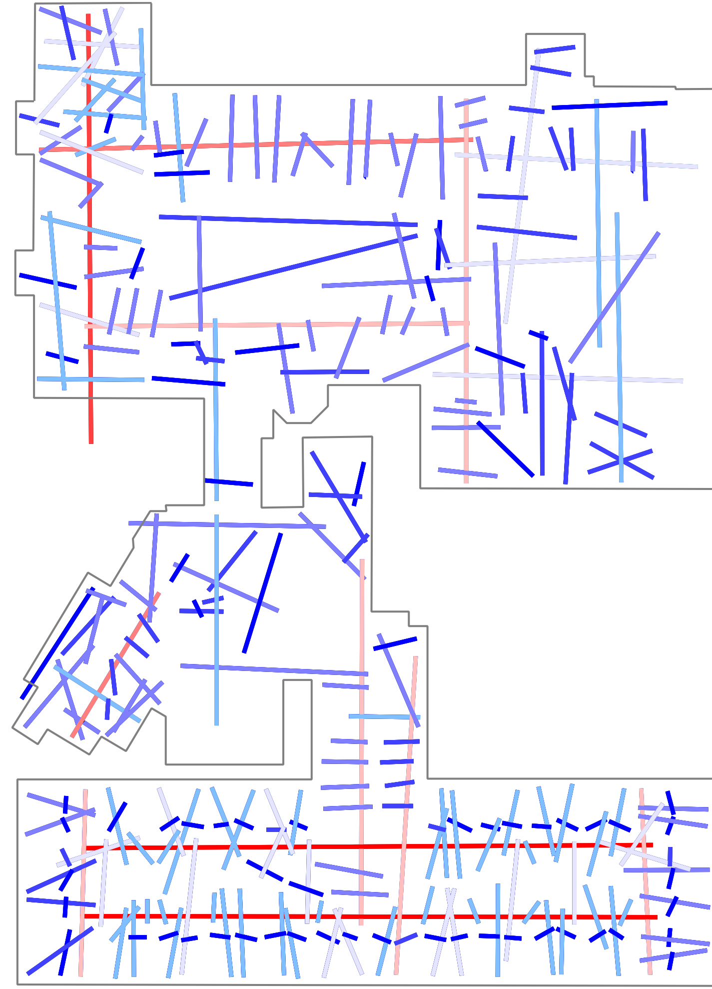


Figure 7.4 *City Hospital as seperate systems,*
Syntax analysis of all lines at depth 3

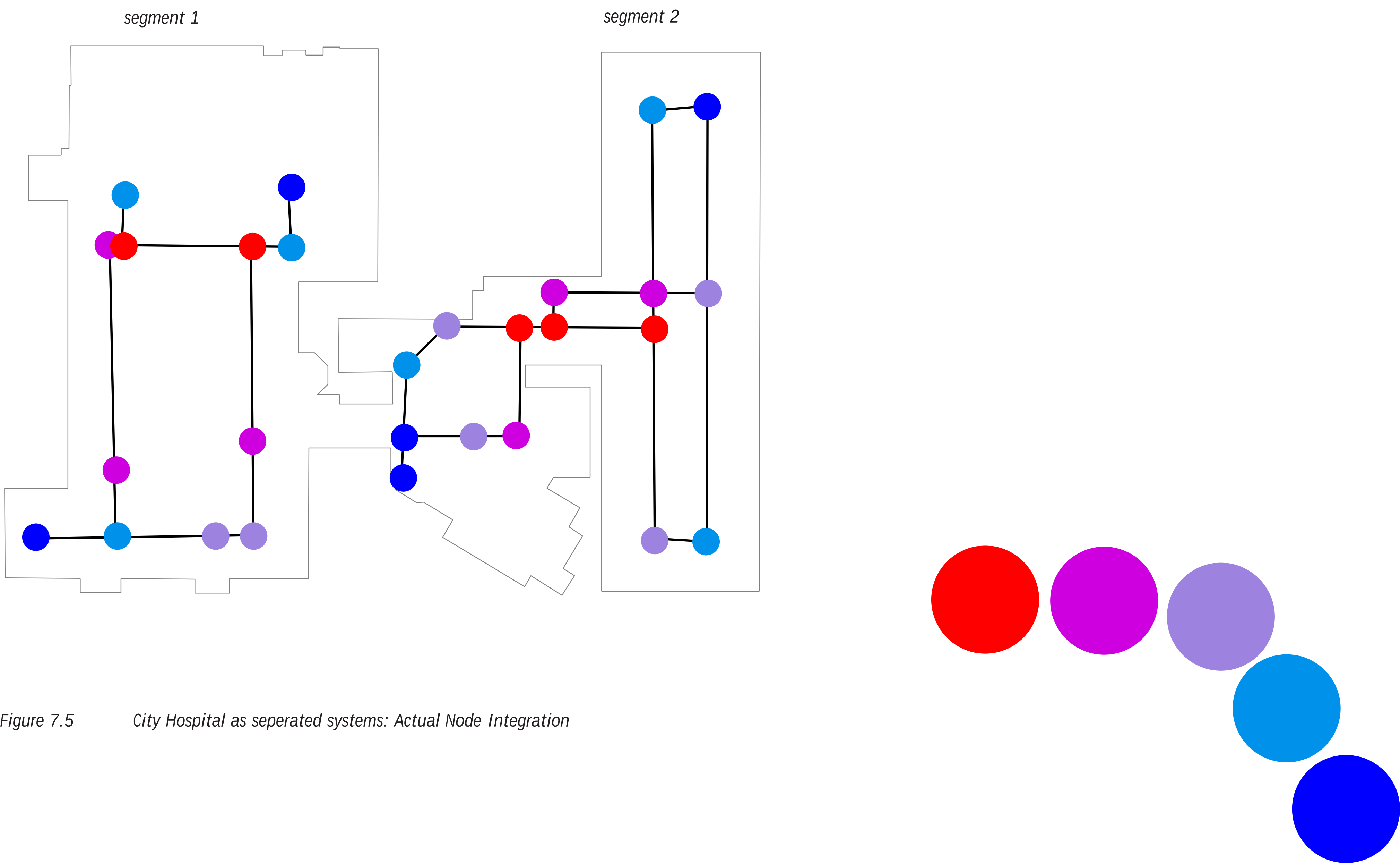


Figure 7.5 *City Hospital as seperated systems: Actual Node Integration*

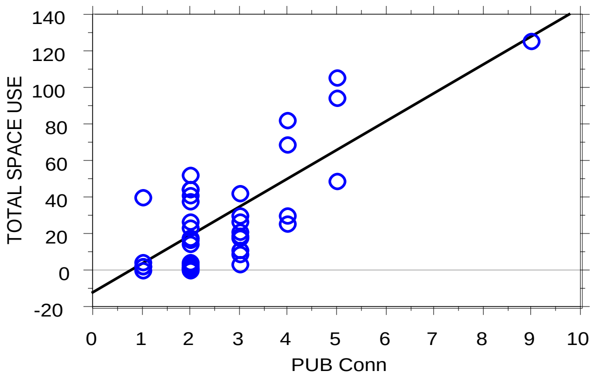


Figure 7.6 Correlation of Total Line Use in Open exploration with Public Connectivity in Urban hospital (r=.768, p=<.0001)

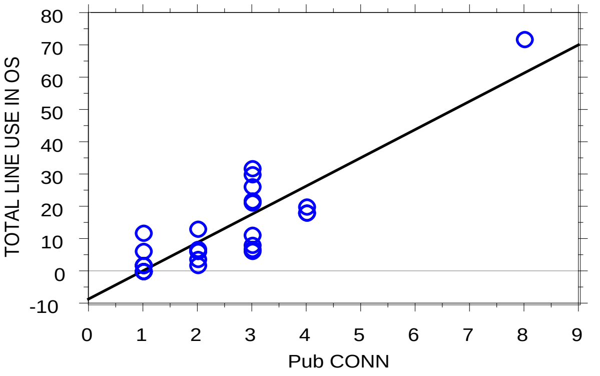


Figure 7.7 Correlation of Total Line Use in Open exploration with Public Connectivity in University hospital (r=.884, p=<.0001)

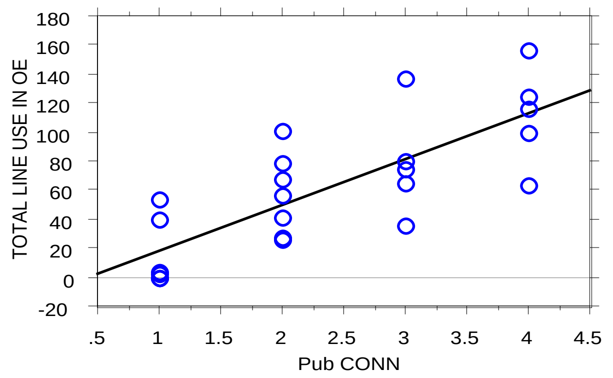


Figure 7.8 Correlation of Total Line Use in Open Exploration with Public Connectivity in City Hospital. (r=.786, p=<.0001)

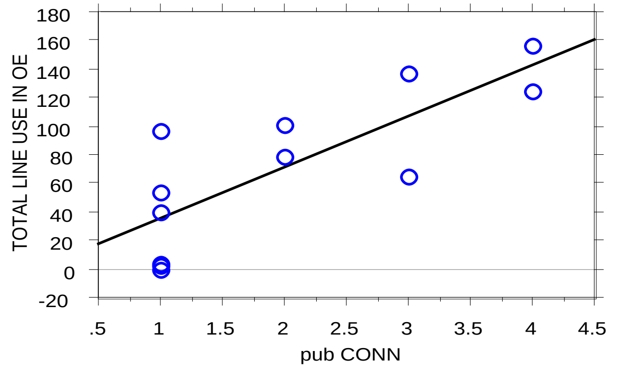


Figure 7.9 Correlation of Total Line Use in Open Exploration with Public Connectivity in City Hospital segment 1. (r=.798, p=<.0019)

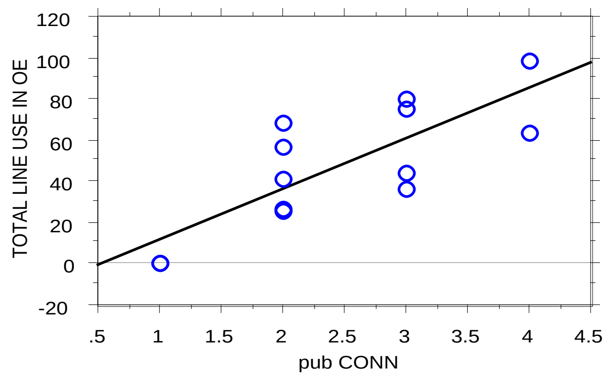


Figure 7.10 Correlation of Total Line Use in Open Exploration with Public Connectivity in City Hospital segment 2. (r=.792, p=<.0012)

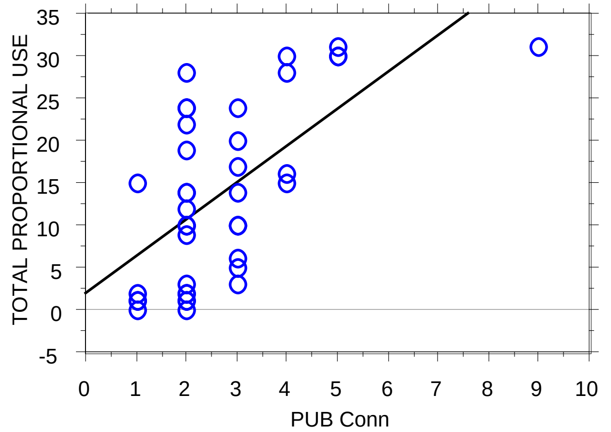


Figure 7.11 Correlation of Proportional Line Use in Open Exploration with Public Connectivity in Urban Hospital. (r=.627, p=<.0001)

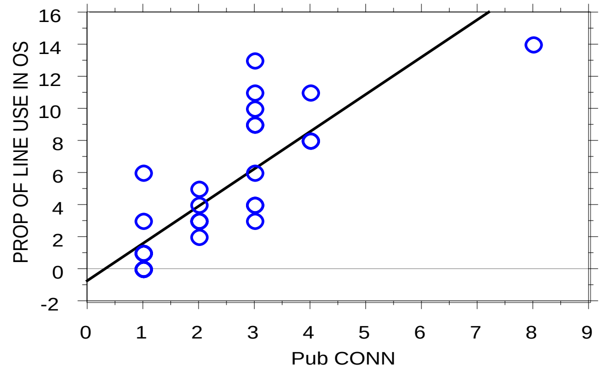


Figure 7.12 Correlation of Proportional Line Use in Open Exploration with Public Connectivity in University Hospital. (r=.814, p=<.0001)

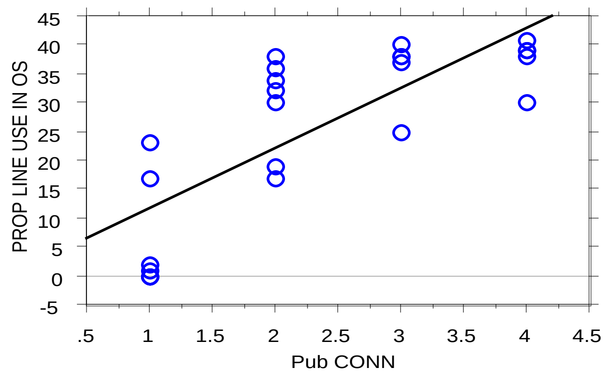


Figure 7.13 Correlation of Proportional Line Use in Open Exploration with Public Connectivity in City Hospital. (r=.784, p=<.0001)

