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The network of patterns: creating a design guide using Christopher Alexander's pattern language

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Abstract. This research seeks a comprehensive process for developing a design guide utilizing pattern language and social network analysis. Pattern language is a structured mechanism for describing good design practices, the patterns. Network analysis helps analyze quantitatively the relationships between the patterns and identify the relative importance of each pattern. The result is also visually delineated as a web of networks to illustrate how these patterns are clustered and connected. In this study, downtown design, which planners and designers are familiar with, is used as an example to explain the process of developing a comprehensive design guide. The results reveal that pedestrian streets and building complexes function as key patterns among the downtown-related patterns. Using the techniques and methods from this study, we can clearly see the entire web of patterns with connective maps, which was never-before visualized. The process can also provide information about key patterns that can serve as backbones for prospective projects. Planners and designers, understanding the network of patterns, can prioritize and categorize tasks and projects of their own.

Keywords: pattern language, network analysis, design guide, downtown, interface

Introduction

In the 1970s modernism was criticized for destroying the local context of neighborhoods and ruling people's everyday lives with a monolithic vision of globalism. In response, there have been several attempts to lead the environment back to the premodern traditional environment (Bhatt, 2010; Salingaros, 2005). As a part of this movement, *A Pattern Language* by Alexander et al (1977) had focused on unconscious, intuitive, and user-friendly design processes to create 'good' places. For its practicality, pattern language has been broadly adopted by planners, constructors, and others. *A Pattern Language* introduces 253 empirical design rules and solutions, called 'patterns', to suggest guidelines for creating places. Within these 253 patterns, a single pattern may be chosen for the simple implementation of a project. A group of patterns may be considered for a more comprehensive development. The essential inspiration of the book, however, is the connective structure of those patterns; in other words, the combined use of related patterns (Salingaros, 2005). The authors of *A Pattern Language* have pointed out the importance of understanding the links and relationships within the network of patterns. Originally, they suggested a single set of related patterns for each pattern. The linked patterns reinforce the functions of one another; the patterns can be either essential foundations for the completeness of a particular design, or supplements to those core patterns, or both. This connective structure helps to create a coherent and comprehensive set of design patterns for developing places rather than a design solution that independently functions for limited purposes (Duarte and Beirão, 2011). In addition, implementing related patterns together or in sequence creates synergy. It is assumed that the implemented pattern possesses sequential influence, which makes implementing the related patterns more efficient and accommodating.

No previous literature had looked at the pattern language as a web of relationships constructed from several patterns visually and statistically. In this paper I not only present this interweaving relationship visually, but also construct a process for examining these relationships quantitatively in a network, which covers a complete set of patterns for a target project. To demonstrate the process of how to build the network and analyze the relationships for a specific project, I focus on patterns related to a downtown design. Downtown is used as an illustrative example to provide a common ground for readers to relate their knowledge and understanding to the findings of this study; planners and designers have persistently studied the physical aspects of downtowns and sought ways to design better downtowns (Filion et al, 2004; Loukaitou-Sideris and Banerjee, 1998; Robertson, 1990;1999; 2001). With the patterns related to downtown, I demonstrate and suggest a process to create a design guide using the pattern language, and explore the systematic usage of patterns by employing network analysis. In due process, I visually and analytically examine the connectivity among the patterns to understand how those patterns are linked and influence one another, what patterns engage most actively in relationships, and how certain patterns control the conditions of the network using network analysis. Users may adopt the process in this study for other types of design projects by following the steps suggested hereafter.

A Pattern Language

Structure of pattern language

Pattern language is one of the popular design methods in urban design and architecture. It describes empirical design practices to meet the goals of projects and allows designers to create a logical design process following the path suggested in the book. The book, compared with other academic textbooks or technical manuals for professionals, is more like an encyclopedia for people who are willing to design their own houses, streets, and communities like experienced architects and planners do (Sime, 1986). Users can quickly look up a pattern of interest to construct a systematic design, and/or to find a solution for an existing problem (Lea, 1994).

A Pattern Language consists of 253 chapters and each chapter explains one pattern. For users' convenience, every pattern is explained in a fixed format; each chapter addresses, in sequence, pattern context, examples, design elements and disciplines, problems, and solutions for issues that may occur during the design process (Salingaros, 2005). For example, chapter 100, Pedestrian Street, starts with problems of missing social intercourse due to cars and corridors taking over the majority of the movement process. "Most of the moving about which people do is indoors—hence lost to the street; the street becomes abandoned and dangerous" (Alexander et al, 1977, page 489). Then the authors encourage people to consider several principles to create a properly functioning pedestrian street: "no cars; but frequent crossings by streets with traffic … buildings … planned in a way which as nearly as possible eliminates indoor staircases, corridors, and lobbies, and leaves most circulation outdoors" (page 490). It also suggests 'desirable' physical aspects of the pedestrian streets: "the width of the street does not exceed the height of the surrounding buildings" (page 490). These guidelines and solutions are also supplemented with a diagram like the example in figure 1.

Connective rule

Each chapter enumerates other patterns that are linked to a source pattern in the prelude and postscript of each chapter, with larger patterns in the prelude and smaller patterns in the postscript. All linked patterns are pulled from 253-pattern pool. These patterns tell which patterns would be required and which apply next in the sequence. Suggested larger patterns are the groundwork of the source pattern, which often takes several years to complete. Smaller patterns, on the other hand, address tasks and elements that assist in the completeness

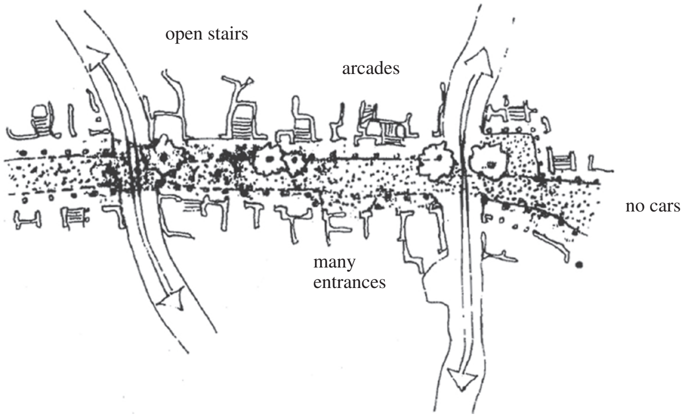


Figure 1. A diagram to build better Pedestrian Street from Alexander et al (1977).

of the source pattern. Smaller patterns are relatively easier to achieve than larger ones, and are likely to be under the control of individuals or small groups. Table 1 shows the linked patterns of Pedestrian Street, for instance. Larger patterns, usually large-scale physical conditions, are listed as preconditions to encourage proper functioning of the pedestrian street. From Promenade to Market of Many Shops, all call for dense pedestrian streets. The remainder of the larger patterns are related to network and circulation in the town as we build the street. Smaller patterns, usually small-scale physical conditions and programs, add to Pedestrian Street so that it can prosper. To fill the street with pedestrians, smaller patterns suggest "making frequent entrances and open stairs along the street, instead of building indoor corridors, to bring the people out; and give theses entrances a family resemblance so one sees them as a system … and shape the street to make a space of it" (page 491). This connective structure of pattern language, allowing combinations of patterns, guides users to form an intricately connected network; even though users start with a handful of patterns, they can create a pretty long list of patterns thanks to connected patterns.

Since the connective rule is created from problem-solving experiences, it does not have a mathematical algorithm. While loosely described, the connections are worthy of consideration since the order of collectively assembled design elements enable the creation of special relationships between them (Hillier and Hanson, 1984). Even though Alexander and his coauthors did not mention it explicitly in the book, they might assume that separately scattered objects could not integrate functions and are not enough to evoke the social ordering of people in a place. Thus, a set of hierarchically organized patterns guided by the connective rule helps to prevent fragmented implementation of single patterns that may result in the

Table 1. Larger and smaller patterns of Pedestrian Street.

