Strategies for Research in Healthcare Settings: Challenges and Opportunities

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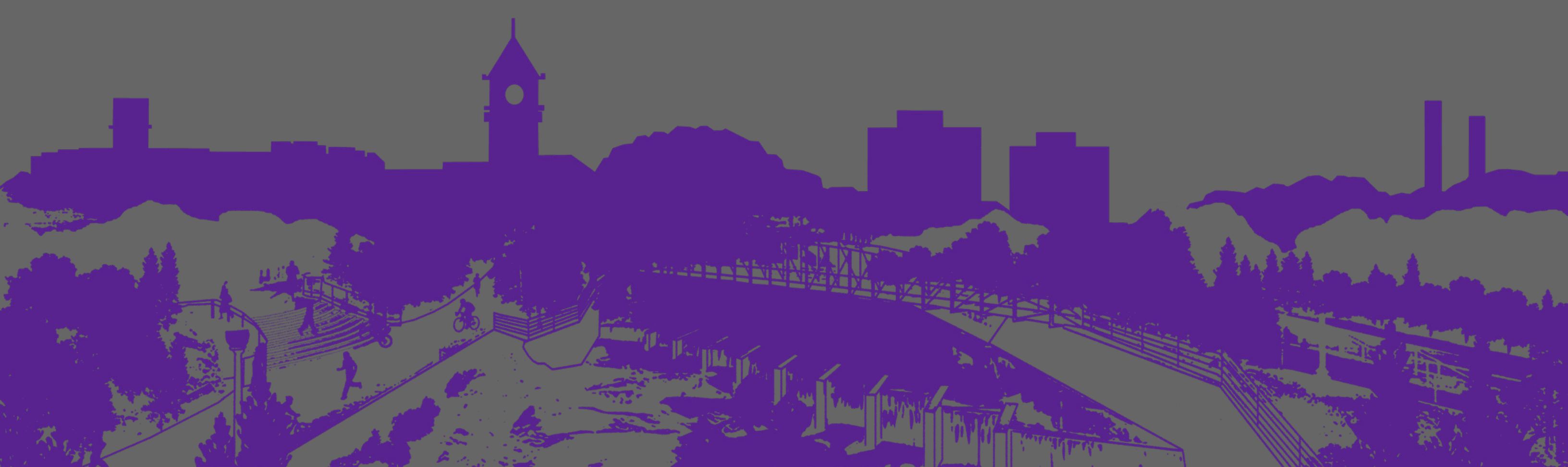

Five Essential Decisions for Clarity of Space Syntax Methodology

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ABSTRACT

Human understanding of environments often develops through asynchronous experiences. Individuals are either peripatetic, learning about the 'relations' between environmental units as they move about, or, if stationary, experience the effects of diurnal and seasonal changes. Either way, what they 'see' is always changing. The environmental learning of mobile humans is often called a 'cognitive map', and in turn is related to moving behavior and navigational decision making.

Modelling the effects of continuous changes of location with sufficient rigor for quantitative analyses has been challenging. The theory and methodology of Space Syntax offers precise ways of measuring complex environmental properties that arise from connections of each space to all other spaces contained in the same layout – sometimes directly, sometimes through other intermediate spaces. These analyses indicate a visual 'structure' perhaps comparable to that of a moving human's experience. As such, they can be understood as synchronous models of asynchronous experiences. Increased computational powers now allow finer tuned layout investigations by considering topological, metric, and geometric relationships, defining different kinds of unit spaces, and choosing the radii of analyses. However, since moving humans may or may not travel to or see all spaces in a layout, Syntax analyses might be considered 'idealized' because all spaces in a plan drawing and connections to all other spaces are the base of analysis.

This presentation will couple foundational concepts of Space Syntax with advanced analytical techniques. After a brief review of research that used these variables to investigate human and medical outcomes, it will conclude with a discussion of its drawbacks and opportunities. With respect to the agenda of this conference, the case studies and discussions will focus on healthcare and public health outcomes.

INTRODUCTION

Changes in our location bring attention to how different spaces are connected to one another. Properties of spaces based on such connections could be theoretical representations of our moving experiences. In this scenario, Space Syntax offers precise ways of understanding and measuring complex spatial properties that arise from connections that each space has to all other spaces contained in the same plan – sometimes directly, sometimes through other in-between spaces. Syntax analyses depict a visual 'structure', and this is perhaps comparable to the experience of a moving human. In other words, a Space Syntax model can be understood as a synchronous depiction of asynchronous experiences. However, since moving humans may or may not travel to or experience all the spaces in a layout, Syntax models could be considered an 'idealized' experience structure (see Figure 1).

Currently, increased computational powers allow finer-tuned layout modeling by considering topological, metric, and geometric relationships, defining different kinds of unit spaces, and choosing differ-

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ent radii for analyses. With the possibilities of analysis increasing, five important decisions prior to selecting the Space Syntax methodology are essential. This paper describes those and emphasizes that this clarity is crucial at the onset of any study that uses Space Syntax.

Theoretical Concepts Underpinning Space Syntax

At the beginning of any discussion on Space Syntax, it is prudent to shed some light on some of its fundamental concepts that remain significant today. Most important is the idea that spatial connections are understood and identified based on the experiences of the moving human person inside an environment. From this starting assumption, Space Syntax then proceeded to compute quantitative values of unit spaces to mimic aggregates of the moving humans (Hillier, 1970, 1973, 1977; Hillier & Leaman, 1974; B. Hillier et al., 1972). Two important variables were named 'Integration' and 'Choice'. However, currently the more descriptive terms 'Closeness' and 'Betweenness,' respectively, are used as they are indicative of the professed relationship between spatial attributes and human experiences.

The second concept is a 'non-discursive' grasp of space (Hillier, 2007, chapter 3). This concept can be understood when we think of giving directions to strangers. Typical descriptions in such a condition might be "keep going straight and when you reach the intersection take a right", or "take a left at the junction". These examples illustrate that the concept of connections (between spaces) is at the root of our spatial understanding, even before we consider distances and/or shapes. Indeed, to first receive directions such as "go 536.9 yards, turn 96.3 degrees" would be uncommon, and perhaps disturbing, to say the least. Space Syntax is built on this fundamental spatial property – i.e., connections between spaces. Indeed, Hiller has stated "Relations, it seems, are what we think with, rather than what we think of" (Hillier & Hanson, 1984, p. 02).

The third aspect, related to the previous ones is that built spaces are permeable and hence continuous –apparently infinitely. A person can go out of the bedroom to the living room, to the front yard, to the street, to the grocery store, to the friend's house, etc., on and on. Because space is continuous, the idea of immediately connected spaces (called Level 1 connections) and spaces connected through one or more spaces (Level 2, 3 4, 5, etc. connections) can be comprehended. The idea of continuity makes even more sense when this experience is empirically investigated through the lens of spatial cognition, something that began at least two decades after Syntax was introduced (Dalton, 2003; Haq, 1999; Penn, 2001).

Finally, also from a human-centered understanding, ideas of synchronic and diachronic experiences are relevant. Considered from the perspective of Ferdinand de Saussure (2006), logical and psychological connections between coexisting items of a system, i.e., what we see 'at once' (passive observer) is synchronous learning, and "connexions (sic) between sequences of items not perceived by the same collective consciousness" (p. 06), i.e., what we experience over time is diachronic. Space Syntax calculates variables of each space by considering relations from each space in the plan to all other spaces in it, -- thus it is an idealized aggregate. In other words, if a person were moving from all spaces to all other spaces, then their experience would be captured by Syntax values. Thus, the Syntax representation of variables is diachronic information presented in a synchronic form, i.e., simultaneously in a plan diagram (see Figure 1).