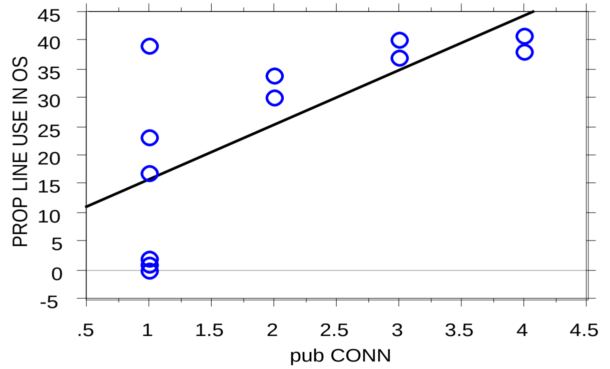


Figure 7.14 Correlation of Proportional Line Use in Open Exploration with Public Connectivity in City Hospital segment 1. (r=.711, p=<.0095)

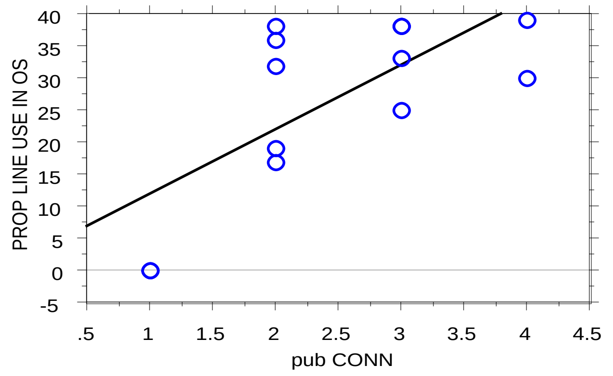


Figure 7.15 Correlation of Proportional Line Use in Open Exploration with Public Connectivity in City Hospital segment 2. (r=.705, p=<.0072)

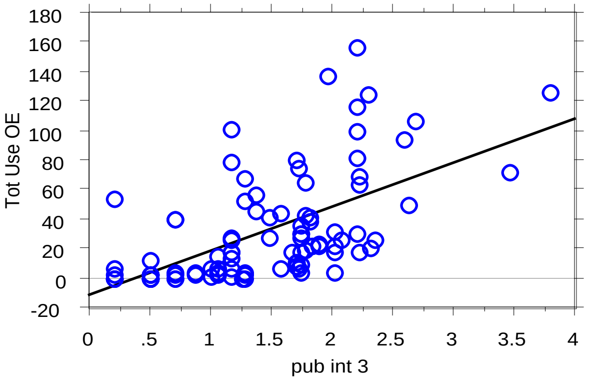


Figure 7.16 Correlation of Total Line Use in Open exploration with Public Integration 3 in all 3 hospitals (r=.594, p=<.0001)

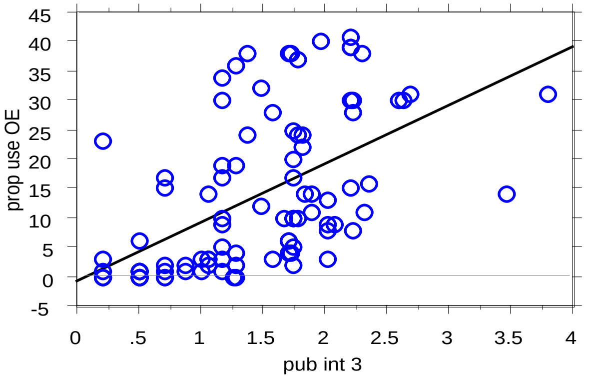


Figure 7.17 Correlation of Proportional Line Use in Open exploration with Public Integration 3 in all 3 hospitals (r=.553, p=<.0001)

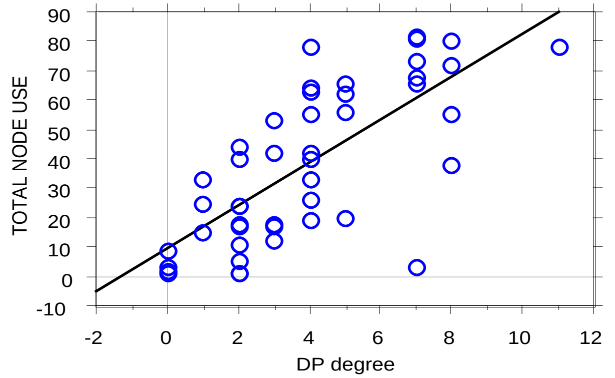


Figure 7.18 Correlation of Total Node Use in Open exploration with DP Degree in Urban Hospital (r=.723, p=<.0001)

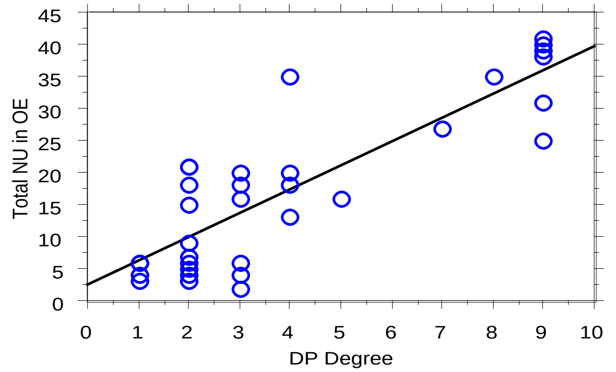


Figure 7.19 Correlation of Total Node Use in Open exploration with DP Degree in University Hospital (r=.839, p=<.0001)

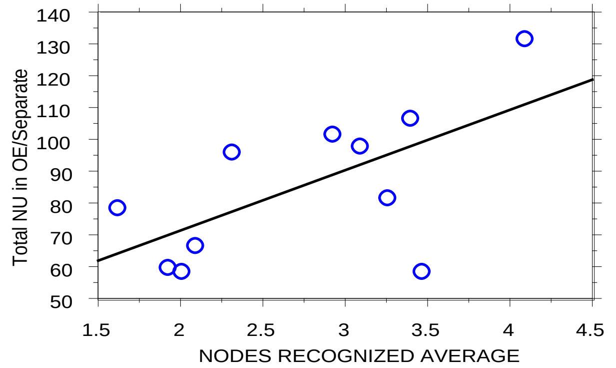


Figure 7.20 Correlation of Total Node Use in Open exploration with Nodes Recognized in City Hospital segment 1 (r=.629, p=<.0380)

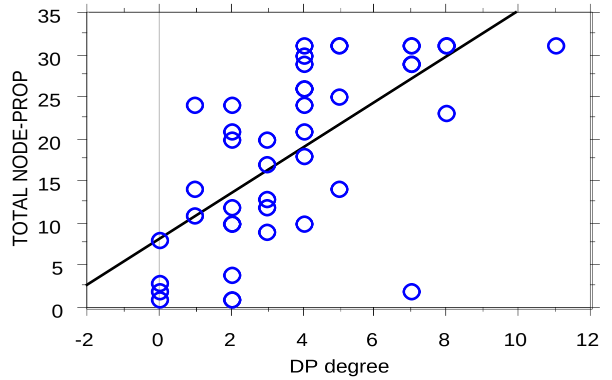


Figure 7.21 Correlation of Proportional Node Use in Open Exploration with DP Degree in Urban Hospital (r=.678, p=<.0001)

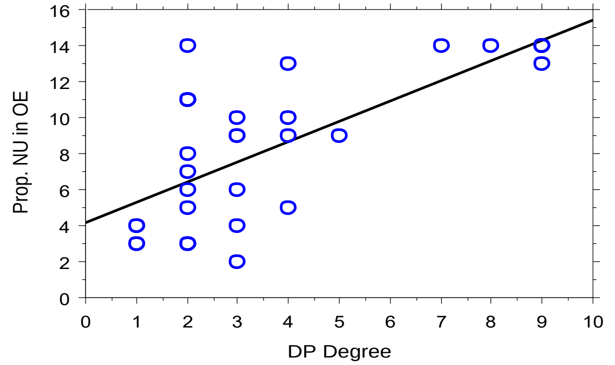


Figure 7.22 Correlation of Proportional Node Use in Open Exploration with DP Degree in University Hospital (r=.724, p=<.0001)

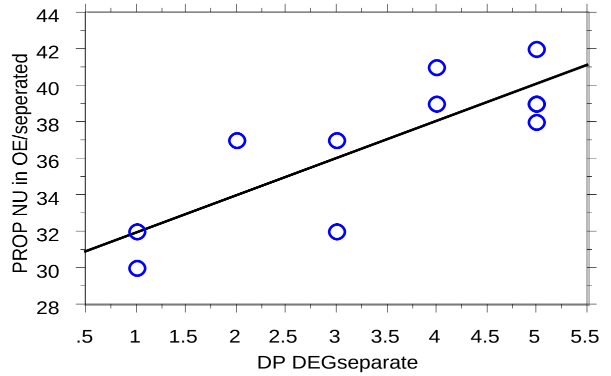


Figure 7.23 Correlation of Proportional Node Use in Open Exploration with DP Degree in City Hospital segment 1 (r=.821, p=<.0020)

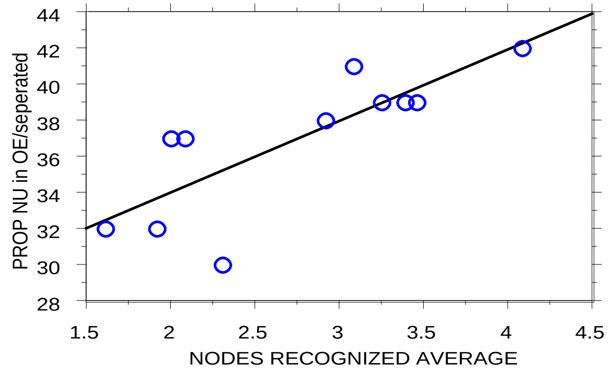


Figure 7.24 Correlation of Proportional Node Use in Open Exploration with Nodes Recognized in City Hospital segment 1 (r=.800, p=<.0031)

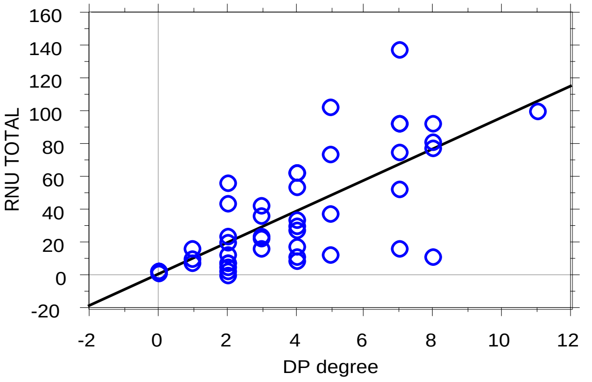


Figure 7.25 Correlation of Total Redundant Node Use in Directed Search with DP Degree in Urban Hospital (r=.719, p=<.0001)

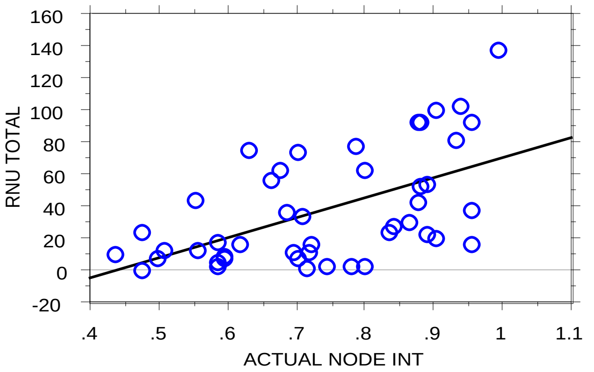


Figure 7.26 Correlation of Total Redundant Node Use in Directed Search with Actual Node Integration in Urban Hospital (r=.561, p=<.0001)

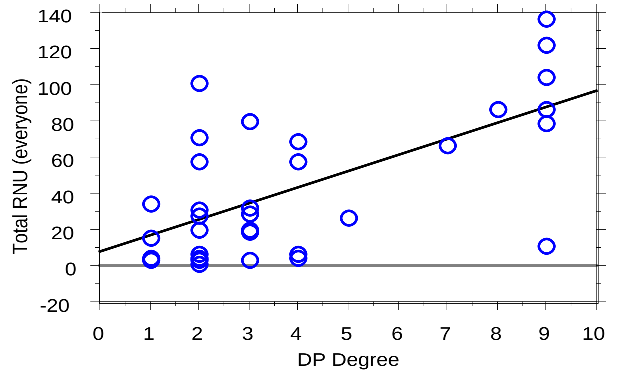


Figure 7.27 Correlation of Total Redundant Node Use in Directed Search with DP Degree in University Hospital (r=.637, p=<.0001)

