Proceedings of the Ninth International Space Syntax Symposium
Edited by Y O Kim, H T Park and K W Seo, Seoul: Sejong University, 2013

SPATIAL ANALYSIS OF THE RELATIONSHIP BETWEEN SPACE SYNTAX AND LAND USE DENSITY

125

Hye Young, Kim
University of Seoul
e-mail : lucykhy@naver.com

Chul Min, Jun
University of Seoul
e-mail : cmjun@uos.ac.kr

Abstract

Space planning is essential in sustainable urban planning, and it is important to analyze space to propose directions of urban planning. Recently for metric spatial analysis, studies related to space syntax have actively been carried out and it has turned out that it has a close relationship with constituents of each urban. However, few studies have been done on integrated analysis of street structure, land use and building density. Thus, this study aims to analyze the relationship between land uses of urban and the street structure and to present directions of urban planning. For this purpose, 22 administrative dong of Kangnam-gu Seoul where the street network has regularly developed and land uses are in a balanced harmony were analyzed. For the land uses, the total floor areas such as commercial • business, residential facilities and for the street structure, the street networks structure were considered, and space syntax was used to grasp the hierarchical spatial structures. For the analysis, individual spatial data were applied and processed with a weighted average of the proportion they occupy in the dong as weight. In addition, the relationship between the street structure and the land uses and the relationship with the land prices were examined, and through an IPA analysis, the relationship between the street structure and the land uses were analyzed and visualized. Understanding impacts on the spatial structures through space syntax will be used for effective urban planning.

Keywords: *Space Syntax, IPA, urban planning, land use, street structure*

Theme: *Urban Space and Social, Economic and Cultural Phenomena*

1. Introduction

Spatial analysis can be useful in providing guideline for urban development and specific planning. An urban area depends on the street structure for hierarchical order, which is also closely related with land use. So far, advancement in urbanization has led to a higher building density, rather than to a sprawl of urban areas. For this reason, a quantitative spatial analysis needs to be done that considers the street structure, land use and building density, to ensure sustainable urban planning.

Previous studies have broadly used socio-economic statistical data including demographic data, employment and land price. However, data by administrative unit lacked accuracy, and also not suitable for microscopic analysis. As "accessibility" emerged as an important element in spatial analysis, the traffic volume as well as a shortest metric distance to a given area or a facility came to be used more broadly. However, measuring traffic volume can be costly as it counts traffic in a designated area over a given time. Shortest metric distances are often unclear, and fail to reflect the characteristics of the street structure. To address this limitation, studies on space syntax have been actively undertaken to take into account the street structure and enable quantitative spatial analysis (Hillier and Hanson, 1984; Hillier, 1996; Hillier, 2007). The method stemmed from the study of architecture and emulated in urban planning, following studies that showed spatial properties drawn from space syntax had a close relationship with urban elements (Hillier et al., 1987; Peponis, 1990; Kim and Sohn, 2002; Kim, 2003). And yet, integrated studies on the street structure, land use and building density have been scarcely done.

This study aims to analyze the relationship between land uses of urban and the street structure and to present directions of urban planning. Specifically, this study analyzed 22 administrative dong of the Kangnam district in Seoul. The land use was divided into residential and commercial space, and to calculate building density, the area and floor area were used. To analyze street structure, the study adopted the space syntax theory and used global integration, which indicates accessibility of a designated unit space to the overall space. Additionally, land price was used that accommodates interrelationship among urban elements as well as overall nature of a given space. To minimize error, spatial data were processed to reflect weight by the share of a given space in dong. To verify explanatory power of the global integration, the correlation between the floor area of a building and land price was examined for the global integration for each case of considering shortest metric distances, the length of the road, and without considering the length of the road. The result was compared to the explanatory power of the building's floor area. Lastly, to propose a direction of urban development, the IPA(Importance Performance Analysis) was conducted for a comparative analysis among dongs and the outcomes were represented in visual materials(Kim et al., 2011).