Larger patterns (10)	Smaller patterns (10)
Promenade	Pedestrian Density
Shopping Street	Family of Entrances
Network of Paths and Cars	Open Stairs
Row Houses	Private Terrace on the Street
Housing Hill	Street Windows
University as a Marketplace	Opening to the Street
Market of Many Shops	Gallery Surround
Building Complex	Six-foot Balcony
Circulation Realms	Arcade
Raised Walks	Path Shape

inefficient use of resources and incoherent development of places (Alexander et al, 1977; Salingaros, 2005) This is why the book was titled *A Pattern Language*, not *Patterns*; “words without connection rules cannot make up a language” (Salingaros, 2000a, page 157).

Social network analysis

Any relationships between elements could be mapped as a graph consisting of nodes and ties (Batty, 2004a). A collection of connected design patterns could be also drawn as a network map. Usually, the network of spatial elements can be visualized and examined by several methods. For instance, space syntax is a useful tool to represent relative connectivity and the integration of spatial components (Batty, 2004b). However, this study employs social network analysis (SNA) since the network of patterns does not deal with actual urban morphology but with the topological relations of patterns (Batty, 2004a). SNA is a helpful tool to identify the structure of connections and visualize the relations of entities joined by multiple relationships; in general, people, groups, or organizations are treated as nodes and the relations between them are termed ties, consisting of interactions, connections, and flows between nodes (Corten, 2010; Miura, 2011; Pinheiro, 2011; Tichy et al, 1979). In this study, patterns are considered as nodes and their connections are regarded as ties.

A primary use of SNA is to identify the prominence of individual actors (nodes); in other words, finding important actors (Miura, 2011). Centrality scores are one of the useful measures for determining the relative significance of each pattern. The relative importance of actors in the network is determined partly by a higher number of connections to other patterns. There are three types of centrality scores (see appendix A) to show the centralization tendency of linked patterns: degree centrality, closeness centrality, and betweenness centrality. Degree centrality, the simplest way to measure centrality, refers to which nodes have higher numbers of direct connections (Freeman, 1977). Degree centrality illustrates nondirectional and binary relations in a network. A node with high degree centrality, which means it has a high number of direct relations with other nodes, tends to influence actively other nodes in the given network (Kim et al, 2011). In figure 2 node A holds the highest number of direct connections and thus has the highest degree centrality score and functions as a hub in this network. Closeness can be regarded as a measure of how long it will take to spread information sequentially from the starting point to all other nodes (Newman, 2005). Closeness centrality is the inverse of the sum of the distance of one node to all other nodes. Thus, when a node becomes more central, its total distance to all other nodes becomes less (Freeman, 1977). For instance, a node with the highest closeness has the shortest paths to others, which allows quicker access to other nodes. Nodes B have the shortest paths to all the connected nodes, which means they have the highest closeness centrality.

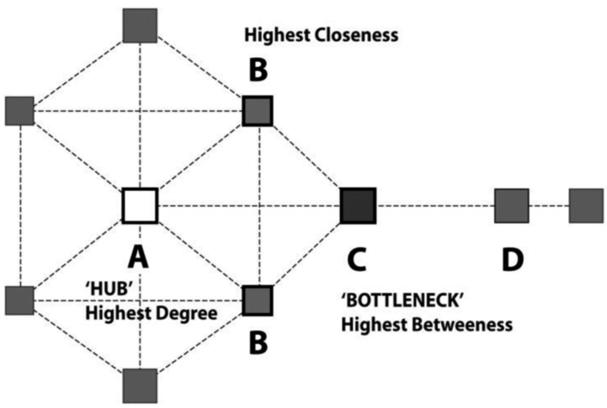


Figure 2. An example of centrality measures in a network (redrawn from the source: Krebs, 2011).

Betweenness centrality assigns a high centrality score to a node that holds large numbers of the shortest paths that link it to other nodes. This score represents the importance of the node in the network. If a node with a high betweenness is removed, the network can be divided and may lose its systematic function. It plays a broker role, one that acts as an intermediary, in the network. Node C is located at a critical point in the network which can split the network in half, isolating node D from A and B. This connecting role gives node C the highest score for betweenness centrality.

Method

Research process

The study employs downtown as a descriptive case to demonstrate the process of creating a list of design patterns using SNA. The study follows similar steps to those provided by Alexander et al (1977) (see figure 3): (i) collect source patterns that seem necessary; (ii) add linked patterns, which are suggested in the book; (iii) drop patterns that seem less important or doubtful; and (iv) include more patterns if necessary. This research follows a similar approach to that suggested in *A Pattern Language*, but makes some adjustment for analysis. First, to collect the source pattern, previous literature on successful downtown vitalization and place making strategies is reviewed.[1] Second, all linked patterns are collected with no distinction between the level of the patterns, larger or smaller.[2] Third, to drop unnecessary patterns (or to select relatively important patterns), SNA is performed and primary and key patterns are revealed based on centrality scores. In addition, a web of patterns presents visually.

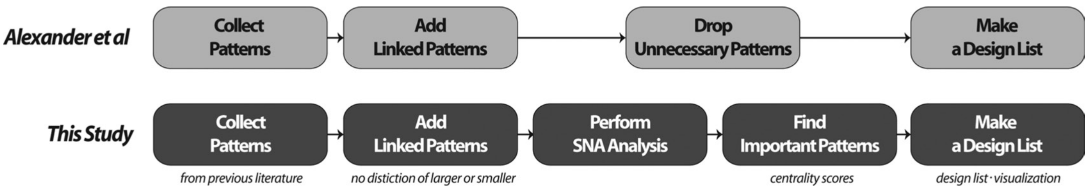


Figure 3. Research processes compared with the work of Alexander et al (1977).

Two sets of network analyses are conducted. In the first, every pattern related to the downtown design is included in order to examine the relationships between all the patterns with regard to frequency and degree, closeness, and betweenness centrality. In the second analysis, the patterns are assigned to four different groups considering spatial levels in the downtown area: urban structure, street, interface, and buildings (see figure 4). The categorization is based on the characteristics of the space, its level of public use, and its spatial configuration. Urban structures and streets are mainly developed and managed by public institutions. Buildings, on the other hand, are often properties of private parties. In between

[1] Choosing source patterns: (1) The data collection starts with observing previous literature (Banerjee, 2001; Burayidi, 2001; Carr and Servon, 2008; Faulk, 2006; Filion et al, 2004; Gruen, 1973; Jones Jr and Foust, 2008; Lennard and Lennard, 1995; Loukaitou-Sideris and Banerjee, 1998; Montgomery, 1998; Paumier et al, 1988; Robertson, 1990; 1999). Table B1 in apendix B shows the global design strategies for creating a successful downtown. (2) After choosing design goals and strategies from previous literature, corresponding patterns were selected from *A Pattern Language*. Some of the design patterns were specifically mentioned in previous literature (eg, Individually Owned Shops, Pedestrian Street, University as Marketplace) and others were added when they seem related to strategies for success (eg, Food Stands, Street Café, Gallery Surrounded). Through this process, fifty-six patterns were chosen, see table B2.

[2] Alexander et al (1977) suggested that patterns larger than the proposed project are better off not being included. In most cases, individuals do not have enough resources to implement patterns larger than the project. However, this study includes larger patterns as well as smaller patterns at the same level, as both public and private agents for downtown development might find them useful.