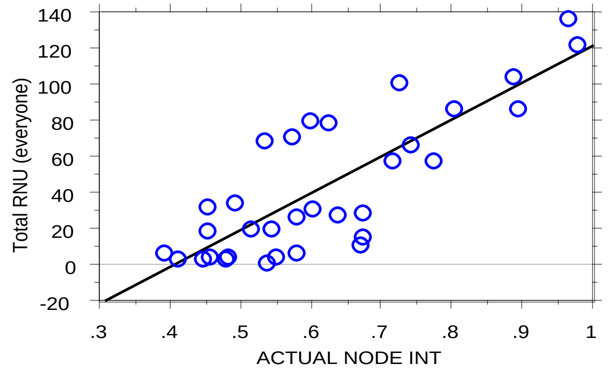


Figure 7.28 Correlation of Total Redundant Node Use in Directed Search with Actual Node Integration in University Hospital (r=.817, p=<.0001)

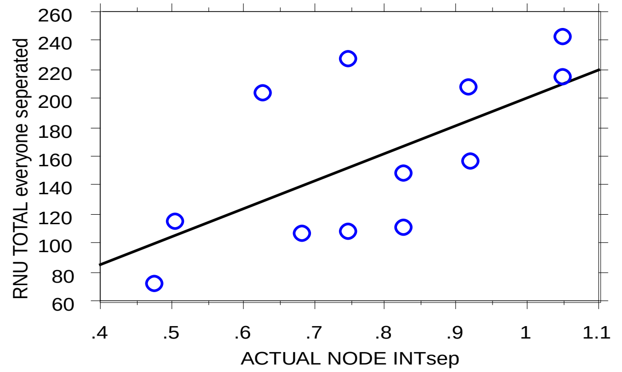


Figure 7.29 Correlation of Total Redundant Node Use in Directed Search with Actual Node Integration in City Hospital segment 1 (r=.656, p=<.02)

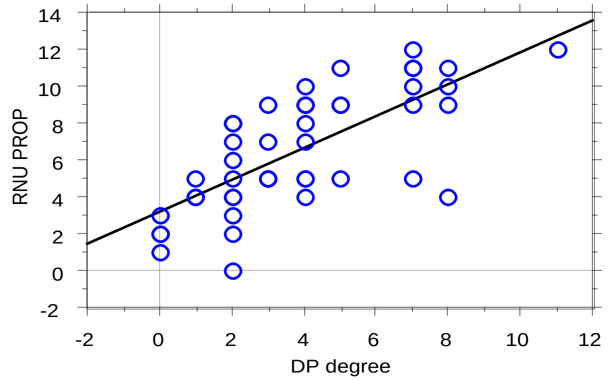


Figure 7.30 Correlation of Proportional Redundant Node Use in Directed Search with DP Degree in Urban Hospital (r=.713, p=<.0001)

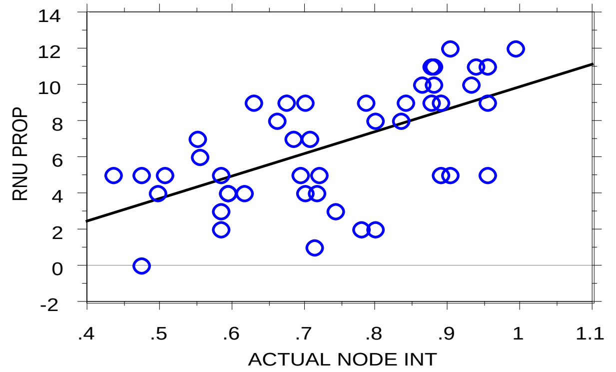


Figure 7.31 Correlation of Proportional Redundant Node Use in Directed Search with Actual Node Integration in Urban Hospital (r=.606, p=<.0001)

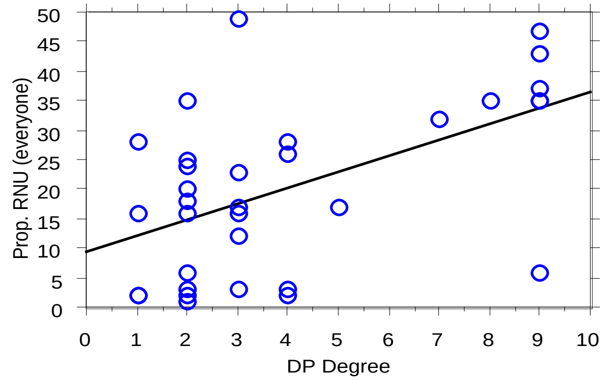


Figure 7.32 Correlation of Proportional Redundant Node Use in Directed Search with DP Degree in University Hospital (r=.536, p=<.0013)

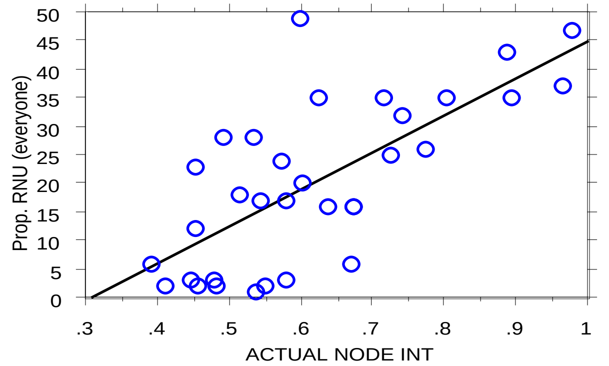


Figure 7.33 Correlation of Proportional Redundant Node Use in Directed Search with Actual Node Integration in University Hospital (r=.708, p=<.0001)

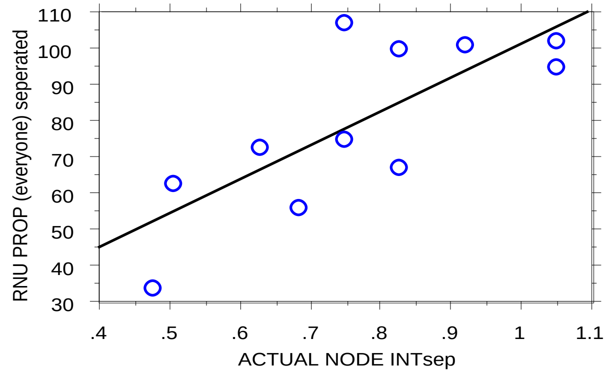


Figure 7.34 Correlation of Proportional Redundant Node Use in Directed Search with Actual Node Integration in City Hospital segment 1(r=.765, p=<.0061)

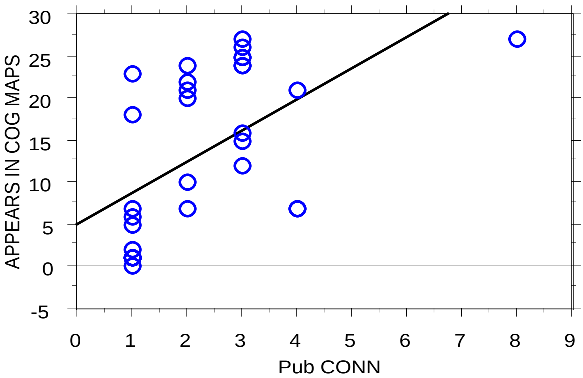


Figure 7.35 Correlation of Corridors appearing in Cognitive maps with Public Connectivity in University hospital (r=.556, p=<.0009)

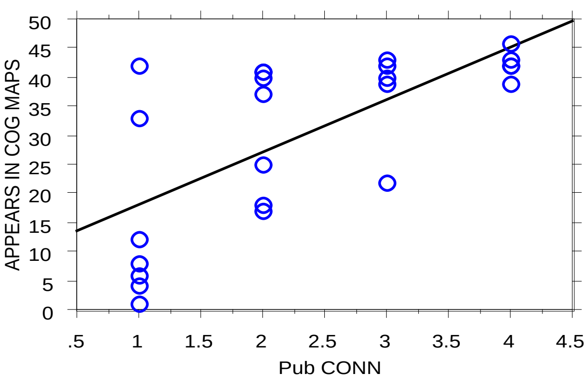


Figure 7.36 Correlation of Corridors appearing in Cognitive maps with Public Connectivity in City hospital entire (r=.678, p=<.0003)

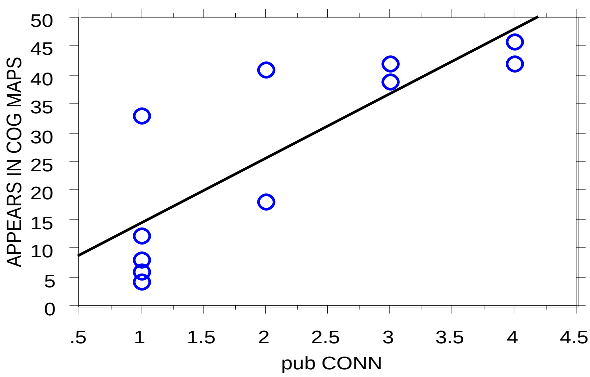


Figure 7.37 Correlation of Corridors appearing in Cognitive maps with Public Connectivity in City hospital segment 1 (r=.817, p=<.0021)

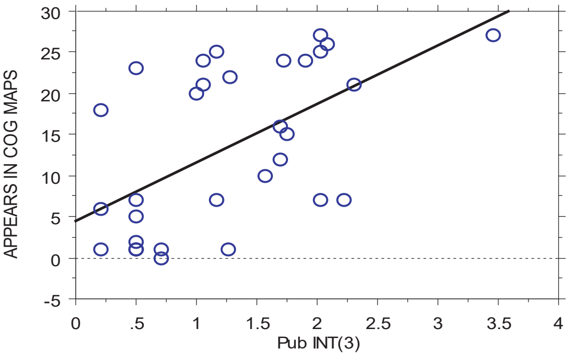


Figure 7.38 Correlation of Corridors appearing in Cognitive maps with Public Integration (3) in University hospital (r=.561, p=.0008)

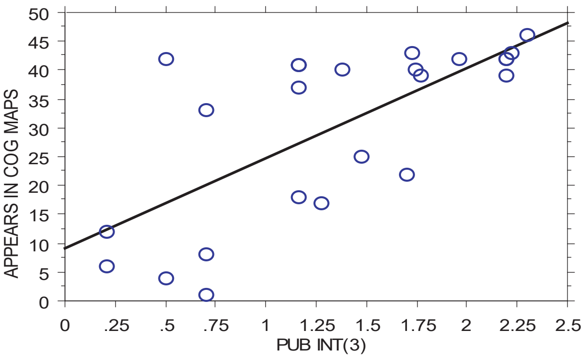


Figure 7.39 Correlation of Corridors appearing in Cognitive maps with Public Integration (3) in City hospital entire (r=.697, p=.0002)

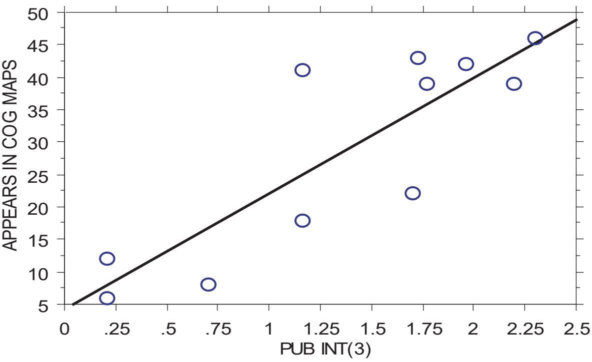


Figure 7.40 Correlation of Corridors appearing in Cognitive maps with Public Integration (3) in City hospital segment 1 (r=.853, p=.0009)

Chapter VIII

Discussion

This section summarizes some of the more important contributions that have come out of this thesis. They are: 1. Topologically constructed configuration is acquired relatively quickly in the cognitive understanding of moving humans. This leads to the consideration of an alternate model of cognitive development. 2. 'Expectation of Exploration' is an important construct to consider in wayfinding, and 3. The 'mean depth' of an entry has a significant effect on wayfinding. Furthermore, this chapter will discuss implications for Space Syntax in studies of environmental cognition, the role of signage in wayfinding and methodological lessons learned. It will then conclude with a discussion of future directions for this research.

1 Cognition and Configuration

Two rather different sequences of environmental learning have been identified in the research literature. Some experimental evidence supports the notion that landmark knowledge is acquired first, followed by route knowledge and then by survey knowledge (Hirtle & Heidorn, 1993). However, other research demonstrates that configurational knowledge may be acquired early, in addition to, or instead of, route knowledge (Garling, Book, & Ergezen, 1982). This apparent contradiction may reflect the experimental task. Many of the previous studies that have found that configurational knowledge is slow to develop have had participants traverse one or a few routes; it is difficult for participants to build configurational knowledge under such conditions. Alternatively, when real world knowledge is targeted, then memory tasks are usually used. These are imprecise because they rely on recall and certain human skills like verbalization and drawing; these skills are not uniformly distributed. In real world, configurational learning takes place over time, and by traveling through many routes that crisscross one another.

Whereas the role of the setting or the experiment as a factor in this difference of results remains to be researched, the study conducted here points to the possibility that *configuration* may be something that people are able to pick up *quite quickly* in their relationship with an environment when they have reason to explore it.

It was seen in this experiment that in open exploration wayfinding was better predicted by variables of local connections such as Public Connectivity. This quickly changed and by the time the subjects were doing directed searches, about 15 to 20 minutes later, Actual Node Integration, a global variable, had become an important predictor. At the same time, reliance on Nodes Recognized had decreased. This was the same in all three settings. Another important indicator is that even *during* open exploration, Public Integration (3) had the highest correlation with Proportional Node Use in all the three cases. Thus it can be assumed and even argued, that as people get to know the environment more, their *topologically constructed* configurational knowledge increase. Furthermore, it happens in a very short time. Two other tests were carried out to test this finding.