2. Research Site (Kangnam, Seoul)

The site is located on the southern part of the Han River in the city of Seoul (Figure 1). It is a secondary center of the city and sits on the southeastern part of the city, approximately 10km away from the city center. The district was built according to urban planning, and has a wide, grid road network, except for the green belt area on the southern part. Currently, the Kangnam district has 22 administrative dong, and accounts for 6.53% of the Seoul area(39.55 ㎢). Specifically, residential area accounts for 56.28%, commercial areas 6.14%, and green space 37.58%, showing a well-balanced use of land. A majority of residence is in forms of large condominiums or multi-unit houses spread across the district. The area lacks manufacturing facilities, and some of the more developed areas include Sinsa-dong, Nonhyun-dong, Yeoksam-dong, Apgujeong-dong and Samsung-dong.

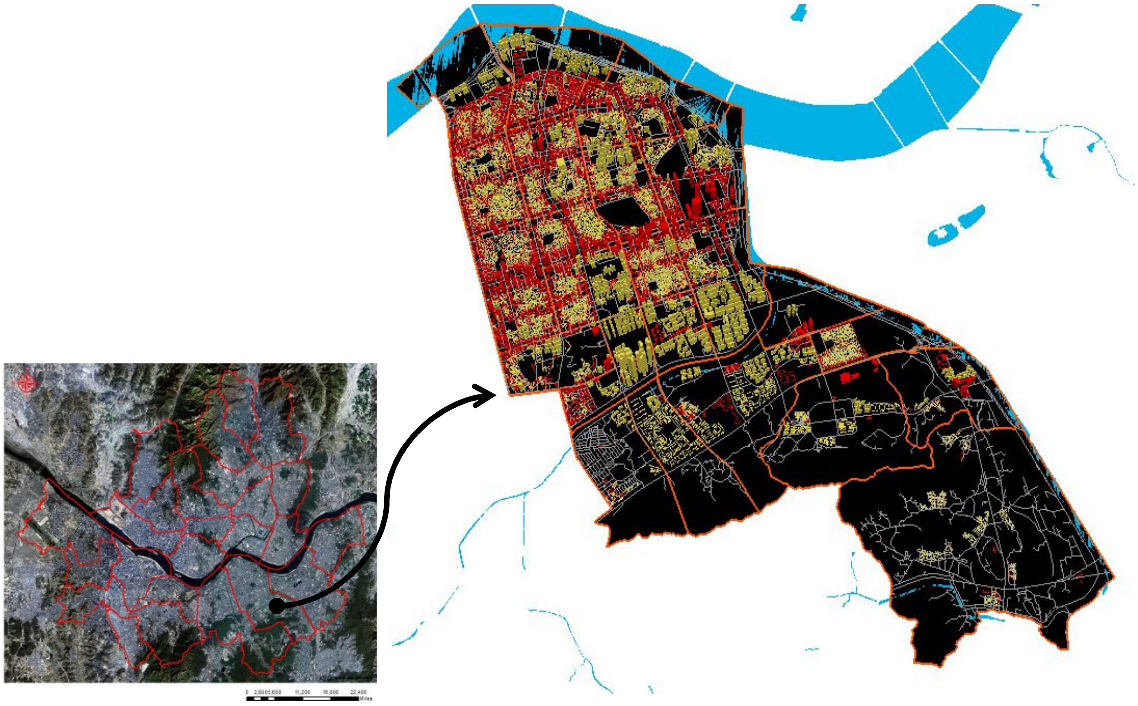


Figure 1 The location and configuration of Kangnam area

3. Spatial GIS Data and Data Processing

For integrated analysis of the street network, building density by land uses and land price, spatial data was built and processed by dong unit, using Arc GIS 10. The 22 administrative dongs cover the area of 1.8 ㎢ on average, and the largest dong covers 6.36 ㎢ (Segok-dong), the smallest 0.73 ㎢ (Daechi 4-dong). Spatial data were analyzed by reflecting the differences in area, and even within each dong, weighted average values were calculated by reflecting area and length of each data set, using the SPSS 12.0.

3.1. Road Accessibility

Accessibility data of the road were measured in terms of three criteria to compare with explanatory power of building density or land price. The metric lines were measure the average distance between a center point of given parcels and the nearest road. For global integration, two cases were considered to either reflect the length of the road or not. Analysis by dong unit requires aggregate data, and the size of the space is greater than the building space. The depth has greater power than a metric distance (Yun and Kim, 2007), but the space syntax does not take into account road-length. This should be considered since an urban area has larger road capacity with more intersections, compared to the outskirts of a city.