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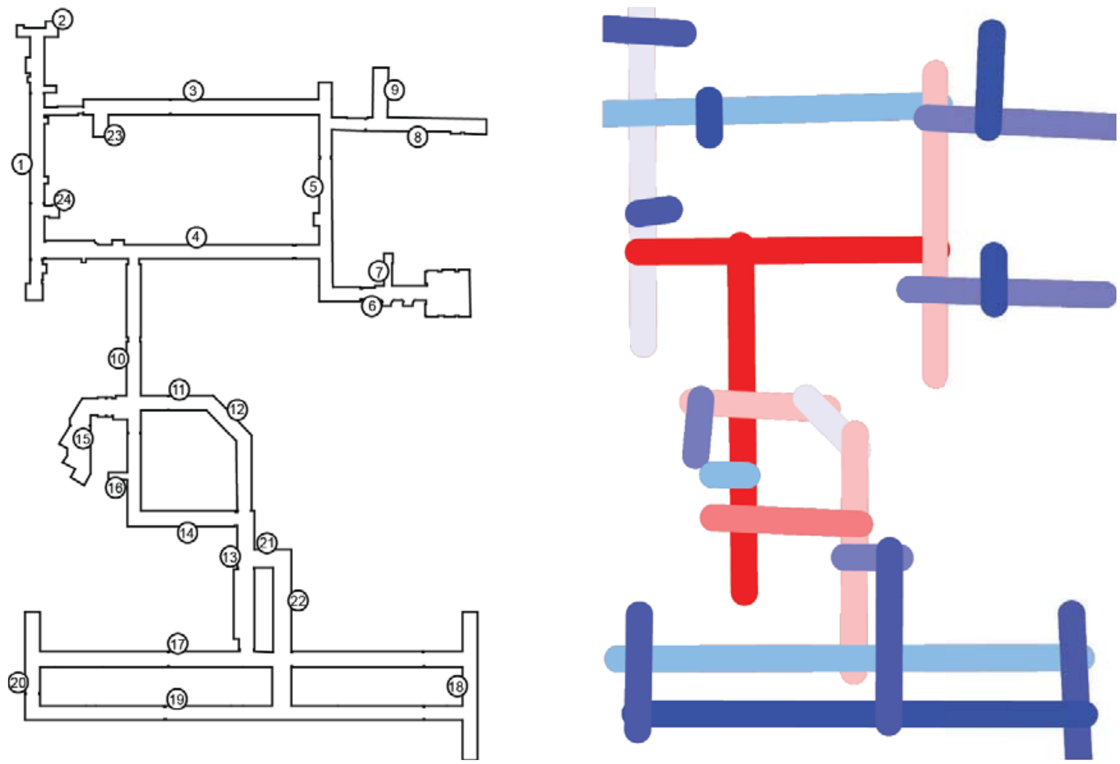
Figure 1

A Plan and a Space Syntax Model



Note: Corridors are unit spaces and topological connections to the entire plan are considered. Colors represent Closeness(n) values with higher to lower values depicted from red to blue colors. Source: Author

Introduction to Methodology

Space Syntax is both a theory and a methodology. It focuses on the relations between spaces as seen in plan drawings of various scales, quantifies each space based on these relations, and suggests that they have associations with numerous human aspects. Space Syntax began in the 1970's by considering topological relationships between unit spaces (in a plan) and hypothesizing a connection with social patterns -- thus the title of its first book was The Social Logic of Space (Hillier & Hanson, 1984). With time, some operational decisions made at the beginning stages were reconceptualized and elaborated, sharper ideas about spatial relationships and calculation methods of spatial variables were put forward, and more robust connections to human functions were postulated. In the process, powerful computer software to analyze large plans, and to include the newer conceptualizations of human attributes were developed.

Access to these digital tools has made analysis of spatial connections easy, and worldwide recognition of Space Syntax has spurred additional empirical research to investigate associations to other kinds of aggregate human-space relationships. These investigations have led to quite a few useful results. For example, Space Syntax variables were found to be positively correlated to pedestrian movement patterns in cities (Hillier et al., 1987; Peponis et al., 1989), traffic flows (Penn et al., 1998), land values (Kubat, 2009), wayfinding use of corridors inside buildings (Haq & Zimring, 2001; Peponis et al., 1990), spatial cognition (Haq, 1999; Hölscher et al., 2012; Penn, 2001), depression symptoms in homes (Chambers et al., 2018), etc. In hospital settings Space Syntax was related to nurse and physician positioning (Lu & Zimring, 2012), nurse entries to rooms (Hendrich et al., 2009), bed preferences by patients (Alalouch et al., 2009), and mortality rates (Ossmann, 2016), among others.

Advances in Space Syntax concepts and developments of the software took place concurrently with one influencing the other. For example, new ways to define unit spaces were developed and new relationship patterns between them identified. These were programmed into the software allowing newer kinds of layout analysis, and novel hypotheses relating them to unexplored aggregates of human attributes were tested.

As more and more research is reported, a clarity of Space Syntax methodological decisions is needed both to support the research questions posed, and to make sure that the selected variables and analyses are appropriate. Since Space Syntax has become much more fine grained and precise, it is no longer enough to simply provide very general statements such as "Space Syntax research suggests.....". This paper identifies and explains five decisions about Space Syntax factors that must be made in the beginning of any spatial analysis and explained thoroughly.

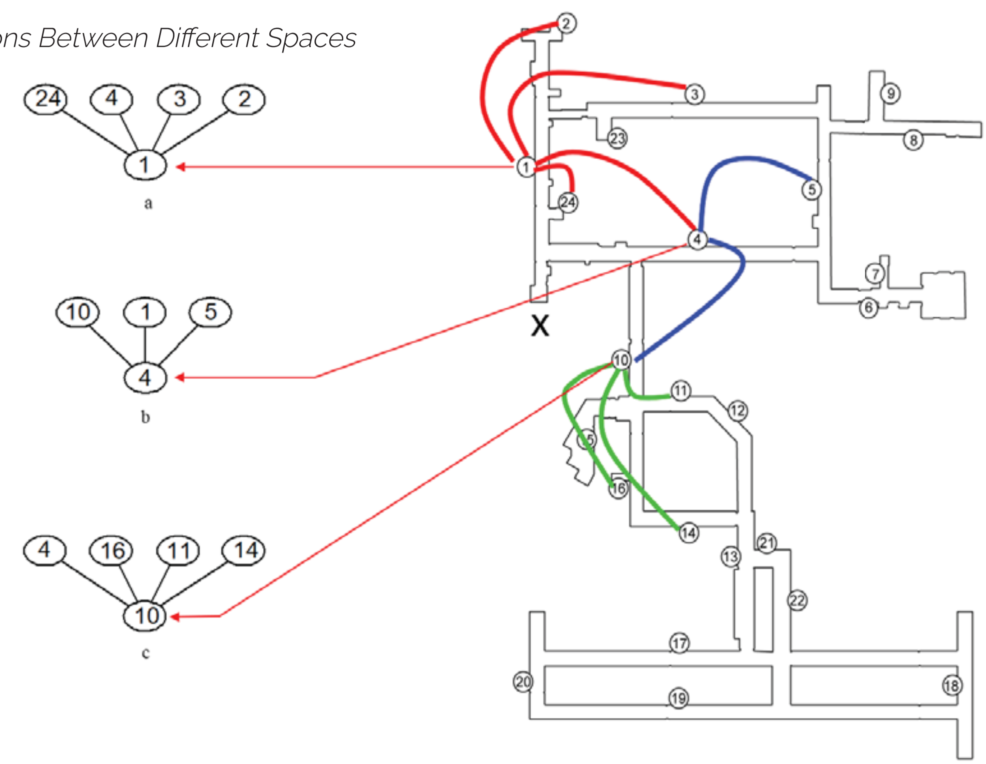
Foundational Ideas Behind Space Syntax Methodology

As previously indicated, the original idea of Space Syntax methodology was based on connections that each space has with all other spaces in a plan, either directly to adjacent spaces, or through a set of other spaces. Based on this notion of connections, and considering all spaces as both origins and destinations, Space Syntax calculated numerical values of each space.