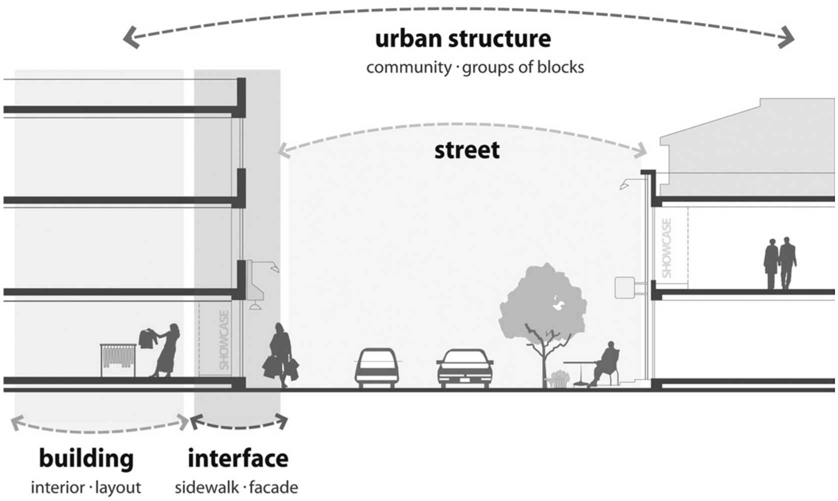


Figure 4. Spatial reclassification of a downtown area.

these two entities lies an interface; the space between building and street is specifically called an interface in this study. The second analysis explores how patterns are interacting within each level of space.

Data processing

Connections between source patterns and linked patterns are stored as an edge list with the numbers given in *A Pattern Language* (see figure 5). To perform the SNA, a pair of patterns that connect to each other in both directions, a parallel edge, is coded as having one connection. For example, Shopping Street (32) and Pedestrian Street (100) are connected both ways, but coded as one link; Pedestrian Street is a smaller pattern of Shopping Street and Shopping Street is a larger pattern of Pedestrian Street.

Original Edge List → **Final Edge List (No Parallel Edges)**

source pattern	linked pattern	
…	…	
32	97	
32	**100**	
…	…	
100	31	
100	**32**	**Delete**
100	38	
…	…	

source pattern	linked pattern
…	…
32	97
32	**100**
…	…
100	31
100	38
…	…
…	…

Figure 5. Example of an edge list of the study. See appendix B for names of pattern numbers.

For the first analysis, fifty-six source patterns were chosen on the basis of previous literature and four hundred and ninety-three pairs remained after removing eighty-nine parallel edges. For the second analysis, fifty-six source patterns were classified into four groups: eighteen patterns for urban structure; twelve for street; fourteen for interface; and twelve for building.(3) After dividing the source patterns for each space, the steps suggested above are repeated to collect linked patterns for each group. Stata 12.0 was used for SNA, which computes SNA with recently introduced computing commands that provide scores

(3) For the second analysis, source patterns are reclassified by spatial levels (see table B3).

of degree, closeness, and betweenness centrality (Corten, 2010; Miura, 2011). For the visualization of the network of patterns, Netdraw 2.089 was used.(4)

Results

Table 2 and table 3 compare and summarize the scores of frequency,(5) degree, closeness, and betweenness centrality in the top-tier. There is no actual natural break point to determine the best arrangement of values into different classes. Thus, patterns ranked in the top thirty are listed for the whole downtown pattern in table 3. For spatially reclassified spaces, patterns in the top-five are listed in table 4. The full list of results is given in appendix C.

Whole downtown

The most frequently linked patterns were *Pedestrian Street* and *Building Complex* with thirteen links, followed by *Arcades* and *Path Shape* with twelve when analyzed with all the patterns in a single network. The pattern with the highest degree and closeness score was *Pedestrian Street* and the pattern with the highest betweenness score was *Building Complex*.

Spatial reclassification

At the urban structure level, *Promenade* was linked most frequently, while *Activity Nodes* had the highest degree, closeness, and betweenness. At street level, *Activity Pockets* appeared the most. *Pedestrian Street* showed the highest degree and betweenness centrality score, and *Path Shape* had the highest closeness score. At the interface level, *Outdoor Room* was the most observed pattern and *Sitting Wall* indicated the highest degree score. The pattern with the highest closeness score was *Building Fronts* and the highest betweenness centrality score was *Arcades*. At building level, *Building Complex* was linked the most and also had the highest centrality scores.

Findings

Key patterns and primary contributors

Frequency partially explains how important a pattern is. However, frequency scores do not always concur with centralization tendency scores. Stair Seats for example, ranked 5th in frequency, 14th in degree, 28th in closeness, and 22nd in betweenness centrality scores. This indicates that simple counting fails to provide sufficient information regarding the sequential influence of patterns and their roles in a given web.

The outcomes from network analyses, centrality scores, reveal the differentiated and weighted importance of patterns in the network. This study suggests that key patterns and primary contributors are defined by these centrality scores. Patterns with the highest centrality scores are termed key patterns. The top-ten patterns (except key patterns) in the whole network, the first analysis, and the top five excluded key patterns in the reclassified groups, the second analysis, are termed primary contributors (see table 4). In the first analysis, the key patterns were Pedestrian Street and Building Complex. Pedestrian Street had the highest degree score and closeness score at the same time. This indicated that Pedestrian Street was the most active node serving as a hub for the whole network. In addition, the highest closeness score suggested that the pattern held the role of a deliverer of influence, spreading connections to other nodes more quickly. On the other hand, Building Complex

(4) Stata also has a network visualization command, netplot. Stata creates a square-shaped graph, while Netdraw creates a rectangular-shaped one. For better presentation (to fit a size of paper), the graph created by Netdraw software is used.

(5) Frequency is the total number of times one pattern showed up in the final edge list. For example, Magic of the City (10) has linked patterns City Country Fingers (3), Mosaic of Subcultures (8), Local Transportation Areas (11), Web of Public Transportation (16), Promenade (31), Night Life (33), Carnival (58), and Dancing in the Street (63). In this set, each pattern is counted as one.

Table 2. Patterns with high frequency and centrality scores: whole downtown.

Frequency		Centrality					
pattern	frequency	degree		closeness		betweenness	
		pattern	score	pattern	score	pattern	score
Pedestrian Street	13	Pedestrian Street	0.1824	Pedestrian Street	0.4933	Building Complex	0.1245
Building Complex	13	Activity Nodes	0.1622	Building Complex	0.4654	Activity Nodes	0.1137
Arcades	12	Building Complex	0.1554	Path Shape	0.4554	Pedestrian Street	0.1045
Path Shape	12	Arcades	0.1486	Path and Goals	0.4498	Arcades	0.0952
Canvas Roof	10	Public Outdoor Room	0.1351	Activity Nodes	0.4405	Sitting Wall	0.0595
Activity Pockets	10	Sitting Wall	0.1351	Street Café	0.4353	Canvas Roof	0.0589
Stair Seats	10	Canvas Roof	0.1351	Circulation Realms	0.4327	Path and Goals	0.0582
Promenade	9	Positive Outdoor Space	0.1284	Arcades	0.4327	Building Thoroughfare	0.0555
Identifiable Neighborhood	9	Path Shape	0.1284	Activity Pockets	0.4327	Shielded Parking	0.0550
Outdoor Room	9	Activity Pockets	0.1284	Small Public Square	0.4315	Public Outdoor Room	0.0517
Small Public Square	9	Small Public Square	0.1216	Shielded Parking	0.4315	Building Edge	0.0501
Raised Walk	8	Path and Goals	0.1216	Promenade	0.4290	Local Transportation Areas	0.0492
Green Streets	8	Promenade	0.1149	Canvas Roof	0.4265	Opening to the Street	0.0453
Gallery Surround	8	Shielded Parking	0.1081	Public Outdoor Room	0.4253	University as a Marketplace	0.0453
Opening to the Street	7	Building Thoroughfare	0.1081	Building Fronts	0.4241	Street Windows	0.0428
Pedestrian Density	7	Stair Seats	0.1081	Shopping Street	0.4217	Four-story Limits	0.0426
Street Windows	7	Building Edge	0.1081	Sitting Wall	0.4205	Something Roughly in the Middle	0.0419
Main Entrance	7	Opening to the Street	0.1081	Pedestrian Density	0.4169		
Network of Paths and Cars	7	Local Transportation Areas	0.1014	Network of Paths and Cars	0.4146	Street Café	0.0417
Positive Outdoor Space	7	Circulation Realms	0.1014	Building Thoroughfare	0.4134	Promenade	0.0382
Family of Entrances	7	Building Fronts	0.1014	Gallery Surround	0.4111	Positive Outdoor Space	0.0362
Individually Owned Shops	6	Shopping Street	0.0946	Opening to the Street	0.4100	Beer Hall	0.0348
Path and Goals	6	Street Café	0.0946	Individually Owned Shops	0.4088	Stair Seats	0.0336
Street Café	6	Small Parking Lots	0.0946	Small Parking Lots	0.4088	Circulation Realms	0.0333
Circulation Realms	6	Pedestrian Density	0.0946	Degrees of Publicness	0.4077	Small Public Square	0.0333