To build global integration data, an axial map was drawn, using the Axwoman based on the 2009 KOTI data of Seoul (Figure 2). The value of global integration is included in the axial line, and the surveyed Kangnam district has 2,318 axial lines. The average value of global integration of the Kangnam district was 1.5367, the maximum value 2.7478 and the minimum 0.5341. Formula (1) shows calculation of weighted average of global integration in both case of reflecting the length of the road and without reflecting by the dong unit.

$$Y_1 = \sum_{i=0}^{k}(L_i \times x_i)/\ w\ ,\quad Y_2 = \sum_{i=0}^{k}(x_i)/\ w \tag{1}$$

Y_1: Weighted average of global integration in consideration of the road length

Y_2: Weighted average of global integration

L_i: Length of axial line

x_i: Global integration value

w : Dong area

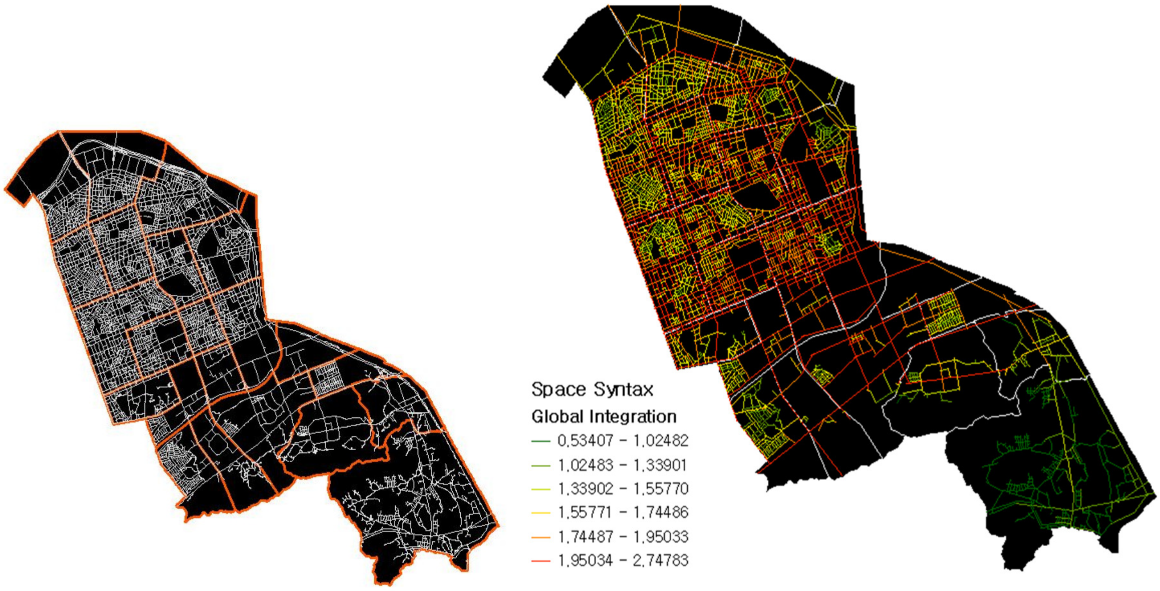


Figure 2 Global Integration of Kangnam

3.2. Building Density by Different Land Uses

The street structure has correlation with building density and land uses. In particular, a commercial area is highly sensitive to accessibility. The land use was divided into residential and commercial areas, and the building area was retrieved from the 2009 architectural data, based on the building use and number of floors. In Kangnam district, commercial and business buildings are lined along the street, while residential buildings are located further inside from the street (Figure 1). The district has 11,679 residential buildings, and 8,604 commercial and business buildings. The data were used to calculate the area and floor area of the buildings to analyze both horizontal and vertical density. By the dong unit, the average area of residential building and commercial building was each 754.7 ㎡ and 631.2 ㎡. And the average floor area was each 5484.61 ㎡ and 4204.41 ㎡.