First, a comparison of the use of two environmental variables: Nodes Recognized and Node Integration in Open Exploration and Directed Search was conducted. . Whereas the first depends on local information, the second considers the relationship of each element to all others in a system. Hence, it cannot be directly perceived.

Tables 7.16, 7.17 and 7.19 show that during open exploration, Total Node Use correlated with Actual Node Integration at levels of .50, p=.0005, .79, p=<.0001 and .48 p=.117 for the 3 hospitals -- Urban, University and City segment 1 respectively. Tables 7.20, 7.21 and 7.23 show that in directed search, correlations of Total Redundant Use with Actual Node Integration *increased* in all cases to .56, p=<.0001, .82, p=<.0001 and .66, p=.02 respectively (p values reflect the significance of the correlations).

On the other hand r-values of correlations between Total Node Use and Nodes Recognized *decreased* from values in Open Exploration to values in Directed Search, i.e. from .64, p=<.0001, .80, p=<.0001 and .63, p=.038 to .32, p=.0317, .57, p=.0039 and .55, p=.078 respectively for the 3 hospitals. (Compare tables 7.16, 7.17 and 7.19 with tables 7.20, 7.21 and 7.23).

Thus, when subjects were new to the environment, they depended more on Nodes recognized and less on Actual Node Integration. As they became more familiar, the situation was reversed. This comparison demonstrates that as a person moves from open exploration to directed searches, i.e. becomes more and more familiar with a setting, his/her reliance on what can be immediately seen and recognized decreases on one hand, and understanding of the configuration of the setting increases on the other. This suggests that cognitive understanding had progressed from local variables to more global ones.

In this regard, an interesting result was obtained when wayfinding performance was compared between the first and the last directed search task of the subjects. This was calculated for City Hospital only. In *all the cases,* the correlations of line use with all of its various properties decreased. This can be understood by comparing each pair of readings shown in table 7.25. From this observation it can be stipulated that either the topological properties are no longer meaningful because by the end of the experiment metric properties had been learned, or alternatively, the environment had been learned so successfully that its physical attributes mattered very little.

This follows a series of tentative suggestions by various researchers. For example, Appleyard (1969) did not find any large differences in sketch maps between residents who had lived in a town from 0 to 6 months and those who had lived more than 60 months. Garling et al's (1982) research hinted at a much shorter period of acquisition of configuration – as he suggested, perhaps during or even instead of route learning in the initial contact with an environment. Later Peponis Zimring and Choi (1990) suggested that "some knowledge of configuration develops independently rather than by somehow aggregating the knowledge of specific routes, at least where cognitively competent adults are involved" (pp. 576).

This study makes a distinction between configuration as a survey knowledge that incorporates metric information versus a higher level of topological comprehension. The fact that topological configuration was considered here and that this featured prominently in the sketch maps of the participants is important. Rovine and Weisman (1995) had reported that the topological accuracy of building placement in sketch maps accounted for an exceptional 62.4% of the variance in wayfinding performance. Later, Peponis et al. (1990), Willham (1992) and Haq (1999a) had found the Syntax variable integration was an important predictor of wayfinding tasks. This research result, supported by previous ones build up to the argument that contrary to the belief that configurational or survey knowledge, is map-like that gets more and more accurate as a person understands the environment, it may actually be internalized as sense of relationships. This understanding of relationships gradually considers both larger and larger systems and an increasingly higher levels of connections in its scope. In this manner, local information is assimilated into global understanding. This is captured by the topologically relational properties that this study has dealt with.

2 EXPECTATION OF EXPLORATION

In the classic study on environmental preference, Kaplan and Kaplan (1982) operated under the assumption that the human mechanisms underlying behavior developed because of everyday survival needs. From such an evolutionary point of view they concluded that among others, 'mystery' was the most consistent predictor of preference. About this property they said,

> "the more preferred scenes are very likely to give the impression that one could acquire new information if one were to travel deeper into the scene. They provide partial information concerning what might be ahead. Mystery involves the inference that one could learn more through locomotion and exploration" (Kaplan & Kaplan, 1982, pp. 85).

Later Kaplan explained, 'mystery' is

> "… the promise of more information if one can venture into the scene. In other words, it is the inference that one could learn more about the scene if one could explore its third dimension by changing ones vantage point" (Kaplan, 1992, pp. 588).

This of course, points to two other things, both of which were acknowledged by the researchers, but probably not tested in any subsequent studies. Firstly, the definition of mystery itself suggests movement; i.e. it evokes the urge to move from one point to the other so that information gain is maximized. Secondly, regarding the environment, 'mystery' alludes to a complex relationship that cannot be simply operationalized. In this regard Kaplan proposed a construct that includes not only the potential information in a scene, but also the *relationship* of this scene to other scenes: a *relational construct*(Kaplan, 1992). Needless to say, the ideas of relationships were not elaborated and of course, the automated tools for calculating relational measures were perhaps not available.

In a later study of wayfinding that used Space Syntax as a way of calculating relational measures, Peponis et al. (1990) reported two navigational rules for search tasks. These were:

> "(a) if all else is equal, continue along the same line and (b) divert from the line of movement when a new view allows you to see more space and activity or provides a longer view and lets you see further ahead" (pp. 584).

Even though the two studies were operating from very different perspectives and the latter does not cite the former, it is not difficult to see the similarities between the inferences described above. Notwithstanding the fact that Kaplan et al referred to occluded views, and Peponis et al. found that their particpants used open views in navigation, they are similar in the sense that both focus on the role of exploration possibilities, either directly or indirectly. The idea of expectation of new information is very strong in humans, as understood from their evolutionary backgrounds, and it was shown to be so in both environmental preference and in wayfinding choice by the two studies.

The results of the present study also point to the importance of the promise of future information as an important predictor of search patterns. As was pointed out before, the strongest predictors of node use in exploratory wayfinding tasks were Public Connectivity and DP Degree. These variables assess how much further exploration a space will allow. Building on previous theory and on the results in this study, a concept called ‘Expectation of Exploration (EE)’ was proposed. In environmental terms this can be referred to as ‘Exploration Potential (EP)’. This is the extent, or presumed extent, of exploration that each unit of space will offer.

Statistically, ‘Exploration Potential’ did turn out to be a good predictor of space use in Open Exploration. This was tested by a linear regression model using the variables Public Connectivity, DP Degree and Actual Node Integration. It was seen that public connectivity predicts 39%, 66% and 51% ($p=<.0001$ in all cases) of the variance in the number of people who used axial lines (proportional use) in open exploration (Urban Hospital, University Hospital and City Hospital segment 1 respectively). The model to predict proportional node use in open search, using parameters of DP degree predicts 46%, 52% and 67% of the variance in those three settings. For directed searches, considering the effect of configurational learning, an additional factor Actual Node Integration was considered.

Multiple regressions with these two variables predicted 62% ($p=.0001$), 50% ($p=<.0001$) and 60% ($p=.063$) of the variation in redundant node use. From all these results, the validity of the construct ‘expectation of exploration’ may be argued for.

Additionally an implicit rule can be proposed: 'in search mode or in times of uncertainty, always proceed to the area that offers the highest 'Exploration Potential'.

This concept of 'Exploration Potential (EP)' is based on previous theories. For example, it is conceptually similar to Braaksma's node-link network (1980) or O'Neil's inter-connection density (1991). However, EP considers individual units within a layout. In fact, this can be done from the plan drawing of a building only, without even knowing the distribution of function in it. Therefore, designers and building administrators can potentially use this to predict wayfinding problems in their buildings and possible location of signage.

Although 'Expectation of Exploration' and 'Exploration Potential' are important concepts to study preference of spaces in wayfinding situations, perhaps this has not been rigorously defined enough. For example, Nodes Recognized does not have a strict and objective definition. Other factors that are potentially important in this respect may have been left out, such as light, texture, color variations etc. Also, the units of analysis in this study were nodes and axial lines. Proper re-translations of these into architectural elements remain an objective for future research. Finally, decomposition of any layout into constituent axial lines has a component of subjectivity in itself that should be carefully researched. In spite of these, and by the support of the regression models carried out here, it is claimed that 'expectation of exploration' is a promising concept and a possible direction for further research.

3 DEPTH OF ENTRIES

Regarding the point of entry and a general understanding of a layout, it was seen that the mean depth of the entry might be influential in the way a building is explored. People will tend to go to more connected areas in proportion to the mean depth of the entry from which they start their search tasks.

In terms of wayfinding, this is significant because it raises the very important question, "where does wayfinding start?" If the property of the entry itself can feature in wayfinding consideration, then it can be used to some advantage in building design, especially in the context of wayfinding and location of strategic areas.

This concept can also be extended to the task of linking any building with the larger environment. For example, in consideration to the city streets, what should be the most effective location for an entry to a complex? Then a designer may look at the effect of that entry on the interior spaces. Therefore one may work back and forth to come up with the proposal for an entry location that will be most meaningful to the visitors. Also, the designers may use this knowledge to manipulate the entry to suit organizational policies.

4 Space Syntax

In terms of Space Syntax, this study has perhaps served to establish that consideration of topological configuration can be fruitful for studying both wayfinding and environmental cognition. This supports findings from other studies (Evans, Marrero, & Butler, 1981; Rovine & Weisman, 1995). Topics such as layout and configuration have been discussed in earlier wayfinding and cognitive representation studies. However, both of these research areas have had difficulties in deconstructing environments into relationships, or to measure unit spaces from the point of view of such relationships in a manner that they could actually be used as predictor variables in experiments. As pointed out in a previous chapter, there is a dearth of tools that will allow it. From these considerations, Space Syntax is a very effective tool.

If, as was seen in this experiment, topological and visual relationships are indeed important, then the Syntax ideas of natural movement can be expanded. Where as natural movement remains a product of spatial configuration as Space Syntax argues (Hillier, 1993), it can now be debated that this movement also contributes to an understanding of that configuration. Therefore a cycle can be proposed.Configuration creates movement that promotes an understanding of the configurational properties. This then will contribute to more accurate movement and wayfinding.

Additionally, this experiment is considered important because it points to an aspect that has perhaps been less studied in the many previous Space Syntax studies. Researchers in that field emphasize that many empirical findings regarding human movement have been found to be correlated with integration. From this data, integration has been proposed as a significant measure of the environment. “The configurational correlates of movement patterns are in fact the measures of the global properties of the grid which is integration” (Hillier, Penn, J. Hanson, & Xu, 1993). Two factors, however, have been considered influential in this regard: the distribution of the integration core and the intelligibility of the layout (Peponis and Wineman, 2001). Intelligible layouts, by definition, are those that have a good correlation between local connectivity and global integration. In fact, the measurement unit of intelligibility is actually the correlation coefficient ‘r’. As this study demonstrates, and indeed as all Syntax studies done in intelligible settings will show, connectivity is also an important predictor, but one that is less commonly reported. Therefore, it is extremely important to distinguish between the roles of integration and connectivity. Previous attempt to do so was from the point of view of the layout (Hillier, Burdett, Peponis and Penn, 1987); this study suggests that a cognitive approach to do so may also be fruitful.

In this experiment both integration (3) and connectivity were found to be significant in proportional space use and total space use respectively, by first time visitors. Also, since the environmental settings were intelligible they had extremely high correlations between integration and connectivity (.664, .831, .557, .923 and .674 in Urban Hospital, University Hospital, City Hospital, City Hospital segment 1 and City Hospital segment 2 respectively). People understand buildings and cities by walking through it, and in this diachronic experience they are required to process local environmental qualities to build up a cognitive understanding of global relationships. Obviously, in this process, the local qualities intially take preference.

Having said that, the following must also be discussed. This experiment suggests that as people get to know the environment better their reliance on what they can see ahead of them lessens, but reliance on an understanding of topological configuration increases. It was shown here that people initially rely on Nodes Recognized, but later this decreases and reliance on Actual Node Integration increases. Additionally, during open exploration, integration (3) was found to be an important predictor. Therefore, it may be said that in the initial stages of exposure in a new environment people focus on local qualities, but *very quickly* build a more global understanding.

Another significant lesson that has emerged for Space Syntax is that unlike the case of natural movement, configuration is perhaps less predictive of natural movement. Wayfinding behavior is deliberate and in this task people consciously use all possible environmental cues. As was seen in the case of City Hospital, a good understanding of the functional layout was essential for a study of wayfinding movement with respect to Space Syntax. This hospital produced poor results when it was considered as an entire configuration, but performed better when it was taken as two independent systems. This was possible because of a close look at its functional arrangements. Although it is hard to argue on the basis on one setting only, yet in studies of wayfinding, it may be prudent to augment with a functional analysis of the settings. In this regard, computer simulations and experimental work in uninhabited settings that allow experimental control of function could be important.

Although Space Syntax units are uninterrupted visibility lines, considered here as axial lines, in some cases these can be too long to be actually accepted as a cognitively understood unit space by a situated or a moving person. In buildings this may be less of an issue, but it is certainly important when considering urban areas and cities. This needs to be considered in future endeavors that should include a component that considers human sensibilities and axial line length.