Table 2 (continued).

Frequency		Centrality					
pattern	frequency	degree		closeness		betweenness	
		pattern	score	pattern	score	pattern	score
Building Edge	6	Something Roughly in the Middle	0.0946	Individually Owned Shops	0.0811	Individually Owned Shops	0.0331
Dancing in the Street	6			Number of Stories	0.0811	Small Parking Lots	0.330
Wings of Light	6	Gallery Surround	0.0946	Raised Walk	0.4055	Activity Pockets	0.0312
Sitting Wall	6	Street Windows	0.0878	Carnival	0.4033	Path Shape	0.0300
Food Stand	6	Parallel Roads	0.0811	Stair Seats	0.4022	Family of Entrances	0.0281
Seat Spots	6	Degrees of Publicness	0.0811	Street Windows	0.4011	Number of Stories	0.0268
Private Terrace on the Street	6	Network of Paths and Cars	0.0811	Dancing in the Street	0.3957		

Table 3. Patterns with high frequency and centrality scores: reclassified space.

Frequency		Centrality					
pattern	frequency	degree		closeness		betweenness	
		pattern	score	pattern	score	pattern	score
Urban structure							
Promenade	7	Activity Nodes	0.2892	Activity Nodes	0.4882	Activity Nodes	0.3236
Local Transportation Areas	6	Public Outdoor Room	0.1928	Promenade	0.4611	Public Outdoor Room	0.2205
Identifiable Neighborhood	6	Local Transportation Areas	0.1807	Network of Paths and Cars	0.4323	Promenade	0.1634
Pedestrian Street	6	Promenade	0.1807	Identifiable Neighborhood	0.4278	Small Public Squares	0.1610
Mosaic of Subcultures	5	Small Public Squares	0.1446	Pedestrian Street	0.4235	Local Transportation Areas	0.1592
Green Streets	5						
Network of Paths and Cars	5						
Street							
Activity Pockets	6	Pedestrian Street	0.2687	Path Shape	0.4786	Pedestrian Street	0.2970
Raised Walk	5	Something Roughly in the Middle	0.1940	Pedestrian Street	0.4718	Shopping Street	0.2798
Food Stand	5			Shopping Street	0.4408	Path Shape	0.2569
Path Shape	5	Path and Goals	0.1940	Activity Pockets	0.4136	Path and Goals	0.2097
Canvas Roof	5	Path Shape	0.1791	Something Roughly in the Middle	0.4085	Something Roughly in the Middle	0.1909
		Building Thoroughfare	0.1791				
		Building Thoroughfare	0.1791				
Interface							
Outdoor Room	7	Sitting Wall	0.2338	Building Fronts	0.4904	Arcades	0.2166
Gallery Surround	5	Positive Outdoor Space	0.2078	Building Edge	0.4667	Positive Outdoor Space	0.1959
Arcades	5	Arcades	0.1948	Sitting Wall	0.4611	Sitting Wall	0.1757
Positive Outdoor Space	4	Building Edge	0.1818	Positive Outdoor Space	0.4556	Stair Seats	0.1747
Stair Seats	4	Building Fronts	0.1558	Street Café	0.4451	Building Edge	0.1574
Private Terrace on the Street	4	Opening to the Street	0.1558				
Building Edge	4	Canvas Roof	0.1558				
Street Windows	4						
Sitting Wall	4						

Table 3 (continued).

Frequency		Centrality					
pattern	frequency	degree		closeness		betweenness	
		pattern	score	pattern	score	pattern	score
Building							
Building Complex	7	Building Complex	0.3036	Building Complex	0.5895	Building Complex	0.6006
Main Entrance	4	Number of Stories	0.2143	Number of Stories	0.4706	Circulation Realms	0.2219
Structure Follows Social Spaces	4	Shielded Parking	0.2143	Circulation Realms	0.4667	Four-story Limits	0.2149
		Circulation Realms	0.2143	Shielded Parking	0.4628	Shielded Parking	0.2147
Number of Stories	4	Four-story Limits	0.1607	Main Entrance	0.4375	Number of Stories	0.1946
Main Building	4	Corner Grocery	0.1607				

marked the highest betweenness score. This pattern may not be represented as the most important constituent for urban design, however, it has a critical role in connecting patterns that are remotely situated without other viable connections. This is why a node with a high betweenness score is often likened to a ‘bottleneck’ leading to major highways in a transportation network. If this node fails, a good part of the system becomes difficult to complete and the whole system could fail abruptly.

In the second analysis, rankings of the patterns differed between their reclassified spatial groups. In an urban structure category, Activity Nodes showed the highest scores overall, and thus is considered a key pattern. For the street level, Pedestrian Street and Path Shape were found to be key patterns of the network. For an interface design, Sitting Wall, Building Fronts, and Arcades were revealed as key patterns. For buildings, Building Complex had the most influential connections.

Table 4. Key patterns and primary contributors.

Key patterns	Primary contributors	
Whole downtown		
Pedestrian Street	Activity Nodes	Path Shape
Building Complex	Activity Pockets	Positive Outdoor Space Public
	Arcades	Public Outdoor Room
	Building Thoroughfare	Shielded Parking
	Circulation Realms	Sitting Wall
	Canvas Roof [a]	Small Public Square
	Path and Goals	Street Café
Spatial reclassification		
Urban structure		
Activity Nodes	Identifiable Neighborhood [a]	Promenade
	Local Transportation Areas	Public Outdoor Room
	Network of Paths and Cars	Small Public Squares
	Pedestrian Street [a]	
Street		
Pedestrian Street	Activity Pockets [a]	Shopping Street
Path Shape	Building Thoroughfare	Something Roughly in the Middle
	Path and Goals	
Interface		
Sitting Wall	Building Edge	Positive Outdoor Space
Building Fronts	Canvas Roof	Stair Seats
Arcades	Opening to the Street	Street Café
Building		
Building Complex	Circulation Realms	Main Entrance [a]
	Corner Grocery	Number of Stories
	Four-story Limits	Shielded Parking

[a] Indicates patterns were not chosen as source patterns, but appeared with a high centrality score.