The diagrams that follow are offered as a simplified explanation of Space Syntax initial ideas. In the plan shown in Figure 2 (right side), Corridors 1, 4 and 10 are directly connected to a set of adjacent corridors, and these connections are shown in red, blue, and green curved lines respectively. The connection type considered in the original Space Syntax methodology was topology. In other words, Syntax only considered whether a space was connected to another one or not. Size and shapes of the spaces were inconsequential. Thus, each space could be reduced to a dot with lines representing connections to other spaces – bringing forth the characteristics of a graph. The immediate connections of Corridors 1, 4 and 10 in graph-form are shown on the left of Figure 2.

Figure 2

Connections Between Different Spaces



Note: Connections between different spaces are identified (right) and shown in graph form (left).
Source: Author

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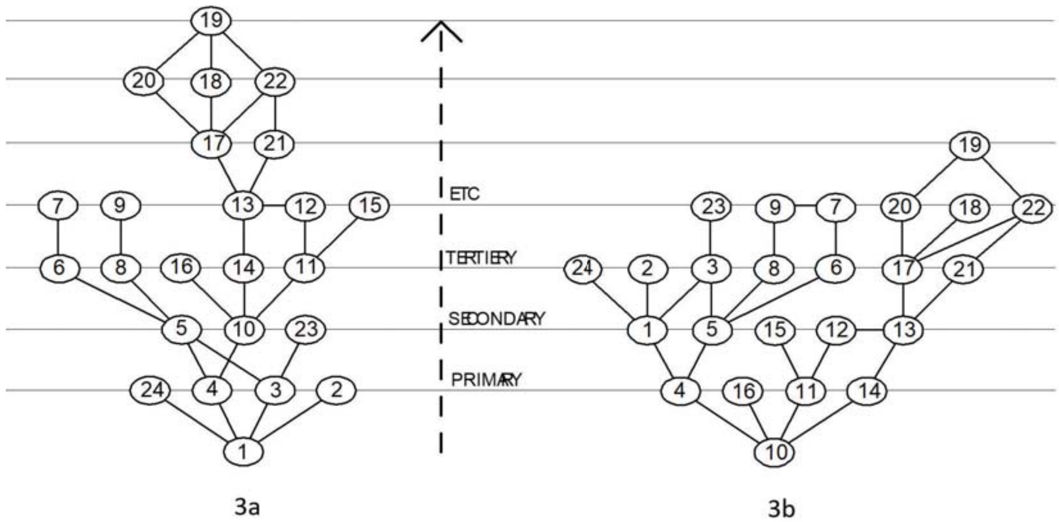
This idea of connections can further be extended to indicate secondary, tertiary, and more distant connections. In other words, a space can be connected to immediately adjacent ones, and, through some spaces to others further away, and so on. To illustrate, using Figures 2c and 3b, Corridor 10 is connected directly to Corridors 4, 6, 11 and 14 (Figure 2). Further, 4 is connected to 1 and 5, 1 is connected to 2, 3, 24, and so on (see Figure 3b). Thus, the notions of direct connections, secondary connections, tertiary connections, etc. are understood.

Figure 3

Connections of Corridors



Note: Connections of corridors 1 and 10 to all spaces (in the plan in Figures 1 and 2) are shown as a graph. 3a shows connections from corridor 1 and 3b shows them from corridor 10. Source: Author

Space Syntax calculations look at each space's connections to all other spaces in the plan, and after comparing those to an idealized plan, generates two kinds of numerical values for each space – Integration and Choice[1]. The Integration value indicates how close an origin space is to all other spaces in the plan, and Choice measures how often a space lies on the shortest paths (connections) between any pair of spaces (Hillier & Hanson, 1984). Recently, these have been replaced with the newer terms 'Closeness' and 'Betweenness' for ease of understanding, and this approach is also used in this paper.

Space Syntax: Five Important Considerations

As mentioned earlier, Space Syntax theoretical concepts have been developed, and methods have become more sophisticated. Fortunately, free software is easy to download and use. As such, plans can be effortlessly modelled with different assumptions. However, doing a computer analysis without a thorough understanding of the concepts is antithetical to developing valuable research questions and selecting methods. This paper proposes five aspects that should be carefully considered, and decisions clearly explained in all research that uses Space Syntax. Each factor is described with appropriate images in the text that follows.

1. Unit Spaces

In that narrative presented previously, spaces have been addressed simply as unit spaces (Corridors were the unit spaces in Figure 2). While a space is indeed a unit in Space Syntax analysis, there needs to be a clear definition about what a unit space (for analysis) is. The first task, therefore, is to describe what these unit spaces will be, and to postulate what it means for the research being undertaken.

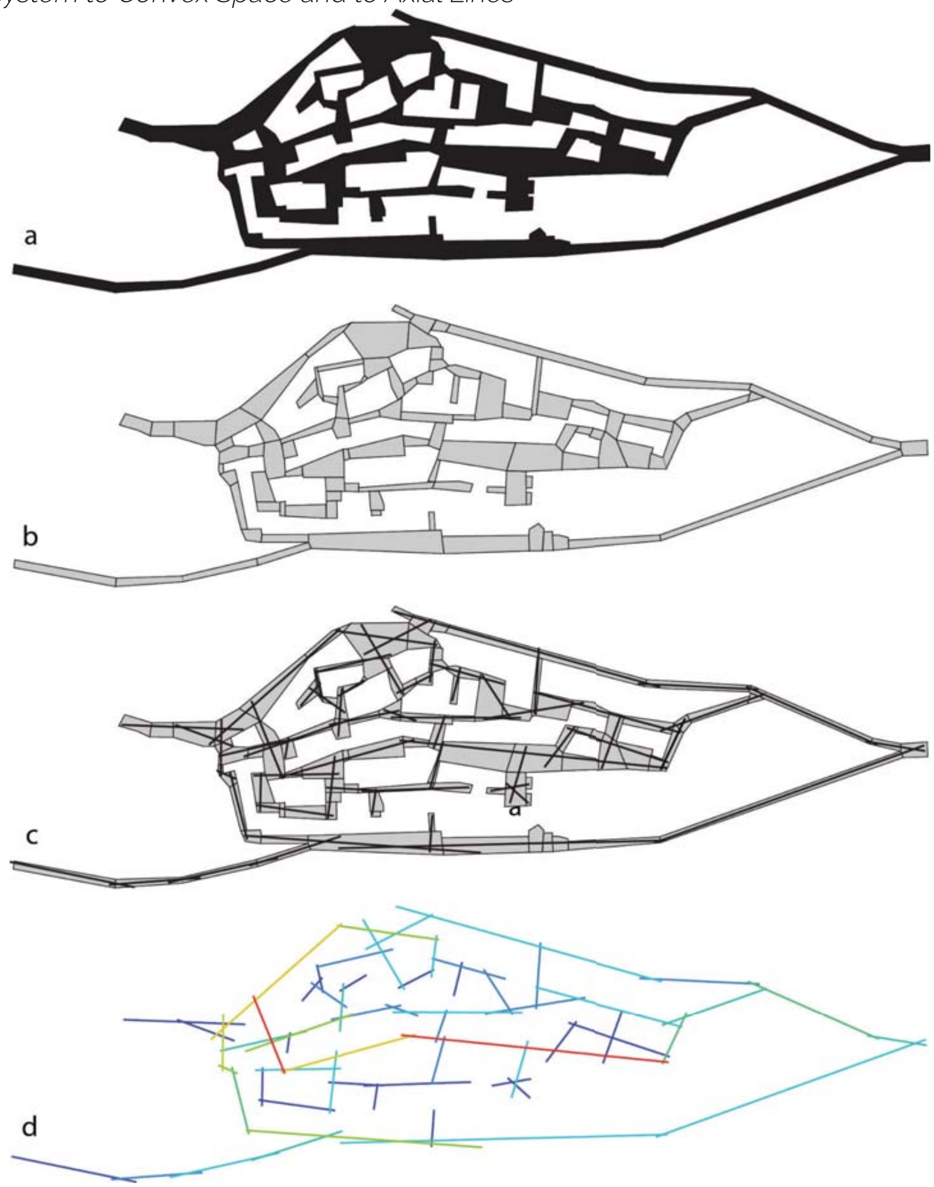
When it began, Space Syntax considered Axial Lines as unit spaces (Hillier & Hanson, 1984). Such