It has been demonstrated that theories of configurational analysis are important and any kind of environmental unit can be subjected to these kinds of analysis. In this experiment, decision points and uninterrupted visibility lines were subjected to configurational analysis and this has proved to be highly significant. In other research elsewhere, isovists are sometimes subjected to configurational analysis and those have been reported to be successful too (Campos, 1999; Turner & Penn, 1999). The most important theoretical consideration that has emerged is that Syntax analysis should consider the following five aspects: axial spread of the configuration, intelligibility, extent of the setting (embeddedness), functional character and cognitive demands on the moving individual.

In terms of applicability, it seems Space Syntax analysis is a good way of testing for possible wayfinding difficulties in buildings and projects. For example, in intelligible settings and controlling for function, some integrated areas can be expected to contain more wayfinding people. In less intelligible layouts, and again controlling for function, more connected areas may become important for wayfinding projects. Alternatively, the syntactic structure of the configuration that would be unveiled by this kind of environmental analysis could be used to locate various public and restricted areas, and in some cases may even be used for the design of strategic changes or for improvements in the layout. Such an exercise was carried out for Urban Hospital and this is included in Appendix 1. It should also be mentioned that for future projects, consideration of the public area only might be sufficient for public wayfinding. However, for a complete wayfinding proposal that includes the staff, the total environment should be considered.

In conclusion, it can be claimed that topological values of an environment are effective measures in understanding wayfinding difficulties in specific areas of complex buildings. This is substantiated by previous research (Braaksma et. al. 1980, Peponis et.al. 1990, Willham 1992, Haq, 1999a). Since Space Syntax deals primarily with topological information, it has been found to be a potentially important tool to test wayfinding problems, perhaps even before complex buildings are constructed.

5 WAYFINDING AND SIGNAGE

The issue of signage and directions given by staff and other 'helpful' persons cannot be separated from any study of wayfinding. Unfortunately, this was an aspect that was not included here. However, this work took the only opportunity available to explore the influence of 'You-Are-Here' maps in the case of Urban Hospital. That is because the other two settings did not have any such maps.

Previous research on 'You-Are-Here' maps have produced conflicting evidence. For example Levine, Marchon & Hanley (1984) considered such maps to be useful. On the other hand Butler, Acquino, Hissong and Scott (1993) have found that for newcomers directional signs are much more effective than 'You-Are-Here' maps.

Signage can have both a local/'identification' characteristic and a relational/'directional' one. It can also contain a more global 'You-Are-Here' kind of map. It is not unreasonable to assume that they will have varying degrees of acceptability and impact upon the wayfinders. In Urban Hospital, while the first few subjects were being tracked, it was noticed that a good number of subjects were not using the 'global' signage during their tasks. This seemed odd, particularly in the light of research regarding 'You-Are-Here' maps (Levine, Marchon & Hanley, 1984). Therefore in the case of later subjects doing open exploration, a careful note was made of the use of the three 'you-are-here' maps that was located in the setting. Among the 15 subjects recorded, only nine looked at the maps (60%). Among them 1 person (11.11%) used it once, 3 (33.33%) persons used them twice, 3 persons (33.33%) thrice and 2 persons (22.22%) used them 4 times. It should be pointed out that the 'you-are-here' maps in Urban Hospital were not correct. They reflected the proposed pattern of the hospital that could not be implemented. Some people may have understood it quickly and did not come again to look at the map, while others did not. That was not determined. However, the fact that 40% of the subjects did not even bother to look at these maps should be an important pre-consideration for wayfinding 'signage' design.

6 VALIDITY OF THE TECHNIQUES

The scope of this research, as seen by the number of variables and empirical tasks is both its criticism as well as its strong point. It looked at a total of 23 different kinds of environmental measures in 2 major groups -- lines and nodes. These environmental units were tested against 2 kinds of wayfinding uses and various cognitive tests. It used 128 subjects in 3 complex architectural settings and 6 entrances. Together, The subjects carried out 88 open exploration tasks, 508 directed searches, 1248 pointing tasks and 384 distance estimations. Besides that, they produced 96 sketch maps and filled out 96 reports about their wayfinding abilities.

All of these tasks were done in real life settings that included their inherent complexities. These were controlled, as much as possible, by choosing varied kinds of environments, by the design of the experiment and by the criteria of subject selection.

Many researchers have argued against real world settings for experiments, explicitly stating that principles derived in diligently controlled conditions of the laboratory can be used to explain empirical findings obtained in the real world (Winigrad, 1993). They believe that the desirable control is more easily obtained in the laboratory. "Tighter control can lead to a higher generalization to specific domains" (Poon, Welke, & Dudley, 1993, pp.27). Indeed, previous researches on wayfinding and cognition have often used simulations of the environment, such as photographs, slides and videos. But questions have been raised whether such studies have underestimated people's true navigational and cognitive skills (Garling, Lindberg, Carreiras, & Book, 1986, pp. 75). Also it has been argued that configurational knowledge is difficult to obtain through a simple photographic presentation of a route (Hirtle & Hudson, 1991). On the other hand, in a naturalistic environment that is less controlled, people display more regular behavior (Rubin, 1989). Therefore there is some merit to studying in the 'real world'.

7 ENVIRONMENTAL MEASURES AND METHODOLOGY

The environmental measures explored in this study were derived either from topological or from visual relations. In total, this experiment considered 23 different kinds of variables. Among them, six were traditional Space Syntax measures of axial lines, seven were line units that were modified to be applicable to nodes and the remaining ten were those that were taken from other sources or were developed from them. These included theoretically developed units from the concepts of Benedict and Gibson (Benedikt, 1979; Gibson, 1979).

Among the environmental variables, Decision Point Degree (DP degree) was found to be an important measure for the nodes accounting for 46%, 63% and 67% of the variance in proportional use in open exploration for Urban, University and City hospitals respectively. DP Degree is an environmental unit that considers the number of other nodes that can be seen from a given node. Of course it also measures from how many other nodes a person can come to the origin node. This gives a sense of how connected a node actually is.

The Space Syntax variable Connectivity, which has been applied to visibility lines, has similar characteristics with DP Degree because both of them suggests possibilities of further exploration. The value of connectivity as calculated from the public system was most predictive for proportional use in open exploration. This accounted for 39%, 67% and 61% of the variance in Urban, University and City hospital respectively.

It was also found that Nodes Recognized was a valuable environmental measure, especially in the beginning stages of human-environment relationship. Also, as discussed before, DP Degree can experimentally operationalize Nodes Recognized. This gives it some real world applicability because DP Degree can be calculated from the environment itself and from its plan drawing. Therefore any design proposal can be quickly evaluated from the point of view of wayfinding and spatial cognition.

Unfortunately, most of the other non-Syntax units did not provide any good correlation to use of spaces. This is not to say that those units do not feature in wayfinding and cognitive understanding. Rather, new techniques of getting to the internal representation of the mind and new ways of considering these variables need to be developed. At this point it may be added that new techniques are being developed elsewhere that might prove fruitful. Isovist Integration, Overlapping Isovists etc. are some methods that seem to be promising (Campos, 1999; Turner & Penn, 1999). Their applicability in wayfinding and environmental cognition research remains to be explored.

The tracking method that was used in this study was extremely useful. A good rapport with the subjects does increase the possibility of getting good data. This is perhaps better than unobtrusive trackings where the subjects may feel threatened and behave in an unusual manner. In this case, since rapport was established before the experiment, the subjects felt quite comfortable with the experimenter following quietly a few steps behind. There is no reason to believe that this procedure distracted the subjects from their tasks. Unfortunately, it needs high investment in time and resources because the same experimenter needs to run all the subjects and conduct all the trackings. Fortunately, that could be accomplished in this experiment.

Also, it was demonstrated that a person's 'track' i.e. path of movement can actually be taken as a record of his / her understanding of the environment. This is almost like getting a person to draw a sketch map, except that here, the drawing skills and / or media does not interfere with the representation. In the two environments in which the subjects drew sketch maps, the drawn corridors correlated to their proportional use at $r=.58$, $p=<.0005$ and $r=.54$, $p=<.0065$ respectively for University and City Hospitals. Therefore, there is some merit to the collection of tracking information as a representation of cognitive maps.

8 FUTURE RESEARCH

Moving humans are an equal part in human environment interaction studies. This thesis has concentrated on particular properties of the environment and has tried to comment on spatial learning from their behavior patterns. The findings and methods suggest several areas for further research: exploring individual differences, untangling multicolinearity and understanding function.

8.a Exploring Individual Differences

As was suggested in the review of literature, much work in environmental cognition has examined the role of individual differences such as age, experience, gender, visual abilities and other factors in predicting wayfinding and cognitive mapping performance. However this research has not examined individual differences as they interact with environmental form. One specific future step will be to reanalyze the current data from the perspective of individual wayfinders. This will allow us to explore questions such as: Do efficient wayfinders (defined as having few redundant nodes or calculated from their self reports) show different patterns of space use during open search or directed search than less efficient wayfinders? Do they explore more of the setting? Do they visit integrated or connected spaces more frequently?

This approach also has potential application in other studies. For instance: Do visually-impaired wayfinders demonstrate the same patterns? Do old and young wayfinders demonstrate the same patterns?

8.b Untangling Multicolinearity

One of the main obstacles in this research was multi-collinearity between various variables. Future research must consider this drawback. This can be addressed by collapsing the variables into indices using techniques such as factor analysis. However, this will not resolve some of the theoretical questions in this dissertation. For example, an index that combines Integration and Connectivity would have good predictive power it would not allow further exploration of the micro-genetic development of local versus relational knowledge. This can possibly be explored by simulation techniques where plausible environments are created with low intellegibility, allowing for the relative contribution of Integration and Connectivity to be assessed. Simulation also allows other cues such as signage to be controlled.

8.c Understanding Function

When City Hospital was divided into two sections for analysis—an administrative wing and a patient care wing—the predictive power of spatial variables increased. Whereas it is a standard Space Syntax technique to examine the data to search for "natural" spatial units, the use of exogenous criteria is somewhat worrisome. It would be a signficant contribution to attempt to develop spatial for functional criteria to guide such analyses.

9 Concluding Comments

This research explores the relationships of spatial patterns, search patterns and patterns of environmental understanding. It has shown that local and topological measures are good predictors of search and of understanding as reflected in pointing and in sketch mapping. In a simple sense, it is further evidence that Space Syntax measures not only operate as probabilistic descriptions of paths to and through settings; they also predict people's deliberate search patterns and understanding.

This study also suggests some measures that can expand the Space Syntax units such as Nodes, and variables such as DP Degree and Actual Node Integration. It also suggests that Nodes Recognized is a valuable variable, but this needs to be further operationalized.

Perhaps the most startling finding is how quickly people can develop topological understanding of a setting when they are encouraged to explore it. As one would expect people initially rely more on local qualities, but even then, in open search RRA(3) is an excellent predictor of space use.

Appendix

<u>EXTENDED SYNTACTIC STUDIES ON URBAN HOSPITAL.</u>

The experiment undertook for the dissertation revealed that the values of spaces as given by Space Syntax feature powerfully in predicting the way a building is explored. For the purposes of understanding the specific conditions of Urban Hospital, extended Syntax analysis was undertaken. This is presented below

1.a <u>Jog in entry A</u>

From a study of the existing layout, it appeared that an organizational decision regarding entry A was made such that it deliberately isolated and shielded entrants from the rest of the hospital building (See figure 5.1 and 5.5). This was achieved by a design decision that created a 'jog' in the entry, In this configuration, perhaps the intended use was that visitors come in, go up the elevators, visit their patients and come down -- without having to see the old parts of the hospital. Perhaps the clinic visitors were expected to come through the clinic atrium and the emergency visitors through the emergency entrance also. In reality however, especially with the wayfinding confusion outside, people come in from all entrances. Therefore wayfinding becomes difficult.

It was seen from the justified maps (Figure 5.17, 5.18 and 5.19) that from entry A the hospital is conceived as most 'deep'. To determine the syntactic influence of this entry, six axial maps were constructed which disregarded the ‘jog’ in entrance A (See figures A1.1 - A1.6 and Table A1.1).

It can be seen that in all cases the integrated area extends to entry A and conversely, this entry becomes less deep from the rest of the hospital. Removal of this ‘jog’ decreases or very slightly increases intelligibility in the larger system considering all corridors and all spaces. From this, it can be predicted that by removing the roundabout in entry A the hospital can be made easier to understand by the people who come in for its services. On the other hand, if such a ‘segregation’ is an organizational decision, then it seems well executed. From the entrants point of view however, coming in to visit other areas deeper in the hospital from entry A may be disorienting. In reality there is no way to restrict this entry to the visitors of patients only. People come in this doorway whose destinations may be at the back of the complex, or at the clinics located at one side. For them, the entry design is confusing.

1.b <u>Location of the Clinic Building</u>

A series of syntactic analysis without the clinic building was also conducted in order to understand the hospital layout prior to it and the effect of the addition in changing the syntactic hierarchy of the configuration (see figures A1.7 - A1.12 and table A1.2). It was seen that as more spaces are added to the analysis (Figure A1.10-A1.12), the most integrated space becomes the north-south corridor in the east, which was actually considered the back of the hospital. The other highly integrated space is the central east-west corridor. Together they create a ‘+’ (plus) shaped central circulation spine. Also, the western north-south is more prominent when the public system is considered only (figure A1.7). From these, it may be concluded that placing the clinic building in the south and connecting it in the west was a good strategy. However, it is not connected to the eastern north-south corridor that would have made it better related with the rest of the hospital. Although there are misleading signs in this building that allude to this connection, it is actually sealed off.