Maps: networks of patterns

Mapping the actual relationships between patterns has been an interest of architects, planners, and urban designers as whole networks cannot be identified using textbook suggestions (Mehaffy, 2007; Salingaros, 2005). The network map in this study simply illustrates connections of patterns using a bubble diagram. The size and color of the bubble and the distance from the center explains the relative importance of the patterns. Patterns denoted by the highest degree, closeness, and betweenness centrality are likely to be located at the central parts of the web, where the majority of connections interweave. Figure 6 shows how

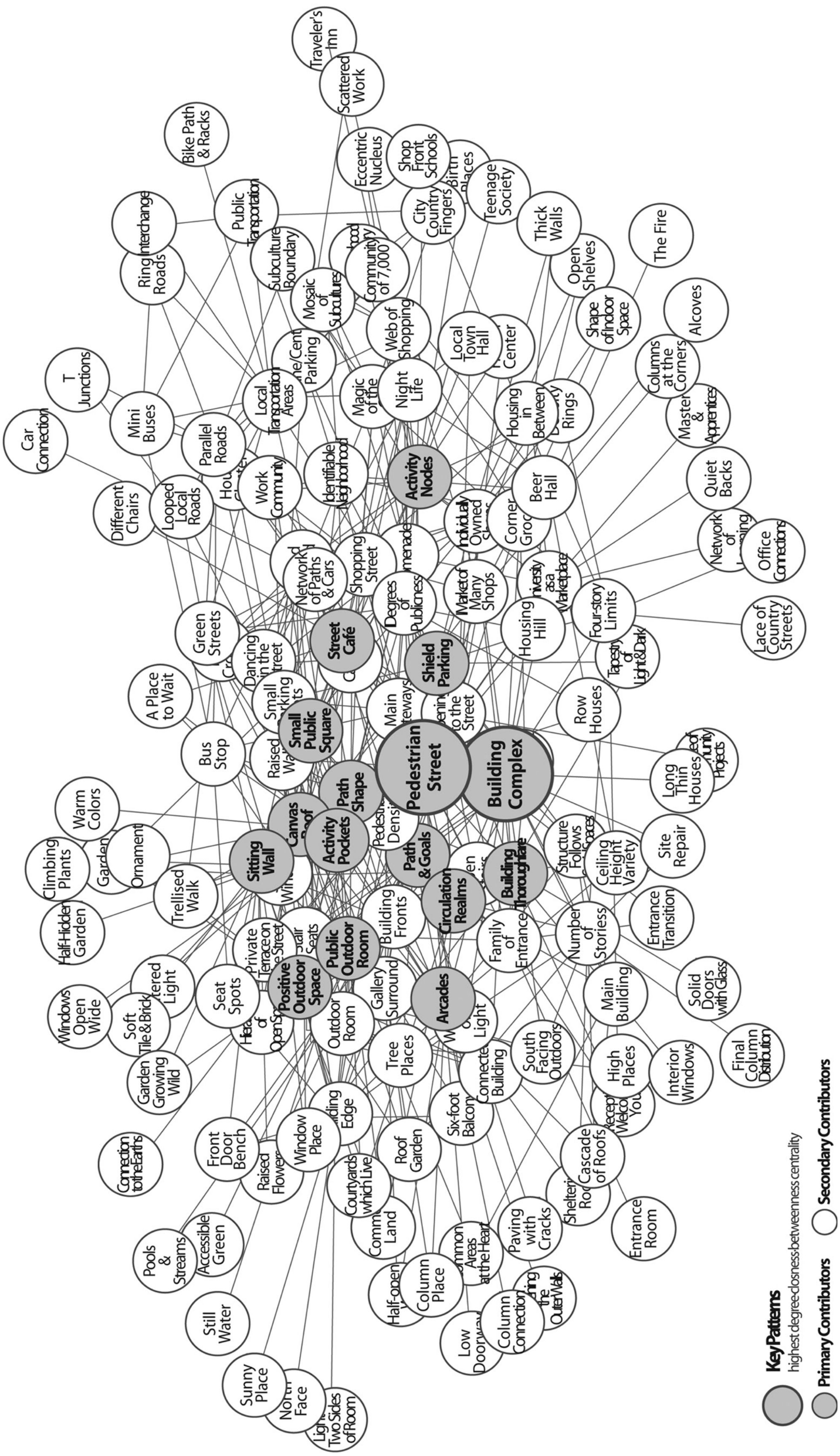
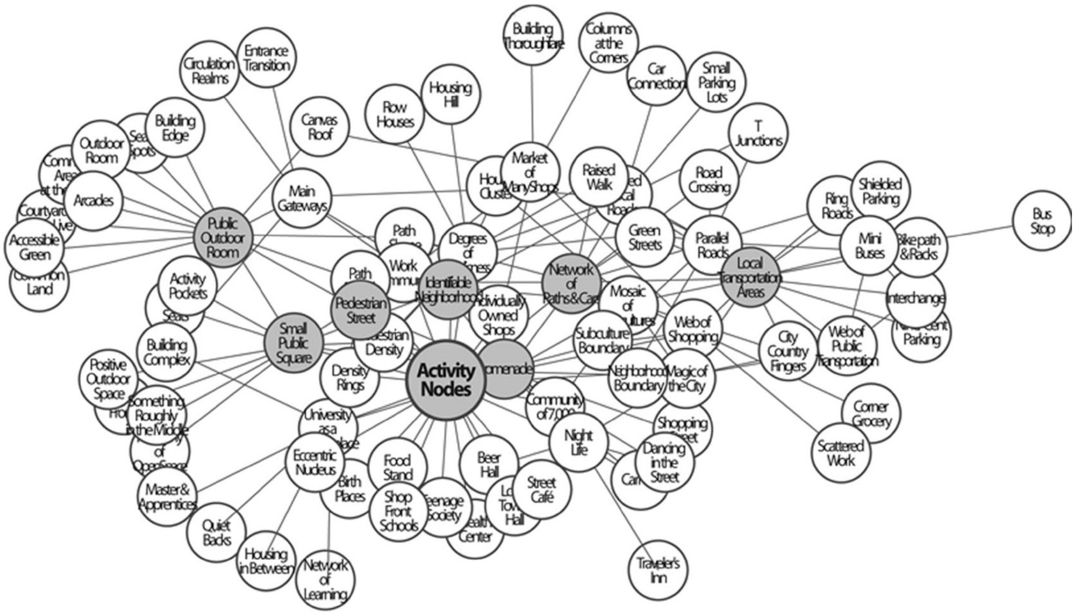
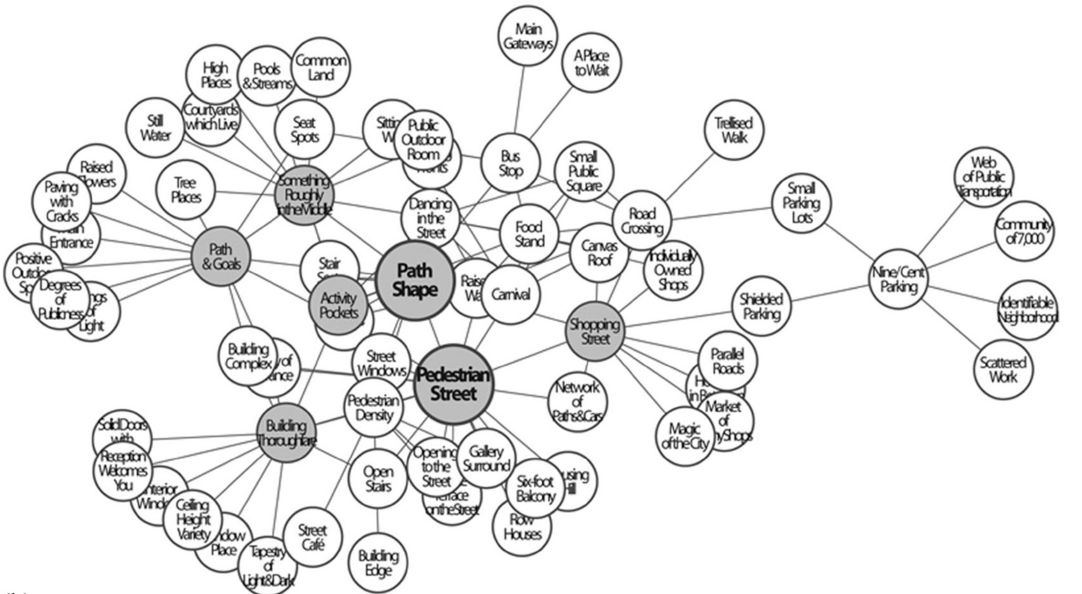


Figure 6. The network of patterns for a downtown design.