3.3. Land Price

Land prices are higher in places with a good accessibility and vibrant economic activities. The price is greatly affected by residential, commercial and business facilities as well as by the surrounding street networks. The data on land price were drawn from the 2006 digital cadastral map and the appraised land value. The Kangnam district has 27,102 land plots excluding roads and streams, which accommodate different facilities ranging from residential and commercial buildings to green space.

4. Comparative Analysis of Explanatory Power of Global Integration

Prior to integrated spatial analysis, the research conducted a comparative analysis of global integration with other accessibility variables to determine whether the collected data are adequate as a variable for road accessibility. The correlation of global integration and the buildings' area and land price was analyzed for cases of considering a metric distance, reflecting the length of the road and without reflecting the length of the road (Table 1).

The metric distance R-value showed a significantly negative correlation with the area of commercial and business buildings. In case of not reflecting the length of the road, the R-value showed a significant correlation with the land price and the area of residential buildings, and its explanatory power on the land price was quite at 0.686. In case of considering the length of the road, the R-value had a significant correlation with all identified variables, and had a high explanatory power on the area of commercial and business buildings (0.946).

Table 1 Correlation of road accessibility and land price and buildings area

	Metric distance	Average global integration	Length-weighted global integration
Land price	-0.361	0.686 (<0.01)	0.636 (<0.01)
Residential buildings	-0.392	0.460 (<0.05)	0.910 (<0.01)
Commercial/business buildings	-0.551 (<0.01)	0.361	0.946 (<0.01)

Generally, commercial areas are highly sensitive to road accessibility, and commercial facilities are mostly located along the road. The global integration that took into account the length of the road had a high explanatory power on the area of commercial/business buildings. Without considering the length of the road, the global integration had a weak explanatory power. This suggests that the area of commercial/business buildings is largely affected by the road capacity and lengths. The explanatory power of the global integration on the area of residential buildings was equally high when the length of the road was considered.

The results of the global integration that considered the length of the road were compared with the floor area of the buildings, which is calculated by multiplying the area by the number of floors in a building (Table 2). All the identified variables yielded a significant correlation, but the explanatory power on the floor area was weaker than on the area. The explanatory power for floor area of residential buildings (0.91→0.341) was much lower than for commercial/business buildings (0.946→0.874) due to a relatively high density.

Table 2 Correlation of Global integration between area and floor area of buildings

	Residential buildings		Commercial/business buildings	
	R	R2	R	R2
Area	0.910 (<0.01)	0.819 (<0.00)	0.946 (<0.01)	0.891 (<0.00)
Floor area	0.341 (<0.1)	0.072 (<0.12)	0.874 (<0.01)	0.753 (<0.00)

5. IPA Analysis of street structure and Building Density by Land Price

The IPA plots importance and performance on the dual axes of x and y, and divides the graph into four quarters by the average value of each axis. The analysis is used to ensure efficient investment of limited resources in marketing business. This research modified the IPA analysis to propose a future direction for more efficient urban planning. The x and y axes were each set as length-weighted global integration and building density and average land price. The average value of each dong is divided into the four quarters of a graph for comparative analysis. Also suggestions on development and investment priority can be made for road infrastructure and facilities by different land uses. The analysis results yielded weighted average value of the dong: 0.05355 for length-weighted global integration, 0.07548 and 0.54846 each for the area and floor area of residential buildings, 0.06312 and 0.42044 each for the area and floor area of commercial/business buildings, 3,209,460 for land price.