Next, another series of axial maps was constructed to evaluate the composite nature had this connection been made (figure A1.13 to A1.18 and table A1.3). These figures show the axial analysis of Urban Hospital had the clinic also been connected to the main building through the North South corridor on the Eastern side. When all the corridors and all the spaces are considered, in both instances ignoring the effect of roads, it can be seen that the strongest space is the corridor being discussed i.e. the eastern corridor (see figure A1.15 and A1.17). If the public corridor system is considered, then it retains its strength but is not the most integrated (see figure A1.13). Only in this case the outside becomes important. The public system shows the strongest north-south connection to be in the west while considerations of all spaces create it in the east. (Figure A1.13 and A1.17) If the intelligibility of this system with that which was built was compared, then an increase in the latter in all the six ways of considering the system is found (compare table A1.1 and table A1.3)

From these analyses it can be safely inferred that the potential of the north south corridor in the east was not realized. Also it led to the confusing area in the central part of the plan. Most of the development was done in the western side, yet the syntactic structure of the configuration is biased towards the east. In such a situation, the ‘architectural emphasis’ i.e. finishes, forms, decorations etc. are contradictory to its syntactic properties.

1.c Suggestions based on syntactic studies

Based on the syntactic and behavioral analysis, some suggestions for Urban Hospital may be put forward. They are:

1.c.1 Make better directional signage in the access roads

This is perhaps the most neglected part in Urban Hospital wayfinding. Being able to arrive at an entrance is the first and a very important component of wayfinding design. The authorities should immediately work with the city administration and provide directional signs from all possible approaches to the hospital.

1.c.2 Make the main entry from the Eastern Street.

This has already taken place informally due to the subsequent closure of the Western street. The entrances in the Eastern street have to be renovated and better signage and information kiosks provided. It is now known that entrances from this side have the least depth and so should make the hospital more intuitive to the visitors.

1.c.3 Create an elongated lobby along the Eastern street.

A north-south elongated lobby could be constructed that connects the two entrances in the eastern side. This lobby could be used as the main arrival point. Syntax analysis has shown that this is a very integrated area and all spaces are less deep from this. Hence it would be easy to direct people both verbally and by signage from here.

1.c.4 Connect the eastern North-South corridor to the clinic building.

This will produce a clear central circulation ring. Syntactic analysis has shown that this is a very important corridor that could be the most integrated one if joined to the clinic. The present circuitous route from the clinic to this corridor is very confusing. Making a straight connection will improve the situation. Also, since the signage is already in place, it will not need additional effort in terms of the signs.

1.c.5 Remove the 'jog' in entrance A

As was shown by the syntactic analysis, removal of the 'jog' in entry A can easily improve the configuration. This in turn will produce a better wayfinding layout.

The syntactic result of these suggestions are shown in figure A1.19

1.c.6 Improve the Signage System

It has been mentioned that the signage is not adequate and the 'You-are-here' maps are poorly designed. Together, these inadequacies produce a confusing condition. It is proposed here that a proper signage system be designed and installed which would take into consideration the syntactic analysis of the hospital and the approach roads leading to the entries.

Table A1.1 Intelligibility of Urban Hospital disregarding 'jog' in entrance A

	Intelligibility
Public Access Corridors	0.4868
Public Access + Roads	0.6315
All Corridors	0.2416
All Corridors + roads	.04410
All Spaces	0.1840
All Spaces + roads	0.2463

Table A1.2 Intelligibility of Urban Hospital disregarding the Clinic building

	Intelligibility
Public Access Corridors	0.4655
Public Access + Roads	0.5547
All Corridors	0.6494
All Corridors + roads	0.6532
All Spaces	0.3480
All Spaces + roads	0.3640

Table A1.3 Intelligibility of Urban Hospital Considering the Eastern connection of Clinic building

	Intelligibility
Public Access Corridors	0.4684
Public Access + Roads	0.5958
All Corridors	0.5523
All Corridors + roads	0.5817
All Spaces	0.3180
All Spaces + roads	0.3508

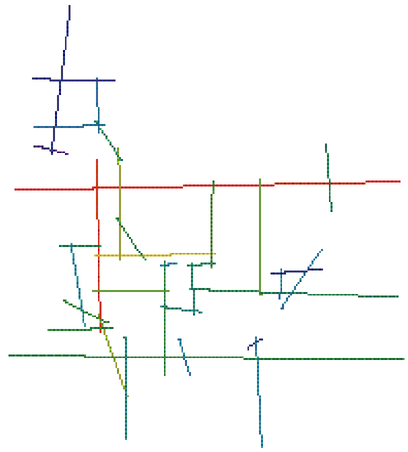


Figure A1.1 Integration map of public access areas with 'jog' in entrance disregarded.

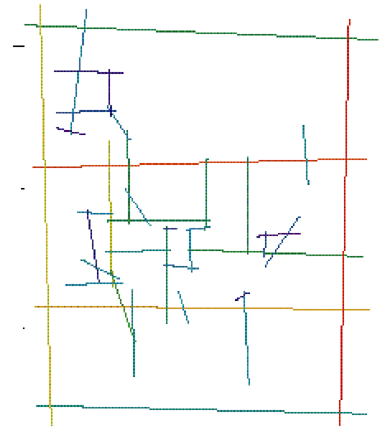


Figure A1.2 Same as figure A1.1, but considering the external roads.

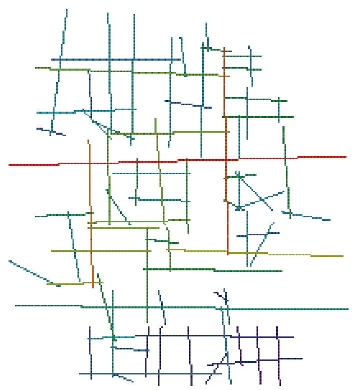


Figure A1.3 Integration map of all corridors with 'jog' in entrance disregarded.

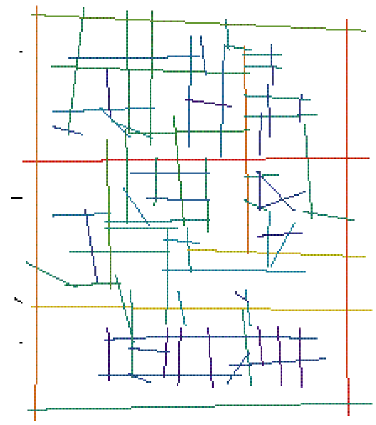


Figure A1.4 Same as A1.3 but considering external roads.

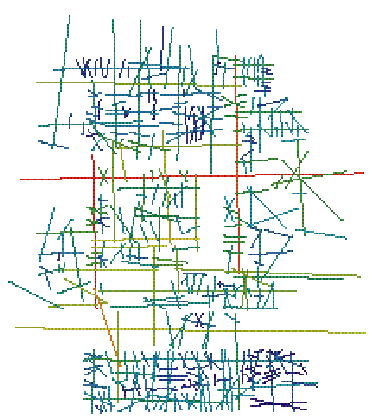


Figure A1.5 Integration map of all spaces with 'jog' in entrance disregarded

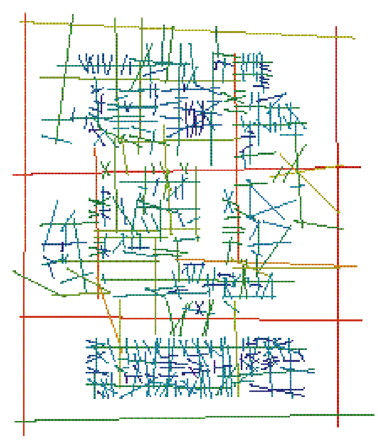


Figure A1.6 Same as A1.5, but considering external roads.

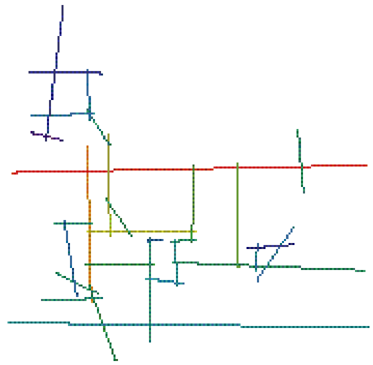


Figure A1.7 Integration map of Public corridor system disregarding the clinic building.

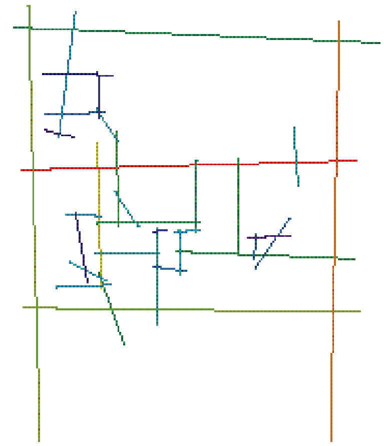


Figure A1.8 Same as figure A1.7 but considering external roads.

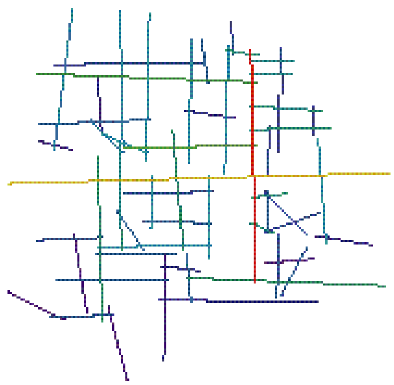


Figure A1.9 Integration map of all corridors without the clinic building.

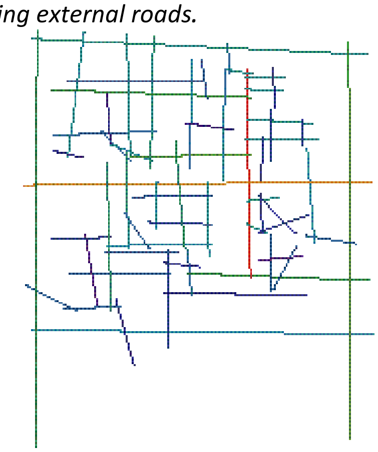


Figure A1.10 Same as figure A1.9 but considering the external roads.

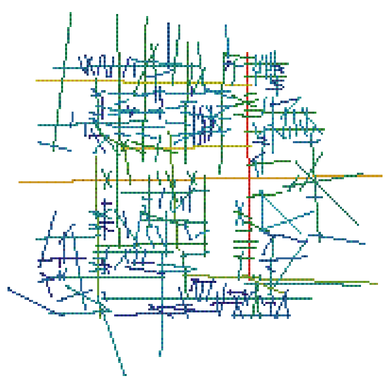


Figure A1.11 Integration map of all the spaces in the hospital except the clinic building.

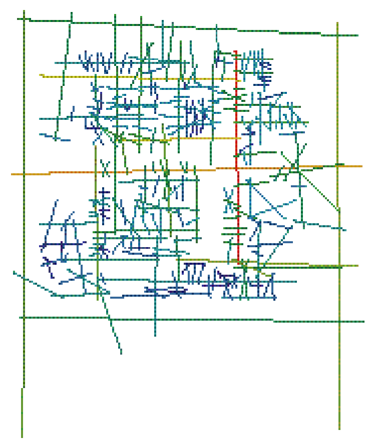


Figure A1.12 Same as figure A1.11 but considering the external roads.

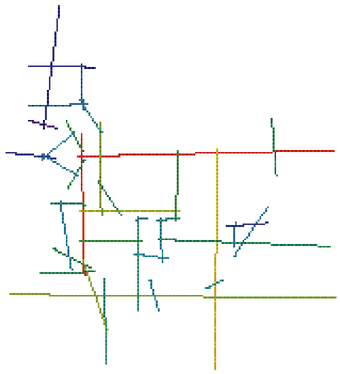


Figure A1.13 Integration model of public corridor system considering the eastern connection of the clinic with the main hospital.

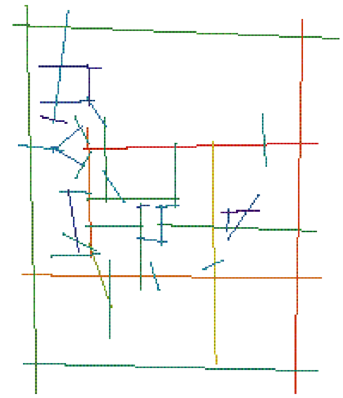


Figure A1.14 Same as figure A1.13 but considering external roads.

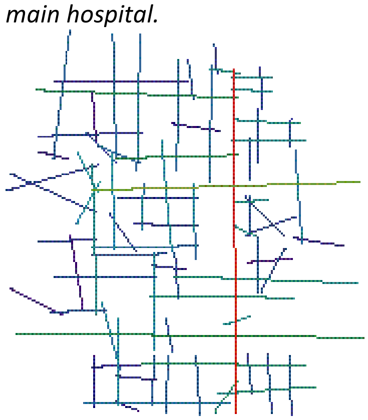


Figure A1.15 Integration model of all corridors considering the eastern connection of the clinic with the main hospital.

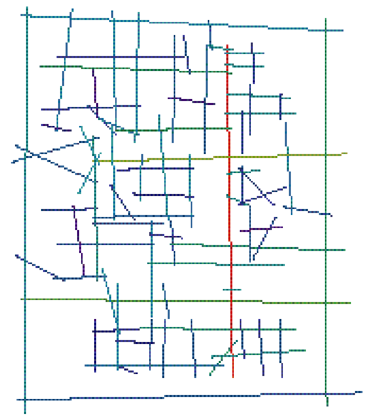


Figure A1.16 Same as figure A1.15 but considering the external roads.