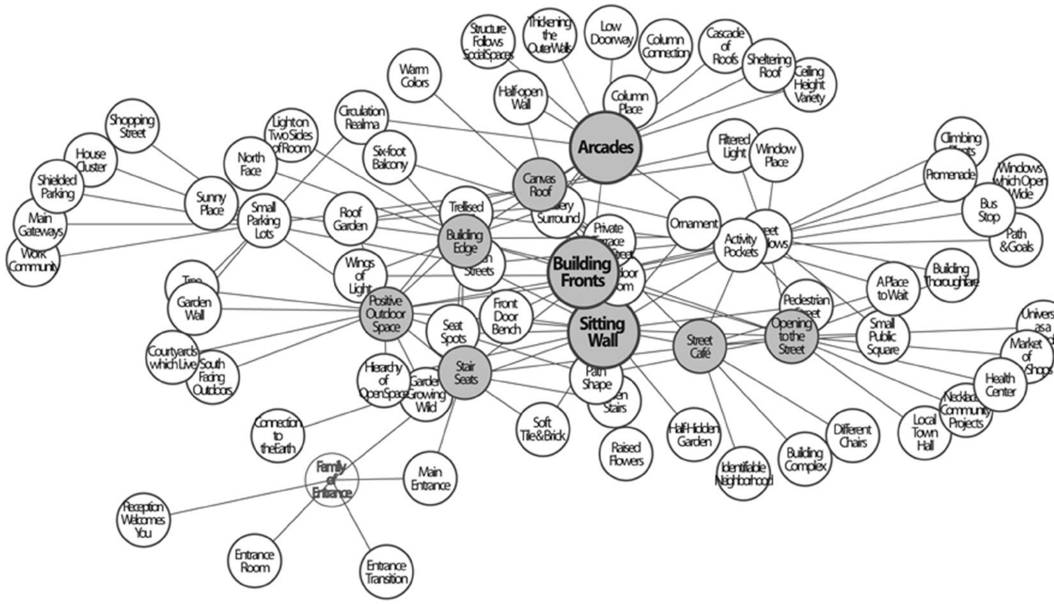


(a)

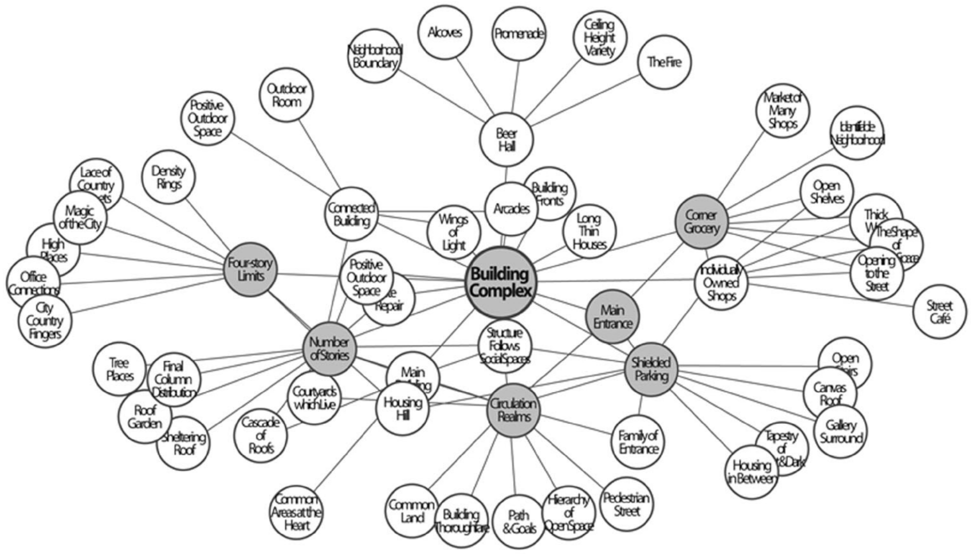


(b)

Figure 7. The network of patterns for reclassified space: (a) urban structure; (b) street; (c) interface; and (d) building.



(c)



(d)

Figure 7 (continued).

whole patterns are connected to one another visually. Figure 7 represents the connection of patterns at different spatial levels. This complicated network diagram shows the whole structure of the network in one figure for users to understand the general dynamics and the centralization tendency of patterns. Source patterns, generally ranked in the top tier of the list (table 4), are located at the central area of the network map, while nonsource patterns, mostly appearing at the bottom of the list, reside in peripheral parts of the map.

Connective rule for completeness

The result indicated that many key and primary patterns belong to the source patterns, which were retrieved from previous studies. Some nonsource patterns, however, were included. For example, Canvas Roof, not chosen as a source pattern, was included as a primary contributor. It reveals the capability of performing SNA to decrease the chance of missing some critical patterns due to lack of knowledge or simply by mistake when choosing design elements individually for a project. This may be more so when few patterns are chosen since they may identify more patterns that are unnoticed at the start. The study failed to find quite a number of nonsource patterns since it gathered all the possible design strategies from previous studies, which calls for a significant number of source patterns. The second analysis, which used a handful of source patterns, strengthens the argument above. In the analysis of urban structure patterns Identifiable Neighborhood and Pedestrian Street appeared as primary contributors in addition to the source patterns. Neither of them was included at the start; Identifiable Neighborhood is unnoticed from the start and Pedestrian Street is excluded from belonging to street design. In addition, for street design patterns Activity Pockets, elements of interface often formed around edges of buildings, is suggested as a primary component for street design. The results indicated that Activity Pockets could set the groundwork for, or facilitate the process of other patterns required for street design. As in the above examples, users may find critical but hidden design elements that do not seem directly related to the proposed project.

Importance of interface design in downtown

In general, to make a successful downtown, installing infrastructure is widely accepted as the starting point of downtown design, which is carried out by public institutions. More specifically, street condition improvement, perceived as a public duty, almost always leads to downtown design projects. However, the results of this study suggests otherwise. It draws more attention to 'interface' spaces. Among two key patterns and sixteen primary contributors for the whole downtown design, six of them belong to the interface design, Activity Pockets, Arcades, Canvas Roof, Sitting Wall, Street Café, and Positive Outdoor Space. Often, the interface is not a public space, but it serves for public use. This trait of being semipublic or semiprivate has misled planners into overlooking the importance of the 'interface' patterns. Even if they have recognized the importance, the issues of owners' preferences and property rights make it a sensitive matter. In addition, public sectors tend to limit their responsibility to urban structure and street design while private sectors focus more on buildings, which leaves the interface unmanaged. Despite the hardship in controlling and managing the interface space, it is recommended that planners and designers give more attention to interface designs. Interface space requires management by joint effort; they are mostly built by the private sector but used by the public. Public and private stakeholders should establish clear roles for interface projects. Public sectors may provide local design guidelines and offer incentives to encourage the private sector to build active interface spaces.