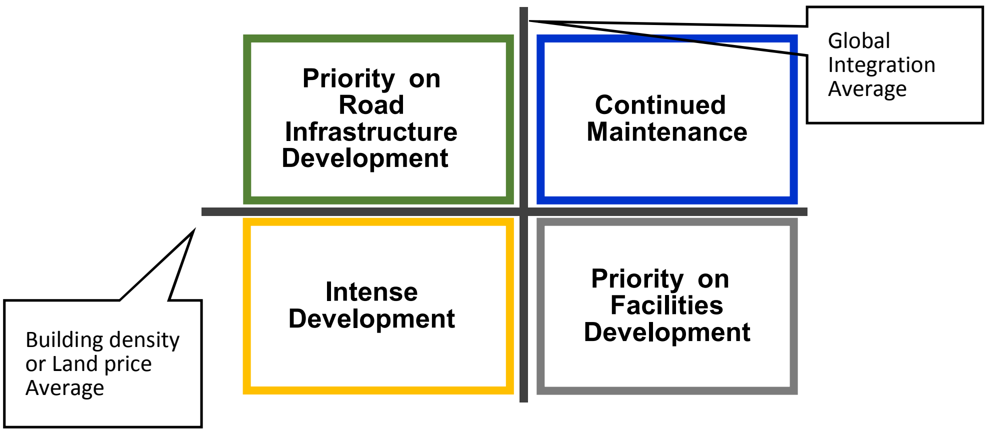
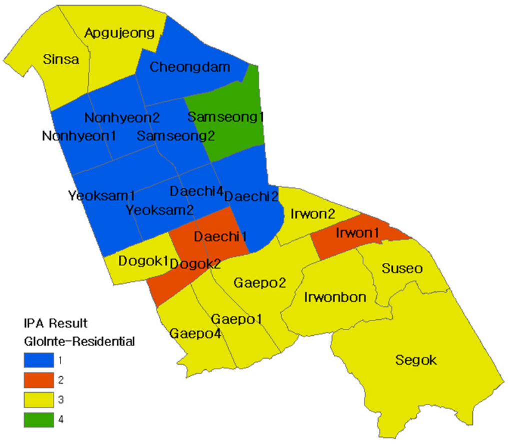


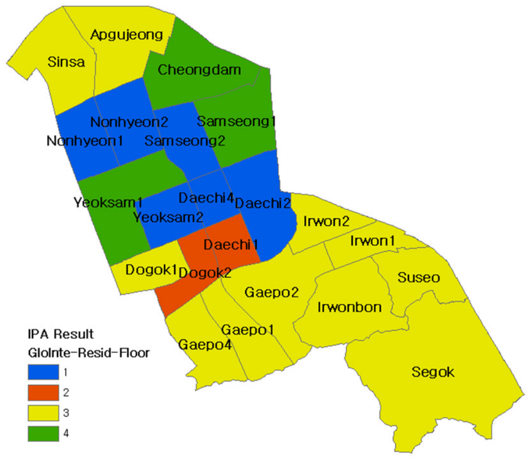
Figure 3 An integrated Analysis of spatial relationships with street structure through IPA definition

For the survey of urban area in the Kangnam district, the IPA analysis was defined as follows (Figure 3): continued maintenance area for the first quarter where roads and land facilities(both high values) are relatively well maintained; priority on road infrastructure development area for the second quarter where roads need to be improved compared to facilities; intense development area for the third quarter where both roads and facilities are relatively less developed; and priority on facilities development area for the fourth quarter(both low values) where residential and commercial·business facilities, as well as building density, need to be enhanced compared to roads. This categorization result was represented visually (Figure 4).

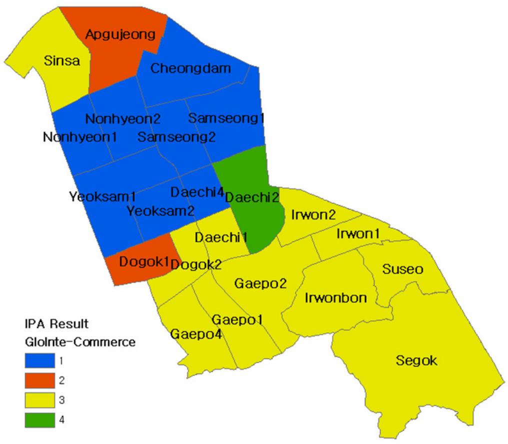
Figure 4 The result of integrated analysis in Kangnam