[1] Other variables are also calculated, but Integration and Choice are the two mostly used.

lines were described through the concept of Convex Spaces. The idea about convex space came from human awareness, and was defined as that space where all points in its perimeter would be visible from all the points within it (Hillier & Hanson, 1984). The task of the researcher would be to reduce the plan to a set of 'largest' convex spaces (see Figure 4b). It is important to understand that this process had a subjective component when spaces of complex shapes were considered because they had to be manually 'broken up' into convex pieces. Then, all the convex spaces in the plan had to be connected using the fewest and the longest lines possible (Hillier, 1999). These were called Axial Lines and were then considered the unit spaces in Space Syntax analysis (see Figure 4c). Over time, axial lines were directly drawn to represent linear spaces such as building corridors and city streets (without including the notion of convex spaces).

Figure 4

Open Space System to Convex Space and to Axial Lines



Note: (a) Open space system of a small town (streets and squares) shown in black (b) Open space system divided into a set of convex spaces, (c) Longest and fewest (axial) lines drawn to connect all the convex spaces, (d) Closeness values of axial lines. Source: Author

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New versions of Space Syntax software can now generate axial lines automatically. The software can produce all possible axial lines as depicted in Figure 5a. Since the software produces too many lines for meaningful relationship with real spaces, it can automatically reduce the number of lines too (Figure 5b). However, the possibility of manually drawing the lines is also available. Occasionally, this option might be used to match the analysis with the research question being asked (see Figure 5c).

The last kind of axial lines are called segmented lines, where the axial lines are segmented at their intersections to create another kind of axial map (see Figure 5d). In such a condition, the length of each line is reduced at their segments and the total number of lines in the plan increases. Please note that axial lines produced in any of the three methodologies can be segmented. This approach is especially useful in urban conditions, as shown in Figure 5e.

Figure 5

Examples of Different Axial Lines and Their Analysis

Figure 5a. Computer generated all possible axial lines and their topological analysis. (Closeness values) Source: Author

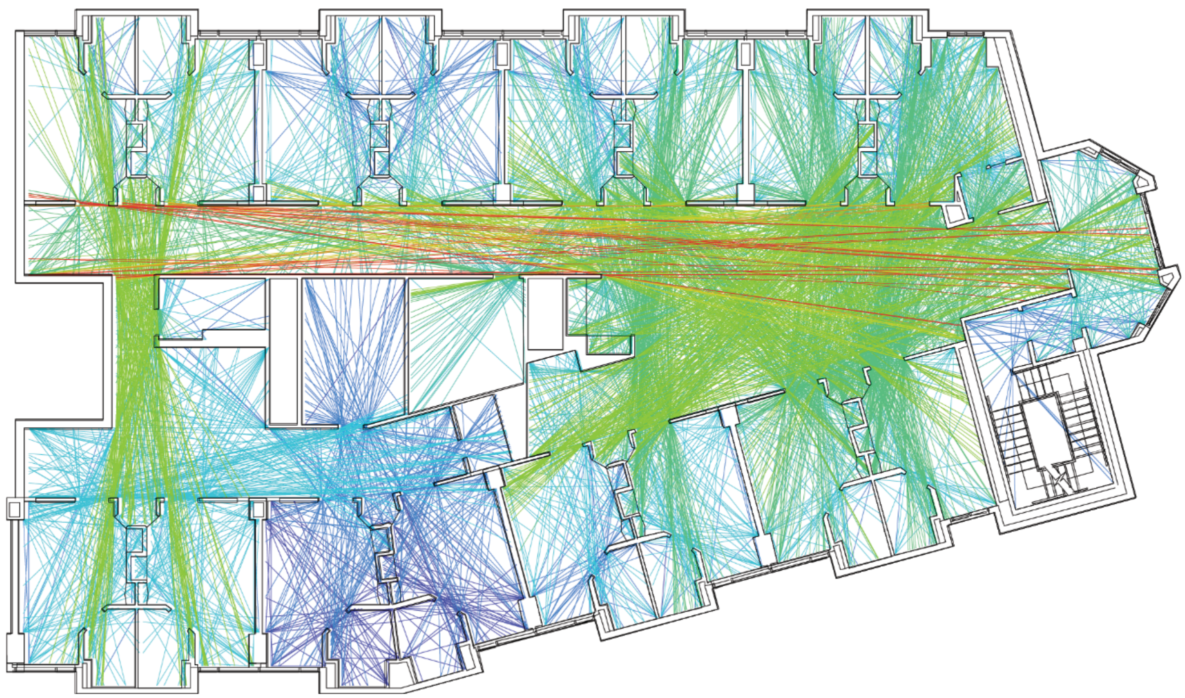

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Figure 5b: Computer has automatically reduced the number of lines from those shown in 5a. (Closeness values) Source: Author

Figure 5c: Axial lines manually drawn with digital tools to correspond specifically to the research intention. (Closeness values) Source: Author

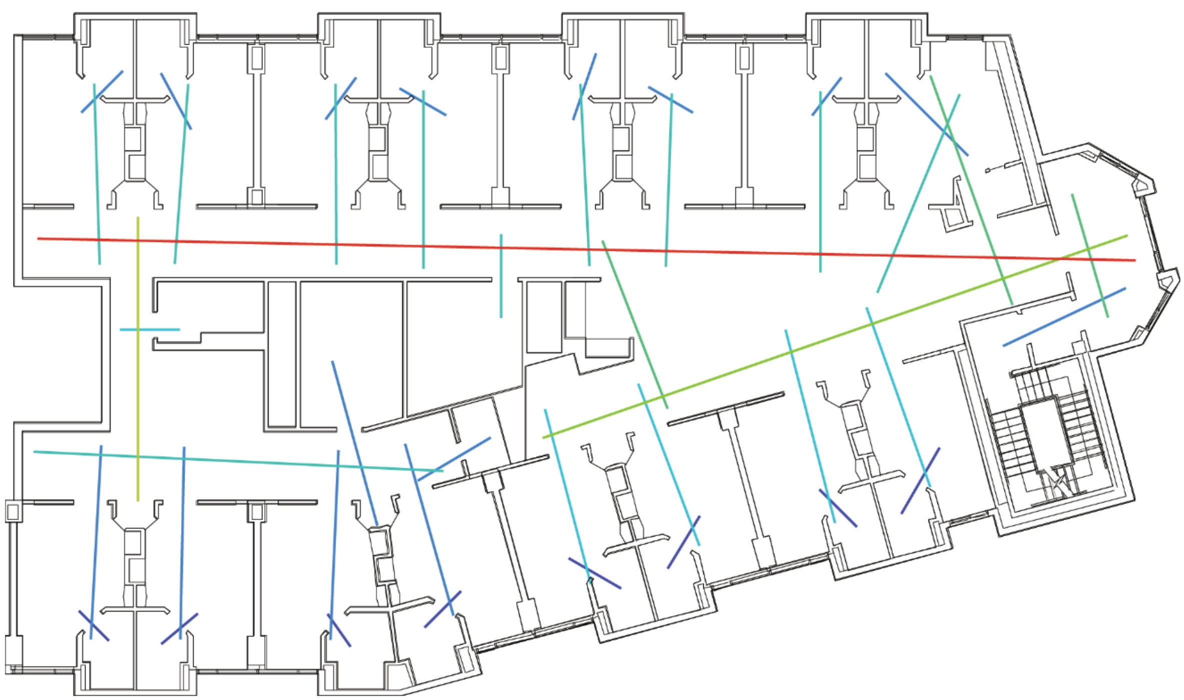

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Figure 5d. Axial lines are segmented at their intersections to create a segmented line map. (Betweenness values) Source: Author