Implementing pattern language for future planning

A Pattern Language provides a relatively simple way of physically master-planning projects in a comprehensive manner; the book explains intuitive steps to create a list of design patterns for a project. The possibility of implementing plans using pattern language had initially been tested in Oregon by Alexander (1975) and his collaborators. In planning a campus town at the University of Oregon—called the Oregon Experiment—Alexander and others experimented with patterns from *A Pattern Language* and special patterns created for local conditions. Patterns from the book became the backbone for the project and additional patterns were applied to deal with specific problems at the local level.

In addition to the steps suggested in the book, the following process might be considered: (1) decide necessary patterns for the project; (2) add linked patterns; and (3) drop patterns that seem less important or doubtful. The process of this study leads to a strategic implementation of the patterns concerned with outcomes from the quantitative analysis: detailed information on the relative importance of the patterns and the sequential effect of patterns in a given network.

The process to create a list of design guidelines with pattern language:

Step 1. Collect patterns that are important for the project.

Step 2. Find all linked patterns illustrated in the book.

Step 3. Conduct SNA and establish connections between patterns. If necessary, conduct SNA in subsets of patterns.

Step 4. List key patterns and primary contributors.

Step 5. Examine the sequential influence of listed patterns and plan the implementing phases of each project.

Step 1: Though collecting patterns and their links seems straightforward, selecting source patterns may not be an easy task. Since source patterns determine the linked patterns, the size and direction of the network of patterns, and eventually the information that influences future implementation of patterns, we need to take a careful approach in selecting the source patterns (Hillier, 2007). The authors of *A Pattern Language* gave general recommendations: find source patterns that describe the project best and pick a few patterns among several candidates. The statement is helpful, but not clear enough to guide planners and architects. It is recommended that source patterns need to be chosen by planning experts based on a community consensus. If the community cannot afford to have experienced experts due to a lack of economic and social resources, they could refer to design strategies from publications such as planning research, planning and design guidelines, and books. The source patterns should be reviewed by planning staff considering the current conditions and future goals of the community (Alexander, 1975; Salingaros, 2000b). In addition, starting with a handful of patterns is recommended; Alexander (1975) used thirty-seven source patterns for the campus town planning in Oregon and Salingaros (2000b) recommended twelve of the most important patterns for beginning a project. Selecting a limited number of patterns, while considering local conditions, not only bring a more feasible list of design tasks as an outcome but also reduces the amount of time and effort to start their projects.

Step 2: Collect all the linked patterns from the book.

Steps 3 and 4: Unlike collecting patterns, dropping patterns is neither intuitive nor user-friendly. The authors do not provide details on how to decide which patterns are unimportant or doubtful. No specific direction or method for examining the importance of each pattern in a given condition is explained. Network analysis provides a rational and statistical basis for identifying the less significant patterns that can be dropped from the list. It also helps to prioritize patterns when planners and designers have to choose a limited number of design elements within their time and budget. In addition to selecting a limited number of patterns, users can also consider categorizing source patterns into smaller sets depending on their characteristics, spatial scales, and local conditions. Scrutinizing key patterns and primary contributors by category helps us to understand the relative importance of those groups in a given project. In this study, analyzing the subsets provided an unexpected finding: patterns related to interface design were found to be the most influential in completing a downtown design. From this information, users can pay more attention to the interface design when planning for a general downtown project.

Step 5: With the result of network analysis, users should study and cross-check between the current conditions of the target project and the suggested patterns. On the basis of the current status of high-priority patterns, the next phase of planning would be to decide by considering consecutive influence among them. For example, to redevelop pedestrian streets, the status of the streets should be diagnosed—some of them may be failing, while others may be stable and ready for the next phase. For the failing streets larger patterns linked to pedestrian streets such as Promenade, Shopping Street, or Market of Many Shops may be considered to make the street function properly. On the other hand, for the successfully installed pedestrian streets, smaller patterns such as Arcade, Path Shape, or Open Stairs may be phased in. With the information of the relative importance of the patterns, users can decide which ones to implement first.

Further discussion

This experience-based process of *A Pattern Language* provides us with opportunities to revise and supplement a plan during the process of planning and implementing. Nonetheless, using only suggested patterns cannot create the unique vibe of a place. Features and elements needed to create a comprehensive design guide would differ from town to town, considering the local conditions and demands. To solve the problem, Alexander encouraged users to add or change any patterns to personalize them. New patterns, so called special patterns, may be added to fit local conditions. For example, the Oregon Experiment applied special patterns such as Local Sports, Classroom Distribution, Department Hearth, Faculty Student Mix, and others for designing a university community. Besides the form and shape of places, patterns that deal with colors, sounds, or some social aspects of settings could also be included. For instance, considering colors in places gives more visibility to people and diversity to places and color-related elements could be another option for patterns (Salat, 2012). As part of the continuing effort to increase the down-to-earth use of pattern language, seeking ways of finding and developing special patterns would further the use of *A Pattern Language*.

For future research, conducting a case study comparing cities' existing comprehensive plans and design guidelines prepared using *A Pattern Language* would verify the extent of validity for pattern language. Furthermore, actual implementation of patterns and user's behavior should be examined in such a comparison. The pattern language suggests a generative and inductive method for collecting design elements, but is less likely to be used as an evaluative method, in the way that space syntax examines the relationships between the geographical and spatial form of place and the ways of encounters in a place.

References

Alexander C, 1975 *The Oregon Experiment* (Oxford University Press, New York)

Alexander C, Ishikawa S, Silverstein M, 1977 *A Pattern Language: Towns, Buildings, Construction* (Oxford University Press, New York)

Banerjee T, 2001, "The future of public space: beyond invented streets and reinvented places" *Journal of the American Planning Association* **67** 9–24

Batty M, 2004a, "Distance in space syntax", CASA WP 80, Centre for Advanced Spatial Analysis, University College London, London, http://discovery.ucl.ac.uk/206/1/paper80.pdf

Batty M, 2004b, "A new theory of space syntax", in CASA WP 75, Centre for Advanced Spatial Analysis, University College London, London, http://discovery.ucl.ac.uk/211/1/paper75.pdf

Bhatt R, 2010, "Christopher Alexander's pattern language: an alternative exploration of space-making practices" *The Journal of Architecture* **15** 711–729

Burayidi M A, 2001 *Downtowns: Revitalizing the Centers of Small Urban Communities* (Psychology Press, New York)

Carr J H, Servon L J, 2008, "Vernacular culture and urban economic development: thinking outside the (big) box" *Journal of the American Planning Association* **75** 28–40

Corten R, 2010, "Visualization of social networks in stata by multi-dimensional scaling", http://www.rensecorten.dds.nl/files/netplot_120410.pdf

Duarte J P, Beirão J, 2011, "Towards a methodology for flexible urban design: designing with urban patterns and shape grammars" *Environment and Planning B: Planning and Design* **38** 879–902

Faulk D, 2006, "The process and practice of downtown revitalization" *Review of Policy Research* **23** 625–645

Filion P, Hoernig H, Bunting T, Sands G, 2004, "The successful few: healthy downtowns of small metropolitan regions" *Journal of the American Planning Association* **70** 328–343

Freeman L C, 1977, "A set of measures of centrality based on betweenness" *Sociometry* **40**(1) 35–41

Freeman L C, 1979, "Centrality in social networks conceptual clarification" *Social networks* **1** 215–239

Gruen V, 1973 *Centers for the Urban Environment: Survival of the Cities* (Van Nostrand Reinhold, New York)

Hillier B, 2007, "Space is the machine: a configurational theory of architecture", http://www.ninsight.at/ak_stdb/SpaceIsTheMachine.pdf

Hillier B, Hanson J, 1984 *The Social Logic of Space* (Cambridge University Press, Cambridge)

Jones R G Jr, Foust C R, 2008, "Staging and enforcing consumerism in the city: the performance of othering on the 16th Street Mall" *Liminalities: A Journal of Performance Studies* **4** 4–1