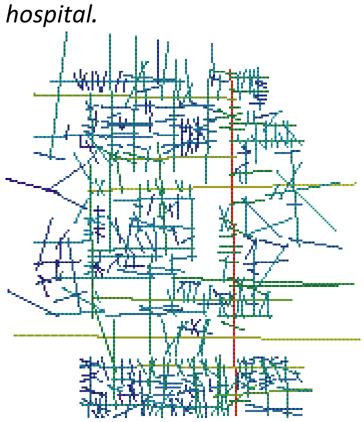


Figure A1.17 Integration model of all spaces considering the eastern connection of the clinic with the main hospital.

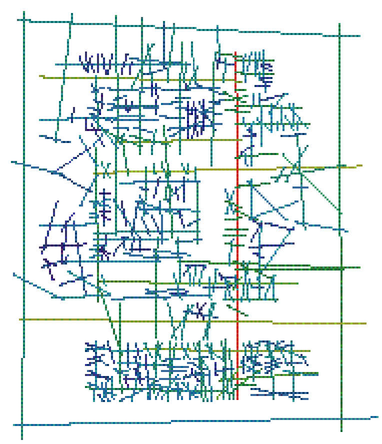


Figure A1.18 Same as figure A1.17 but considering the external roads.

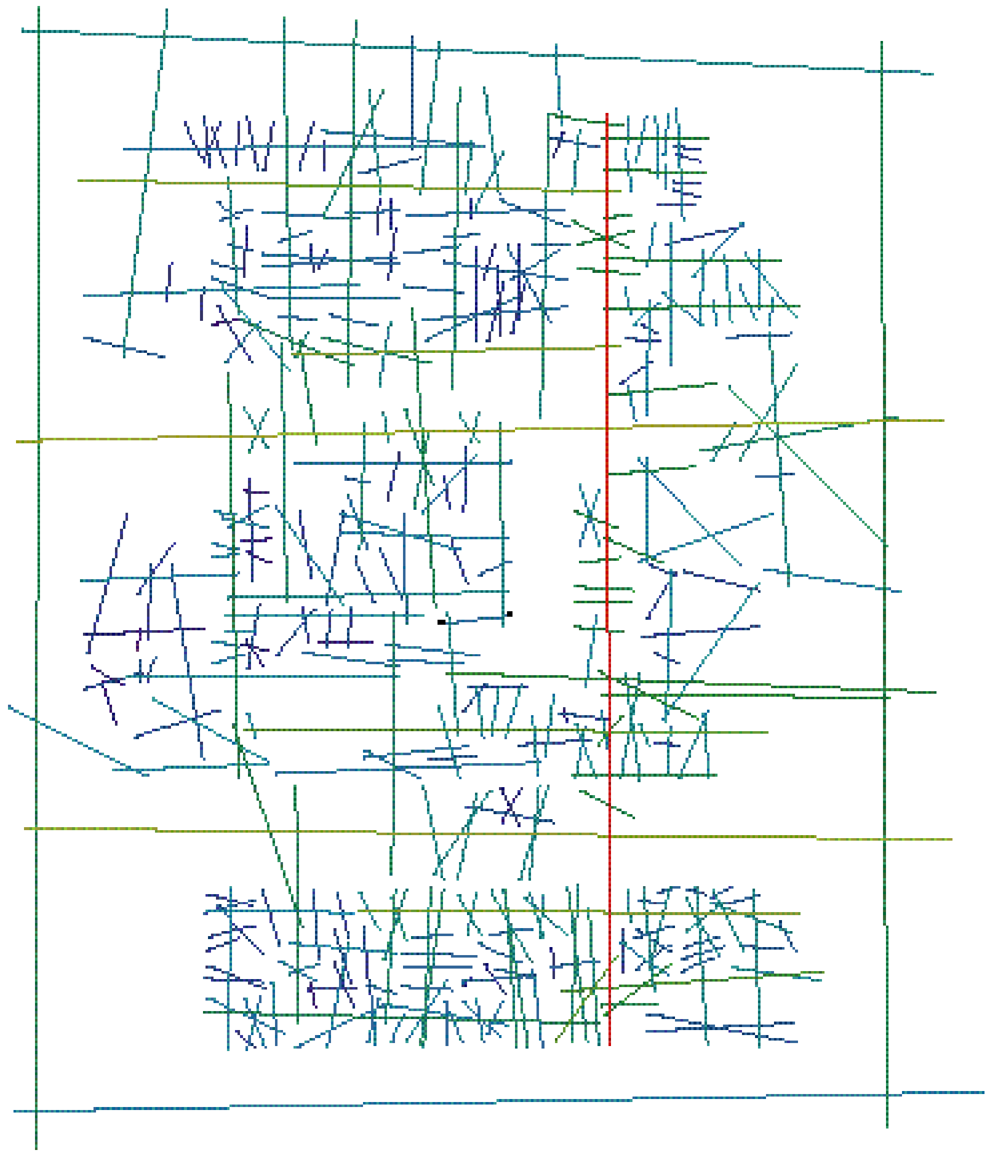


Figure A1.19 Axial map showing proposed changes to Urban Hospital.

Bibliography

Allen, G. L. (1999). Spatial Abilities, Cognitive Maps, and Wayfinding. In R. G. Golledge (Ed.), Wayfinding Behavior, Cognitive Mapping and other Spatial Processes (pp. 46-80). Baltimore and London: The Johns Hopkins University Press.

Appleyard, D. (1969). Why Buildings are known: A Predictive Tool for Architects and Planners. Environment and Behavior (December), 1969.

Appleyard,D.(1970). Styles and methods of structuring a city. Environment and Behavior, 2, 100-117.

Appleyard, D. (1976). Planning a Pluralistic City: Cambridge: MIT Press.

Aragones, J. I., & Arredondo, J. M. (1985). Structure of urban cognitive maps. Journal of Environmental Psychology, 5(2) (Jun), 197-212.

Arthur, P., & Passini, R. (1992). Wayfinding: people, signs, and architecture. New York : McGraw-Hill Book Co.

Bechtel, R. (1967). Human Movement in Architecture. In H.M. Proshansky et al. (Ed.), Environmental Psychology (pp. 642-645). New York: Holt, Rinehart and Winston.

Bechtel, R. B. (1997). Environment and Behavior: An Introduction: Sage Publications.

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

Best, G. (1970). Direction Finding in Large Buildings. In D. V. Canter (Ed.), Architectural Psychology (pp. 92). London: RIBA.

Blades, M. (1991). Wayfinding Theory and Research: The need for a new approach. In David M. Mark and Andrew U. Frank (Ed.), Cognitive and Linguistic Aspects of Geographic Space (pp. 137-165): Kluwer Academic Publishers.

Bovy, P.H.L. & Eliahu, S. (1990) Route Choice: Wayfinding in Transport Networks. Dordrecht, Boston, London:kluwer academic Publishers.

Braaksma, J. P., & Cook, W. J. (1980). Human Orientation in Transportation Terminals. Transportation Engineering Journal, 106 (March, No. TE2)

Burns, P.C. (1998). Wayfinding Errors while Driving. Journal of Environmental Psychology, 18, 209-217

Butler D.L., Acquino A.L., Hissong A.A. and Scott P.A. (1993) Wayfinding for New Comers in a Complex Building. Human Factors.35(1) 159-173

Campos, M. B. d. A. (1999). All that Meets the Eye. Paper presented at the Space Syntax - Second International Symposium Proceedings, Brasilia, Brazil.

Canter, D. (1977). The Psychology of Place. London: The Architectural Press.

Carpman, J. R., & Grant, M. A. (1993). Design that cares: planning health facilities for patients and visitors (2nd ed.). Chicago, Ill.: American Hospital Pub.

Carr, S., & Schissler, D. (1969). The city as a trip: Perceptual selection and memory in the view from the road. Environment and Behavior(1), 7-35.

Choi, Y., K. (1999). The morphology of exploration and encounter in museum layouts. Environment and Planning B: Planning and Design 26, 241-250

Cornell, E. H., C. D. Heth, et al. (1992). “Wayfinding by children and adults: Response to instructions to use look-back and retrace strategies.” Developmental Psychology 12(2)(Mar): 328-336.

Couclelis, H., Golledge, R. G., Gale, N., & Tobler, W. (1995). Exploring the Anchor-point Hypothesis of Spatial Cognition. In T. Garling (Ed.), Readings in Environmental Psychology: Urban Cognition: Academy Press Limited.

Devlin, A. S., & Bernstein, J. (1997). Interactive Way-Finding: Map Style and Effectiveness. Journal of Environmental Psychology, 17(1), Mar, 23-38

Downs, R., & Stea, D. (Eds.). (1973). Image and the Environment: Cognitive Mapping and Spatial Behavior. Chicago: Aldrine.

Evans, G. (1980). Cognitive Mapping and Architecture. Journal of Applied Psychology, 65 (4), 474-478.

Evans, G., Marrero, D., & Butler, P. (1981). Environmental Learning and Cognitive Mapping. Environment and Behavior, 13(1) 83-104.

Evans, G. W. and K. Pezdek (1980). "Cognitive mapping: Knowledge of real-world distance and location information." Journal of Experimental Psychology: Human Learning and Memory 6: 13-24.

Freundschun, S. M., (1991). The effect of spatial pattern of the environment in spatial knowledge acquisition. In David Mark and Andrew Frank (Ed.) Cognitive and Linguistic Aspects of Geographic Space, (pp. 167-183): Kluwer Academic Publishers, The Netherlands

Garling, T. (1995). Introduction: How do Urban Residents Acquire, Mentally Represent, and Use Knowledge of Spatial Layout? In T. Garling (Ed.), Readings in Environmental Psychology:Urban Cognition (pp. 1-12): Academy Press Limited.

Garling, T., Book, A., & Ergezen, N. (1982). Memory for the spatial layout of the everyday physical environment: different rates of acquisition of different types of information. Scandinavian Journal of Psychology, 23 23-35.

Garling, T., Book, A., & Lindberg, E. (1984). Cognitive Mapping of Large-Scale Environments: The Interrelationship of Action Plans, Acquisition and Orientation. Environment and Behavior, 16 (1) 3-34.

Garling, T., Book, A., & Lindberg, E. (1986). Spatial orientation and wayfinding in the designed environment: A conceptual analysis and some suggestions for post-occupancy evaluation Journal of Architectural & Planning Research 55-64, Feb 1986, Vol 3(1), 55-64.

Garling, T., Book, A., Ergezen, N., & Lindberg, E. (1981). Memory for Spatial Layout of the Everyday Physical Environment: Empirical Findings and their Theoretical Implications. Environmental Desigh Research Association 12, 69-77.

Garling, T., Saisa, J., Book, A. and Lindberg, E., (1995). The Sociotemporal Sequencing of Everyday Activities in the Large Scale Environment. In T. Garling ed. Readings in Environmental Psychology: Urban Cognition (pp. 167-186) Academy Press Limited

Garling, T., Lindberg, E., Carreiras, M., & Book, A. (1986). Reference systems in cognitive maps. Journal of Environmental Psychology, 6 (1) (Mar), 1-18.

Gibson, J. J. (1966). The Senses Considered as Perceptual Systems. Boston: Houghton Mifflin.

Gibson, J. J. (1979). The Ecological Approach to Visual Perception: Cornel University.

Gluck, M. (1991). Making Sense of Human Wayfinding: review of Cognitive and Linguistic Knowledge for Personal Navigation with a New Research Direction. David M. Mark and Andrew U. Frank (Ed.), Cognitive and Linguistic Aspects of

Geographic Space, (pp. 117-135). Dordrecht, The Neterlands:Kluwer Academic Publishers.

Golledge, R. G. (1977). Multidimensional analysis in the study of environmental behavior and environmental design. In Irwin Altman and Joachim F. Wohcwill (Ed.), Human Behavior and Environment Advances in Theory and Research (Vol. 2), pp. 1-42). New York and London: Plenum Press.

Golledge, R. (1978). Learning about Urban Environments. Tommy Carlstein, Don Parkes and Nigel Thrift (Ed.), Timing Space and Spacing Time (Vol. 1), New York.

Golledge, R. G. (1987). Environmental Cognition. In D. Stokoels & I. Altman (Eds.), Handbook of Environmental Psychology (Vol. 1), 131-175.

Golledge, R. (1991). Cognition of Physical and Built Environments. In T. Garling & G. Evans (Eds.), Environment, Cognition and Action: An Integrated Approach (pp. 35-62): Oxford University Press.

Golledge, R. G. (1999). Wayfinding Behavior: Cognitive Mapping and other Spatial Processes. Baltimore: Johns Hopkins University Press.

Golledge R. G., Rivizzigno, V.L., & Spector, A. (1976) Learning about a city Analysis by multidimensional scaling. In R. Golledge and G. Rughton (Eds.) Spatial Choice and spatial Behavior. Columbus: Ohio State University Press.

Golledge, R. G., & Stimson, R. J. (1997). Spatial Behavior A Geographic Perspective. New York, London: The Guilford Press.