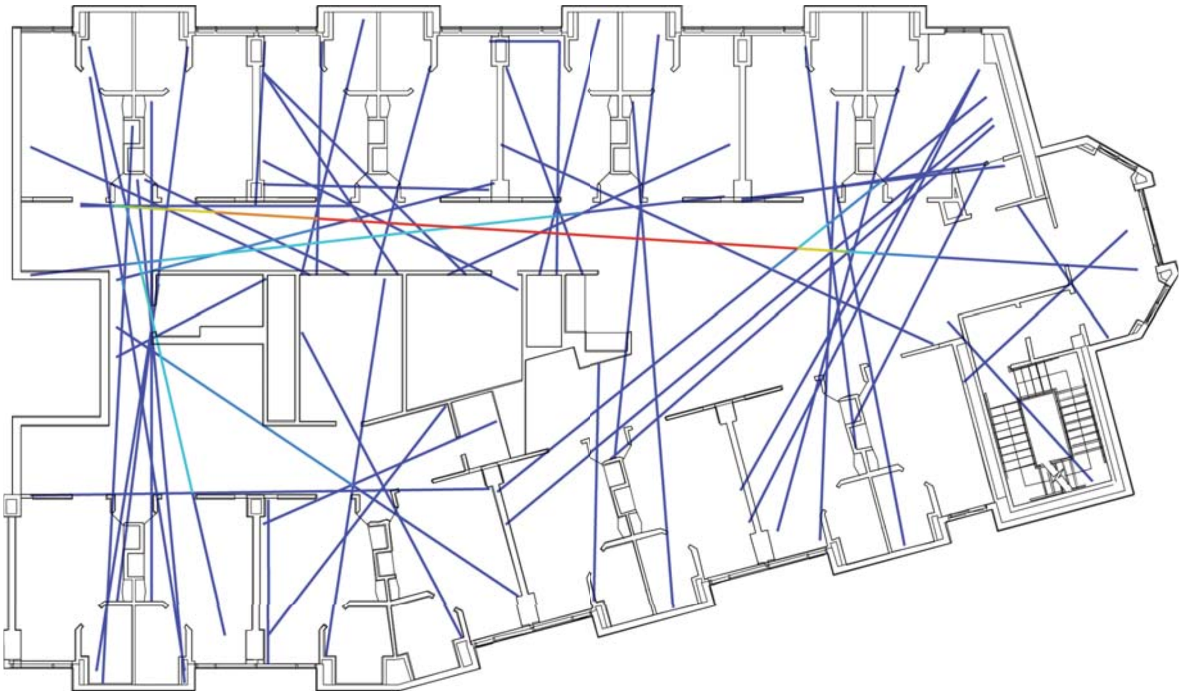
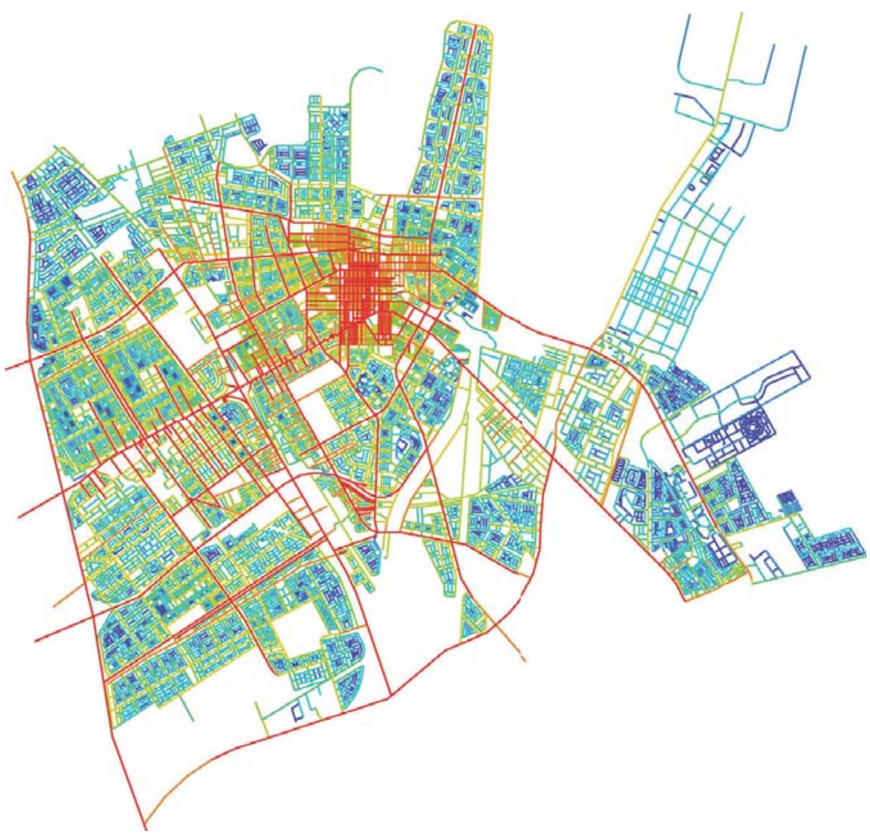


Figure 5e. Streets of Dammam, Saudi Arabia, modelled as segmented lines showing Closeness values. Source: Alrashed (2021)