Kim Y, Choi T Y, Yan T, Dooley K, 2011, "Structural investigation of supply networks: a social network analysis approach" *Journal of Operations Management* **29** 194–211

Krebs V, 2011, "Social network analysis, a brief introduction", http://www.orgnet.com/sna.html

Lea D, 1994, "Christopher Alexander: an introduction for object-oriented designers" *ACM SIGSOFT Software Engineering Notes* number 19, 39–46

Lennard S H C, Lennard H L, 1995 *Livable Cities Observed: A Source Book of Images and Ideas for City Officials, Community Leaders, Architects, Planners and All Other Committed to Making Their Cities Livable* (Gondolier Press, Carmel, CA)

Loukaitou-Sideris A, Banerjee T, 1998 *Urban Design Downtown: Poetics and Politics of Form* (University of California Press, Berkeley, CA)

Mehaffy M W, 2007, "Notes on the genesis of wholes: Christopher Alexander and his continuing influence" *Urban Design International* **12** 41–49

Miura H, 2011, "SGL: Stata graph library for network analysis", http://www.stata.com/meeting/chicago11/materials/chi11_miura.pdf

Montgomery J, 1998, "Making a city: urbanity, vitality and urban design" *Journal of Urban Design* **3** 93–116

Newman M E J, 2005, "A measure of betweenness centrality based on random walks" *Social Networks* **27** 39–54

Paumier C B, Ditch W S, Dimond C C, Rich D P, 1988 *Designing the Successful Downtown* (Urban Land Institute, Columbia, MD)

Pinheiro C A R, 2011 *Social Network Analysis in Telecommunications* (John Wiley, New York)

Robertson K A, 1990, "The status of the pedestrian mall in American downtowns" *Urban Affairs Review* **26** 250–273

Robertson K A, 1999, "Can small-city downtowns remain viable?" *Journal of the American Planning Association* **65** 270–283

Robertson K, 2001, "Downtown development principles for small cities", in *Downtowns: Revitalizing the Centers of Small Urban Communities* Ed. M A Burayidi (Psychology Press, New York) pp 9–22

Salat S, 2012, "The fractal pattern of cities" *Óbuda University e-Bulletin* **3** 263–273

Salingaros N A, 2000a, "The structure of pattern languages" *Architectural Research Quarterly* **4** 149–162
Salingaros N A, 2000b, "Pattern Language and Interactive Design" *Proceedings of the International Seminar: 'Design with the Community' University of Rome* **3** 15–21
Salingaros N A, 2005 *Principles of Urban Structure* (Techne Press, Amsterdam, Holland)
Sime J D, 1986, "Creating places or designing spaces?" *Journal of Environmental Psychology* **6** 49–63
Tichy N M, Tushman M L, Fombrun C, 1979, "Social network analysis for organizations" *The Academy of Management Review* **4** 507–519

Appendix A
Centrality score measures

(1) Degree centrality is measured by the number of direct ties to a node. Degree centrality (n_i) for node $i(n_i)$ in a nondirectional network is estimated as:

$$\text{Degree centrality}(n_i) = \sum_j x_{ij} = \sum_j x_{ji}\ ,$$

where x_{ij} is the binary variable equal to 1 if there is a link between n_i and n_j but equal to 0 otherwise (Freeman, 1979; Kim et al, 2011).

(2) Closeness centrality is estimated as:

$$\text{Closeness centrality }(n_i) = \left[\sum_{j=1}^{g} d(n_i, n_j)\right]^{-1}\ ,$$

where $\sum_{j=1}^{g} d(n_i, n_j)$ is the total distance between n_i and all other nodes. When all the other nodes are not reachable from the node in question, the index reaches its minimum value of zero.

(3) Betweenness centrality is measure based on the assumption that a connection between two nodes, n_i and n_k, follows their geodesics. Therefore, betweenness centrality can be estimated as:

$$\text{Betweenness centrality }(n_i) = \sum_{j<k} \frac{g_{jk}(n_i)}{g_{ij}}\ ,$$

where g_{jk} is the total number of geodesics linking the two nodes, and $g_{jk}(n_i)$ is the number of those geodesics that contain (n_i) (Freeman, 1977).

Appendix B

Table B1. Global design strategies for creating a successful downtown.

Strategies for success	Authors											
	Paumier et al (1988)	Robertson (1990)	Lennard et al (1995)	Loukaitou-Sideris (1998)	Montgomery (1998)	Robertson (1999)	Burayid (2001)	Banerjee (2001)	Filion et al (2004)	Faulk (2006)	Carr and Servon (2008)	Jones Jr et al (2008)
Diversity in use	●		●	●	●	●	●		●	●	●	
Density of population	●				●	●	●			●		
Varying open hours					●							
Street life and people watching	●		●		●	●		●	●	●	●	●
Ownership					●			●			●	
Cultural assets	●		●	●	●	●	●		●	●	●	
Design regulation	●		●	●		●	●					
Development intensity	●				●							
Blocks and streets	●		●		●			●				●
Pedestrian flow and vitality	●	●	●	●	●	●	●		●	●		●
Transportation and parking	●		●	●	●	●	●		●	●		
Public realm	●		●	●	●	●		●	●			
Architecture style	●		●	●	●		●		●			
Landmarks and attractors	●		●		●		●		●			

Table B2. The fifty-six patterns chosen from *A Pattern Language* (Alexander et al, 1977). The number in front of the name of a pattern represents the numbers assigned to that pattern in the book.

Constructs	Patterns			
Diversity in use	19	Web of Shopping	89	Corner Grocery
	32	Shopping Street	90	Beer Hall
	46	Market of Many Shops		
Density of population	10	Magic of the City		
Varying open hours	33	Night Life		
Street life and people watching	63	Dancing in the Street	93	Food Stands
	88	Street Café	166	Gallery Surrounded
Ownership	87	Individually Owned Shops		
Cultural assets	8	Mosaic of Subcultures		
Design regulation	21	Four-story Limits		
Development intensity	96	Number of Stories		
Blocks and streets	23	Parallel Roads	98	Circulation Realms
	49	Looped Local Roads	120	Path and Goals
	54	Road Crossing	121	Path Shape
Pedestrian flow and vitality	31	Promenade	119	Arcades
	55	Raised Walk	122	Building Fronts
	100	Pedestrian Street	123	Pedestrian Density
	101	Building Thoroughfare	243	Sitting Wall
Transportation and parking	11	Local Transport Areas	58	Bike Path and Racks
	16	Web of Public Transportation	92	Bus Stop
	20	Mini-Buses	97	Shield Parking
	22	Nine per cent Parking	103	Small Parking Lots
	52	Network of Paths and Cars		
Public realm	30	Activity Nodes	69	Public Outdoor Land
	36	Degree of Publicness	106	Positive Outdoor Space
	61	Small Public Squares	124	Activity Pockets
Architecture style	95	Building Complex	160	Building Edge
	99	Main Building	164	Street Windows
	102	Family of Entrance	165	Opening to the Street
	125	Stair Seats	244	Canvas Roof
	108	Connected Building		
Landmarks and attractors	43	University as Marketplace	126	Something roughly in the Middle
	53	Main Gateways		

Table B3. Reclassification by spatial levels. See table B2 to identify the names represented by the numbers.

Reclassified level	Pattern numbers
Urban structure	8, 10, 11, 16, 19, 20, 23, 30, 31, 33, 36, 43, 46, 49, 52, 53, 61, 69
Street	22, 32, 54, 55, 58, 63, 92, 93, 100, 101, 120, 121, 123, 126
Interface	88, 102,103, 106, 119, 122, 124, 125, 160, 164, 165, 166, 243, 244
Building	21, 87, 89, 90, 95, 96, 97 , 98, 99, 108