Gopal, S, Klatzky, R., & Smith, T. R. (1995). Navigator: a psychologically based model of environmental learning through navigation. In T. Garling (Ed.), Readings in Environmental Psychology: Urban Cognition.:Academy Press Limited.

Gross, M. and Zimring, C. (1990). Buildings, memory and Wayfinding. In Environmental Design Research Association 21 (pp. 85-93).

Gross, M. and Zimring, C. (1992). Predicting Wayfinding Behavior in Buildings: A Schema Based Approach. In Kalay Y.E. (Ed.) Principles of Computer Aided Design: Evaluating and Predicting Design Performance (pp. 367-377)

Hammer, M., (1999). Well- Connected, New Scientist, 13 Nov, PBI Limited (http://www.newscientist.com/ns/19991113/wellconnec.html)

Hanson J., & Hillier B., (1982). Domestic space organization Two contemporary space codes compared. Archit. & Comport / Archit. & Behav (2), 5-25

Hanson J., & Hillier B., (1987). The architecture of community: Some new proposals on the social consequences of architecture and planning decisions. Archit. & Comport / Archit. & Behav (3), 251-271

Haq, S. (1999a). Can Space Syntax Predict Environmental Cognition. Proceedings of Space Syntax Second International Symposium, Brasilia, Brazil, Fundacao de Apoio a Pesquisa do Distrito Federal, 40.1-40.14

Haq, S. (1999b). Expectation of Exploration: Evaluating the Effects of Environmental Variables on Wayfinding. In The Power of Imagination, (pp. 84-94) Orlando, Florida, EDRA.

Hart, R. A., & Moore, G. (1973). The Development of Spatial Cognition: A Review. In R. M. Downs & D. Stea (Eds.), Image and Environment (pp. 246-288). Chicago: Aldine Publishing Company.

Heft, H. (1983). Way-finding as the perception of information over time. Population & Environment: Behavioral & Social Issues, 6(3) (Fall), 133-150.

Hillier, B. (1985). The nature of the artificial: the contingent and the necessary in spatial form in architecture. Geoforum (16), 163-178

Hillier, B. (1988). Against Enclosure. In N. Tymour, T Marcus, T Wolley (Ed.) Rehumanising Housing, Butterworth

Hillier, B. (1989). The architecture of the urban object. Ekistics, 56, no.334-335, 5-21.

Hillier, B. (1993). Natural movement: or, configuration and attraction in urban pedestrian movement. Environment and planning B, 20(1), 29-66.

Hillier, B. (1996). Space is the Machine. Cambridge: Cambridge University Press.

Hillier, B. (1998). A note on the intuiting of form: three issues in the theory of design. Environment and planning B, 25th Anniversary Issue, 37-40

Hillier, B. (1999). The hidden geometry of deformed grids: or, why space syntax works, when it looks as though it should'nt. Environment and Planning B, (26), 169-191

Hillier, B., Burdett, R., Peponis, J., & Penn, A. (1987). Creating life: Or, Does Architecture Determine Anything? Architecture and Behavior/Architecture et Comportment 3, 233-250.

Hillier, B. & Hanson, J. (1984). The Social Logic of Space (Paperback Edition 1988.). Cambridge: Cambridge University Press.

Hillier, B. & Hanson, J. (1987). Ideas are in things: an application of the space syntax method to discovering housing genotypes. Environment and Planning B (14), 363-385.

Hillier, B., Penn, A., J. Hanson, T. G., & Xu, J. (1993). Natural movement: or configuration and attraction in urban pedestrian movement. Environment and Planning, 20(B), 29-66.

Hirtle, S. C., & Heidorn, P. B. (1993). The structure of cognitive maps: Representations and processes. In Tommy Garling & Reginald Golledge (Eds.), Behavior and Environment: Psychological and Geographical Approaches. (Vol. Advances in psychology), (pp. 170-192): U Pittsburgh, Dept of Information Science, Pittsburgh, PA, USA

Hirtle, S. C., & Hudson, J. (1991). Acquisition of spatial knowledge for routes. Journal of Environmental Psychology, 11(4) (Dec), 335-345.

Jackson, P.G., (1998). In search of better route guidance instructions. Ergonomics, 41 (7), 1000-1013.

Kaplan, S. (1973). Cognitive Maps, Human needs and the Designed Environment. Paper presented at the Environment Design Research Association.

Kaplan, S. (1976). Adaptation, Structure and Knowledge. In G. Moore. and R. Golledge (Ed.), Environmental Knowing: Theories, Research and Methods (pp. 32-46): Dowden, Hutchinson and Ross Inc.

Kaplan, S. (1992). Environmental preference in a knowledge-seeking, knowledge-using organism. In Jerome H. Barkow, Leda Cosmides and John Tooby (Ed.), The adapted mind: Evolutionary psychology and the generation of culture. (pp. 581-598): Oxford University Press, New York, NY, US.

Kaplan, S., & Kaplan, R. (1977). The Experience of the Environment. Man-Environment Systems, 7(6), 300-305.

Kaplan, R., & Kaplan, S. (1982). Cognition and Environment: Functioning in an Uncertain World. New York: Praeger.

Kirasic, K.C., Allen, G.L., & Siegel, A.W. (1984). Expression of configurational knowledge of large scale environments: students performance of cognitive tasks. Environment and Behavior, 16, 687-712.

Kitchin, R. M. (1994). Cognitive maps: What are they and why study them? Journal of Environmental Psychology, 14(1) (Mar), 1-19.

Kohen, R. and T. Schuepfer (1980). “The Representation of Landmarks and Routes.” Child Development 51: 1065-1071.

Kuipers, B. (1978). Modeling Spatial Knowledge. Cognitive Science 2(2): 129-154

Kuipers, B. (1983). The Cognitive Map: Could it Have been any other way? In Herbert L. Pick and Linda P. Acredolo (Ed.), Spatial Orientation: Theory, Research and Application (pp. 345-359). New York and London: Plenum Press.

Lawton, C. A. (1996). Strategies for indoor Wayfinding: The Role of Orientation. Journal of Environmental Psychology, 16, 137-145.

Leiser, D. and Zilbershatz (1989) The Traveller: A Computational Model of Spatial Network Learning. Environment and Behavior, 21(4), 435-463

Levine, M., Marchon, I., & Hanley, G. (1984). The Placement and Misplacement of You-are-here Maps. Environment and Behavior, 16(2), 139-157.

Lindberg E. & Garling T. (1983). Acquisition of different types of locational information in cognitive maps: automatic or effortful processing? Psychological Research, 45. 19-38

Lloyd, R. and Gilmartin, P. (1991). The Effects of Map Projections and Map Distance on Emotional Involvement with Places. The cartographic Journal, 28, 145-151.

Lynch, K. (1960). The Image of the City. Cambridge: Joint Center for Urban Studies.

McCalla, G. I. and Schneider, P. F. (1979) The Execution of Plans in an Independent Dynamic Microworld, Proceedings, Sixth International Joint Conference of Artificial Intelligence, Tokyo, Japan

McCalla, G. I. and Schneider, P. F. (1980) Planning in a Dynamic Microworld, Proceedings, Third Biennial Conference of the Canadian Society for Computational Studies of Intelligence, Victoria, British Columbia, 248-255

McDonald, T. P., and Pellegrino (1993). Psychological Perspectives on Spatial Cognition. T. Garling and R. G. Golledge ed. Behavior and Environment: Psychological and Geographical Approaches, Elsevier Science Publishers.

Magana, J. Z. (1978). An Empirical and Inter-disciplinary test of a theory of Urban Perception. Unpublished Doctoral Dissertation, University of California, Irvine.

Montello, Daniel R., (1998). A New Framework for Understanding the Acquisition of Spatial Knowledge in Large Scale Environments. M.J. Egenhofer and R. G. Golledge ed. Spatial and Temporal Reasoning in Geographic Information Systems, Oxford University Press, NewYork and Oxford.

Moore, G. T. (1975). The Development of Environmental Knowing: An overview of Interactional-Constructivist Theory and some Data on Within-Individual Development Variations. In David Canter and Terrance Lee (Ed.), Psychology and the Built Environment (pp.184-194). New York: John Wiley and Sons.

Moore, & Golledge (Eds.). (1976) Environmental Knowledge Theories, Research and Methods. Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross Inc.

Neisser, U. (1976). Cognition and Reality. San Francisco: W.H. Freeman and Company.

Norberg-Schulz, C. (1971). Existence, Space & Architecture. Oslo, Norway: Studio Vista.

O'Neill, M. J. (1991a). Effects of signage and floor plan configuration on wayfinding accuracy. Environment & Behavior, Vol 23(5), 553-574.

O'Neill, M. J. (1991b). Evaluation of a conceptual model of architectural legibility. Environment & Behavior. Vol 23(3) 259-284, May, 23, 259-284.

Passini, R. (1984) Wayfinding in Architecture. New York: Van Nostrand Reinhold.

Peatross F. D., & Peponis J., (1995). Space, Education and Socialization. Journal of Architectural and Planning Research (12:4), 366-385

Penn A., Desylas J., and Vaughan L., (1999). The space of innovation and communication in the work environment. Environment and Planning B, 26, (193-218).

Peponis J., (1985). The spatial culture of factories. Human Relations (38), 357-390.

Peponis, J., Hadjinikolaou, E., Livieratos, C., & Fatouros, D. A. (1989). The Spatial Core of Urban Culture. Ekistics, 334, 335 Jan-Feb, Mar-Apr, 43-55.

Peponis J., Ross C., Rashid M. (1997). The structure of urban space, movement and co-presence: the case of Atlanta. Geoforum (28), 341-358.

Peponis, J., & Wineman J. (2001). The Spatial Structure of Environment and Behavior: Space Syntax. Forthcoming.

Peponis, J., Zimring, C., & Choi, Y.K. (1990). Finding the building in wayfinding. Environment and behavior, 22, no.5, 555-590.

Piaget, J., & Inhelder, B. (1967). Perceptual Space, Representational Space, and the Haptic Perception of Space, The child's conception of space.: London, Routledge & K. Paul.

Poon, L. W., Welke, D. J., & Dudley, W. N. (1993). What is Everyday Cognition? In James M. Puckett and Hayne Reese (Ed.), Mechanisms of Everyday Cognition (pp. 19-31). New Jersey: Laurence Erlbaum Associates.

Rovine, M. J., & Weisman, G. D. (1995). Sketch-map variables as predictors of way-finding performance. In T. Garling (Ed.), Readings in Environmental Psychology: Urban Cognition (pp. 151-166).

Rubin, D. C. (1989). Issues of regularity and control: Confessions of a regularity freak. In L.W. Poon, D.C. Rubin and B.A. Wilson (Ed.), Everyday Cognition in Adulthood and Late Life (pp. 84-103). Cambridge: Cambridge University Press.

Sadalla & Magel. (1980). The perception of traversed distance. Environment and Behavior (12), 65-79

Sholl, M. J., (1996). From Visual Information to Cognitive Maps, in J. Portugali (ed.) The Construction of Cognitive Maps, (pp. 157-186), Dordrecht: Kluwer Academic.

Siegel, A. W. (1981) The Externalization of Cognitive Maps by Children and Adults: In Search of Better ways to ask Better Questions. In L.S. Libben, A. Patterson and N. Newcombe (ed.) Spatial Cognition and Behavior across the Life Span: Theory and Application (pp. 167-194), New York, Academic Press.

Siegel, A. W., & White, S. H. (1975). The Development of Spatial Representations of Large-Scale Environments. Advances in Child Development and Behavior, 10, 9-55.

Stea, D. (1969). The Development of Mental Maps: An experimental model for Studying Conceptual Spaces. In K.R. Cox and R.G. Golledge (Ed.), Behavioral Problems in Geography (pp. 228-253). Evanston, Ill.

Teklenburg, T.A.F., Timmermans, H.J.P & van Wagenberg, A.F. (1993). Space syntax: standardised integration measures and some simulations. Environment and Planning B,(20), 347-357.

Tobler, W. R. (1976). The Geometry of Mental Maps. in R Golledge and G. Rushton (Ed.), Spatial Choice and Spatial Behavior (pp. 69-81). Columbus: Ohio University Press.

Tolman, E. C. (1948). Cognitive Maps in Rats and Men. Psychological Review, 55, 189-208.

Turner, A., & Penn A., (1999). Making Isovist Syntactic: Isovist Integration Analysis. In Space Syntax: Second International Symposium Brasilia, Brazil. Universidade de Brasilia: 29 Mar-2 Apr, 1999.

Weisman, G. D. (1979). Way-finding in the built environment : a study in architectural legibility., Unpublished Doctoral Dissertation, University of Michigan.

Weisman, G. D. (1981). Evaluating architectural legibility: Wayfinding in the built environment. Environment and Behavior, 13, 189-204.

Weisman, G. D. (1989). Designing to Orient the User. Architecture, Oct, 113-114

Weiss, R., & Boutourline, S. (1962). Fairs, Exhibits, Pavilions and their Audiences. as reported in Hill, (1984).

Willham, D. B. (1992) The topological properties of wayfinding in architecture. Unpublished Masters Thesis. College of Architecture, Georgia Institute of Technology, Atlanta.

Winigrad, E. (1993). Memory in the Laboratory and Everyday Memory. In J. Puckett. a. H. Reese (Ed.), Mechanisms of Everyday Cognition (pp. 55-70). New Jersey: Lawrence Erlbaum Associates.