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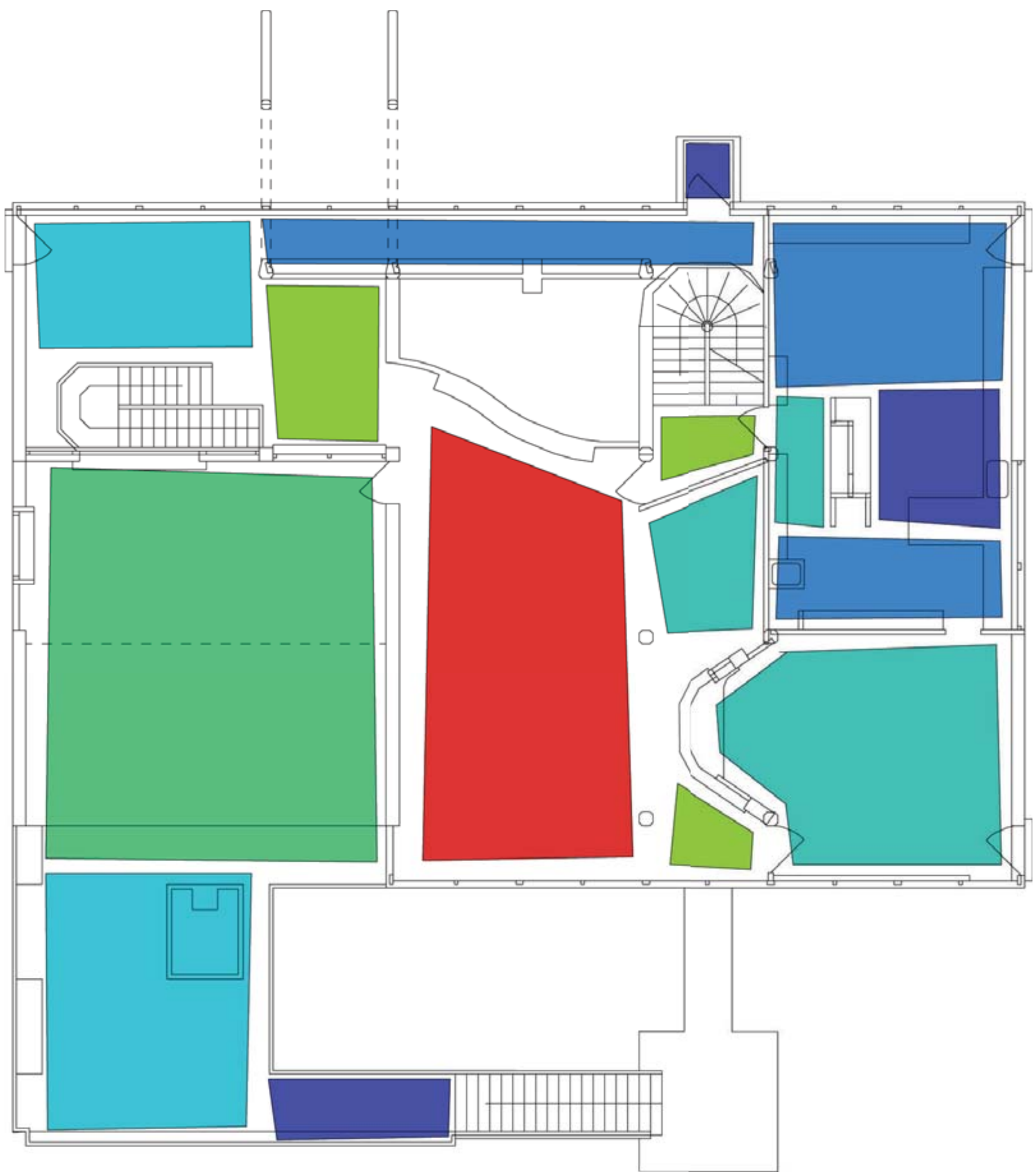
It may not be farfetched to say that the ubiquitous use of axial lines in the first few decades of Space Syntax software was due to two things: (1) most research undertaken was in urban areas where streets could be naturally (and quickly) represented as lines, and (2) the software could only deal with axial lines. The reader is reminded that the theory of Space Syntax was never limited to lines alone. Recent advances of computing now allow researchers to define their own unit space. In addition to axial lines, the following unit spaces have been used in research: rooms (Figure 6a) and units of a grid superimposed on a plan[2] (see Figure 6b). Additionally, researchers have the option of defining their own units and use the software for plan analysis. What is important is that the unit spaces are clearly defined, and the reasons explained with reference to the research question being posed.

Figure 6

Examples of Unit Space and Analysis

Figure 6a. Rooms of this house is used as unit spaces for analysis. (Closeness values) Source: Author



[2] Other variables are also calculated, but Integration and Choice are the two mostly used.

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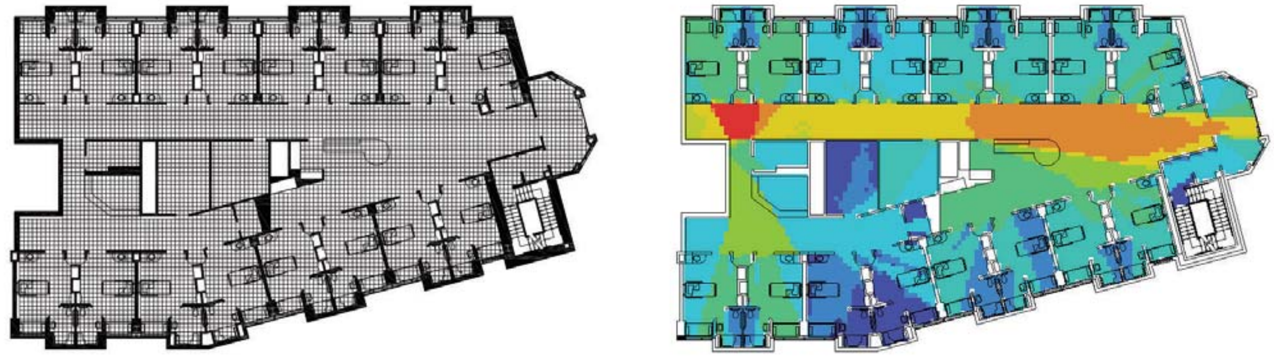
Figure 6b: A grid of appropriate dimensions is laid over the plan and each 'tile' is used as a unit space in this analysis. Source: Author



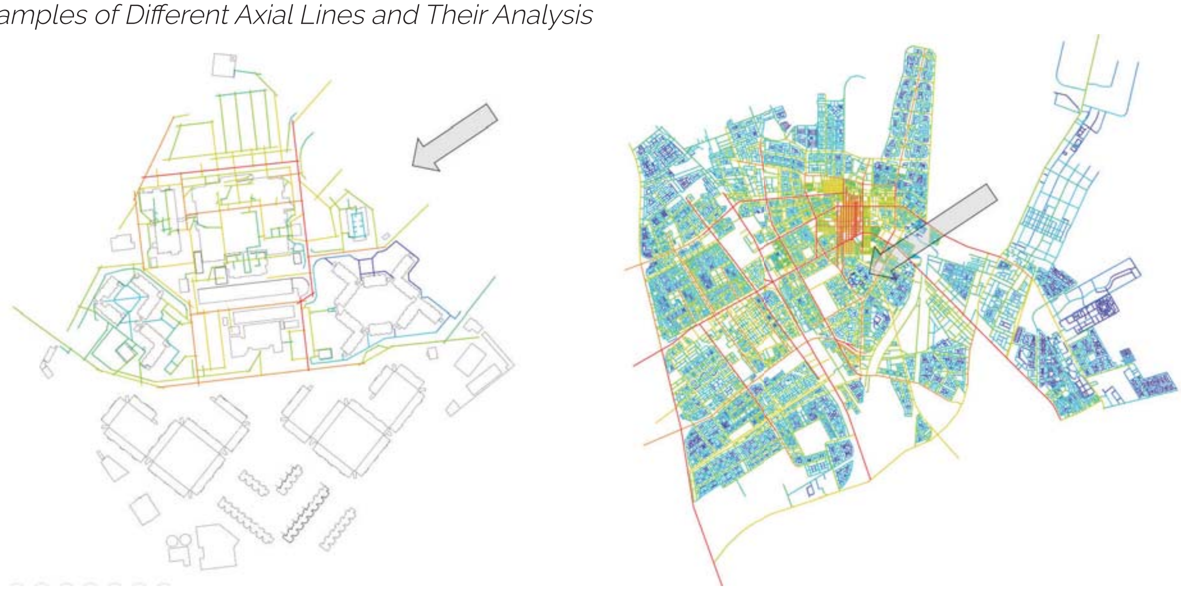
2. Spatial System

A spatial system is a set of researcher-defined unit spaces connected to form a layout or a plan. Layout is the idea of spaces configured together without a sense of enclosure or boundary, whereas a plan is a definite architectural drawing representing a building or an area. In other words, a plan has a boundary, albeit invisible, all around it. This boundary restricts the infinite continuity of spaces (described in Section 1 above) and gives an indication of where a moving person might stop, or a computer might stop counting. Computation by Space Syntax software is bounded within the plan diagram that the researcher selects. It is important to understand that depending on where the boundary is set, values of each space will vary (see Figure 7). Thus, the boundary definitions must be properly argued. In quantitative analysis such variations in values might seriously jeopardize the conclusions.

Definition regarding the boundary is a decision of the researcher, but it must be selected after careful deliberations. These deliberations should be clearly explained so that the Syntax analysis will be appropriately related to the research intentions.

Figure 7

Examples of Different Axial Lines and Their Analysis



Note: Streets inside King Fahad Specialist Hospital is modelled on the left, and all streets in the city of Dammam including the hospital complex, is shown on the right. The Syntax value of any street inside the campus will have two values depending on which model is selected. Source: Alrashed (2021)

A related notion regarding the Spatial System is deciding what is to be included inside the boundary. In Figure 8 that follows, public corridors are considered in 8b, and all spaces in the plan are selected in 8c. Such decisions will also change the Space Syntax variables and have an influence on the empirical work being carried out.

Figure 8

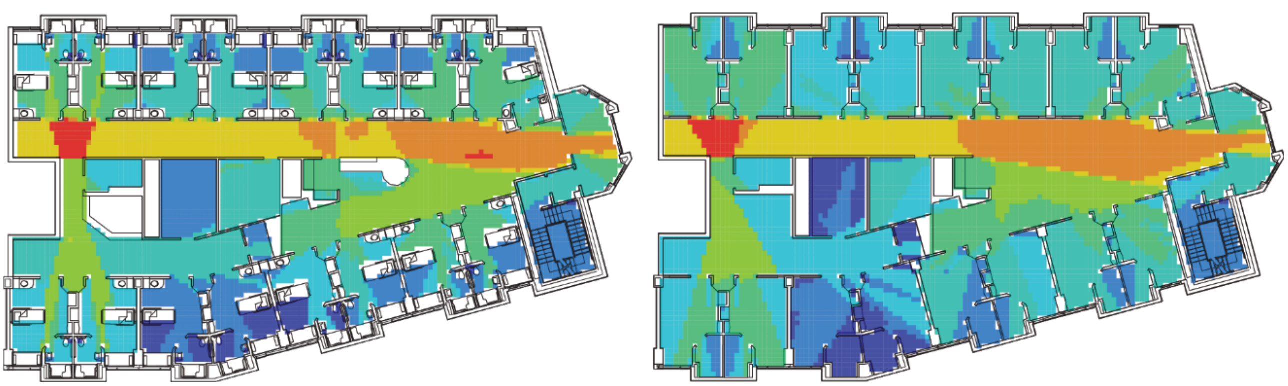
Example of Plan and Axial Analysis

Note: Figure 8a, Plan of a hospital, 8b Axial analysis of public corridors and 8c Axial analysis of all spaces. Source: Author.

Finally, a third factor in the selection of the Spatial System comes from research intentions. For example, if visibility is being considered, then the furniture and interior glass partitions in the plan are ignored for modelling because humans can see over low furniture and see-through glass. On the other hand, when dealing with accessibility, then both furniture and glass walls are drawn because they impede where humans can walk to in the plan (see Figure 9).

Figure 9

Example of Accessibility and Visibility



Note: Accessibility (left) and Visibility (right) models created by selecting appropriate spatial system. Source Author

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3. Concept of Distance Between Unit Spaces, or Connection Types

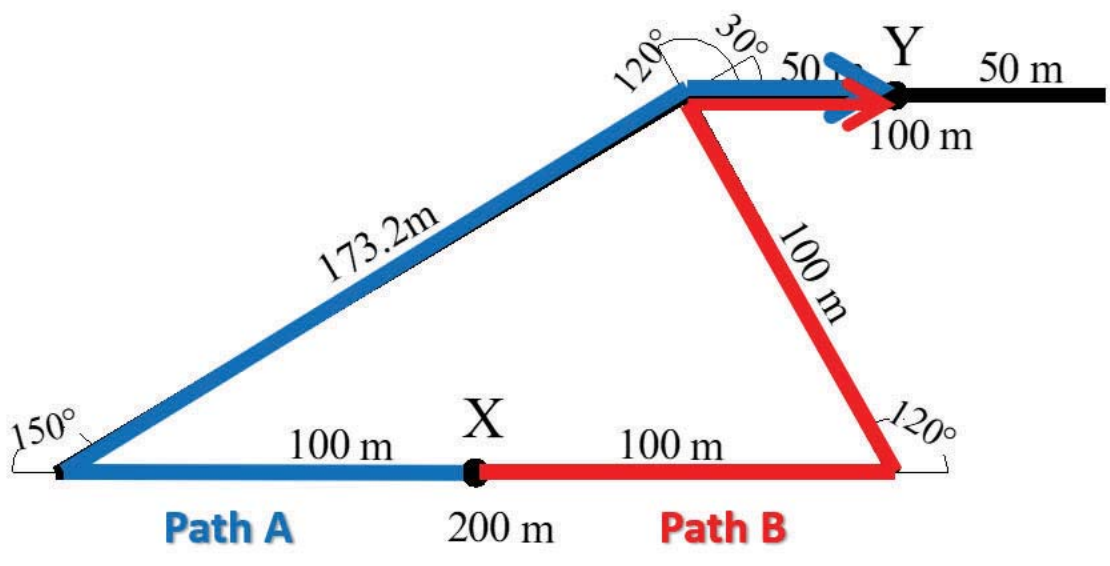
It has been stated many times that relationships between spaces are the basis of Space Syntax analysis. However, the kinds of relationships were not defined. This definition, and further clarification are the third important decision that must be taken at the beginning of any study that uses Space Syntax. Essentially, with the development of software, Space Syntax can now consider three kinds of relationships --topological, metric, and geometric.

The genesis of Space Syntax emphasized topological relationships. Its roots coincide with Syntax's early description of human movement behavior, as described earlier. Topological relationships simply note if a pair of spaces are connected to one another, or not. Taking this simple relationship between spaces, Space Syntax has flourished for more than three decades. At present, two other kinds of relationships can be computed – metric and geometric.

Metric relationship considers the distance between two pairs of spaces in the calculation of closeness or betweenness, and geometric relationship looks at the angles between them. These concepts can be understood with the help of the diagram in Figure 10, which represents a set of axial lines. The centers of two lines are marked as X and Y. Considering metric distance, Path B is shorter than Path A. However, in terms of angles, Path A is shorter. From a topological point of view both paths are the same as they require only two turns. These factors can also be modelled for entire layouts in newer versions of Space Syntax analysis (see Figure 11).

Figure 10

Three Concepts of Distance Between Spaces



Note: Three concepts of distance between spaces: Topological, Metric, and Geometric. Source: Berhie (2016)

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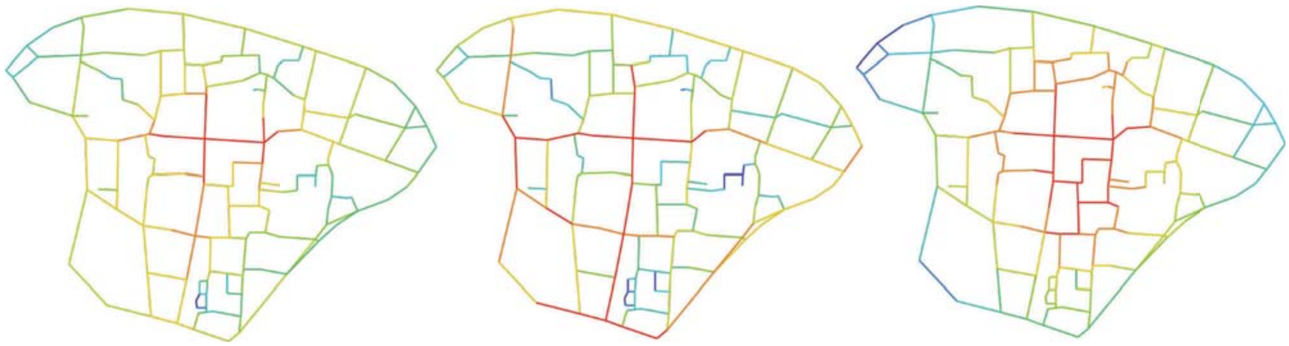
Figure 11

Topological, Angular and Metric Closeness



Note: Topological, Angular and Metric Closeness analysis of a small town using segmented lines as unit spaces. Source: Author

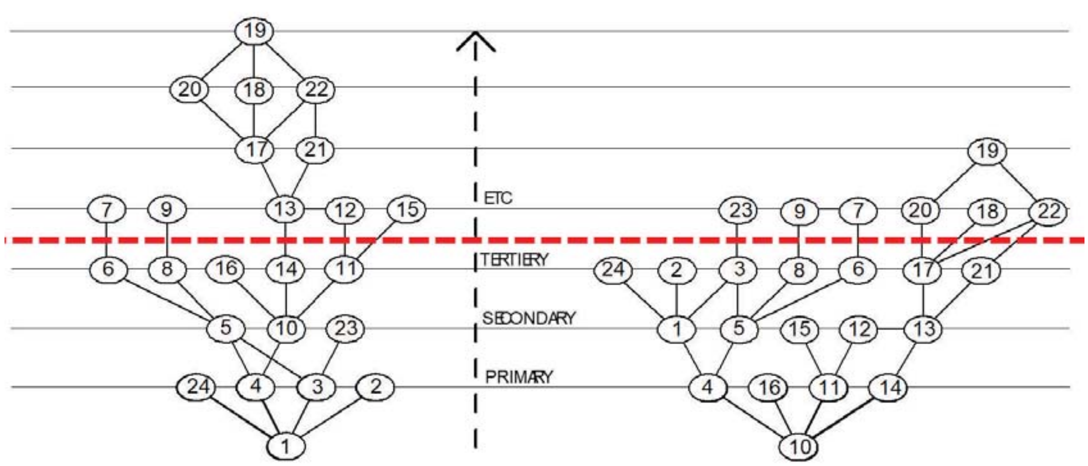
Decisions regarding the distance types between spaces, or connection types are important and must be clearly related to the research question.

4. Radius of Analysis

As explained previously, Space Syntax considers connections from all spaces to all other spaces in the selected spatial layout shown as a plan. However, analysis could be theoretically stopped at any topological, angular, or metric distance to compute another version of the desired variable (Closeness or Betweenness). This difference can be understood by comparing Figure 3 with Figure 12. In the latter, a line could be drawn at any distance from the origin. In this scenario, the topological distance was selected at '3' (see red line in Figure 12) then calculated values would be Closeness-3 or Betweenness-3, and different from the regular Closeness or Betweenness values (referred to Closeness-n or Betweenness-n.; see Figure 13). This 'radius of analysis' could be set anywhere the researcher decides. In many cases, a shorter 'radius of analysis' shows better relationships with human attributes (e.g., see Hillier (2005). It is important to clarify the 'radius of analysis' selected, and the reasons for such a choice need to be clearly explained in the beginning.

Figure 12

Radius of Analysis



Note: Radius of analysis is set at a topological distance of 3. Source: Author

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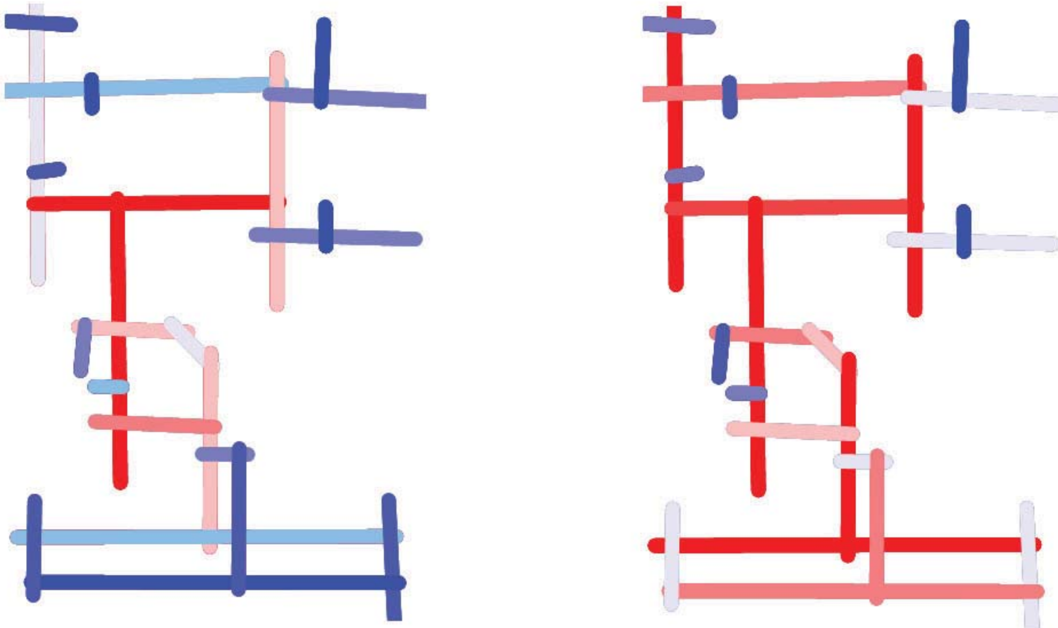
Figure 13

Example of Closeness



Note: Closeness-n (left) and Closeness-3 (right) values of the same layout. Source: Author

5. Variables

The final decision regarding Space Syntax analysis would be selection of variables that would be computed for the unit spaces (see Figure14). The variables 'Closeness' and Betweenness' have been explained before[3]. Researchers need to be very sure about their choice of both the variables and their justifications before any analysis and empirical data collection begin.

Figure 14

Example of Metric Betweenness and Closeness

Note: Metric Betweenness-n (left) and Metric Closeness-n (right) modelled using segmented lines. Source: Author

[3]There are other variables, but these two are mostly used.

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Conclusion

This paper began with some fundamental assumptions regarding Space Syntax, its relationships to human attributes, and its analytical techniques. These have developed and expanded over the years and Space Syntax analysis now can be undertaken in many different ways (see Table 1). In this regard, this paper has identified five very important categories about which the researcher needs to make thoughtful decisions, both in terms of the research questions being formulated, as well as the analyses that are conducted. It is vital to understand that the decisions regarding any one of these categories will produce changes in the computed values of each unit space and will have a profound effect on the results. These decisions are extremely important and must be clearly explained and related to the hypothesis of any research endeavor.

Table 1
Five Areas of Decision Making in Space Syntax Analysis

	DECISION AREAS	**CHOICES AVAILABLE**
	Unit Spaces	Axial Lines [All lines, Reduced Lines, Drawn Lines, Segmented Lines]
		Rooms
		Units of a grid
	Spatial System	Boundary
		What to include inside boundary
		Visibility and Accessibility require identification of different spatial systems.
	Concept of Distance between unit spaces, or connection types	Topological
		Geometric/ Angular
		Metric
	Radius of Analysis	Any topological steps (if topological)
		Any angle (if geometric)
		Any distance (if metric)
	Space Syntax Variables	Closeness (integration)
		Betweenness (Choice)

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