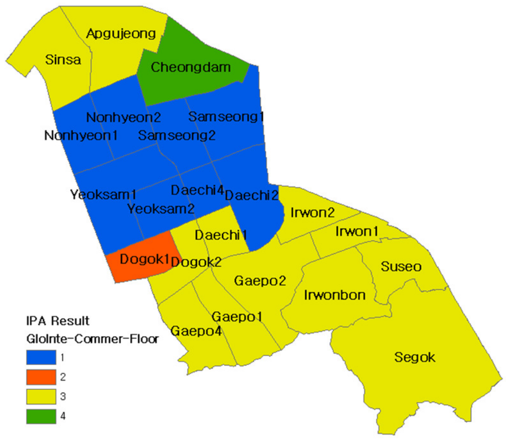
Area of residential buildings



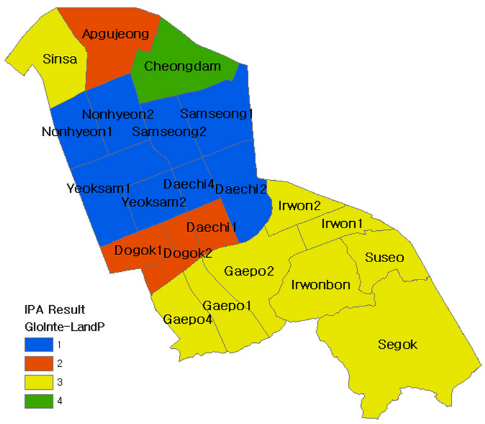
Floor area of residential buildings



Area of commercial buildings



Floor area of commercial buildings



Land price

For the first round of analysis, the x axis was set as length-weighted global integration and the y axis as the area and floor area of residential buildings for IPA analysis. Nonhyun-dong, Yeoksam-dong and Cheongdam-dong were plotted in the first quarter; Dogok 2-dong and Daechi 1-dong were assigned to the second quarter with dense residential buildings, requiring further road development. Cheongdam-dong, Yoeksam 1-dong and Irwon 1-dong turned out to have smaller floor area of residential buildings compared to the level of road development. Sinsa-dong, Apgujeong-dong and a large part of the southern Kangnam district were assigned to the third quarter that needs intense development; these are places with a higher ratio of green space and the Han River. Lastly, Samsung 1-dong fell under the fourth quarter where residential facilities need to be further developed compared to more advanced road systems.

For the second round, the x axis was set as length-weighted global integration and the y axis as the area and floor area of commercial/business buildings. Nonhyun-dong, Yeoksam-dong and Samsung-dong fell under the first quarter. Dogok 1-dong and Apgujeong-dong were assigned to the second quarter with dense commercial/business facilities, calling for improvement in road infrastructure. Cheongdam-dong and Apgujeong-dong turned out to have smaller floor area of commercial/business buildings compared to the level of road development. Sinsa-dong and a large part of the southern Kangnam district fell under the third quarter with the need for intense development. Daechi 2-dong was plotted on the fourth quarter to put priority on facilities development, while it had relatively higher floor area of commercial/business buildings.

For third round of analysis, the x axis was set length-weighted global integration and the y axis as land price to examine how the different land uses and building densities affect land price. For most buildings, the results were the same for either residential facilities or commercial/business facilities. However, the land price in Daechi 1-dong, Dogok 2-dong and Daechi 2-dong was significantly affected by residential facilities; in Dogok 1-dong, Samsung 1-dong and Apgujeong-dong, commercial/business facilities had greater influence on land price, and in Cheongdam-dong, building density showed a significant impact on the land price.

6. Conclusion

This research conducted an integrated analysis of urban area for its street structure and building density by different land uses based on a survey of 22 administrative dong of the Kangnam district in the city of Seoul. In order to consider the size of individual dong and minimize data error, weighted average was calculated for spatial data. To analyze both horizontal and vertical building density by different land uses, the area and floor area of residential and commercial· business buildings were measured. To analyze street structure, global integration, one of the space syntax properties, was used.

To verify explanatory power of the global integration, the analysis results were compared with the case of using a shortest metric distance. To consider the size of urban area and road capacity, two cases were examined: one that considers the length of the road, and one that does not. These three accessibility variables were analyzed for their correlation with the area of land price and the buildings by different land uses. The analysis results showed that when the length of the road was taken into account, the global integration had a significant correlation with all the identified variables, and a close correlation with the area of buildings of all types. Also, the area of commercial·business buildings was significantly affected by the length of the road. In comparison, the explanatory power was relatively weaker for the floor area of the buildings.

In addition, an IPA analysis was done on the street structure, building density by different land uses and land price. Each variable was assigned to one of the four quarters of a graph based on average value of individual dong for comparative analysis. The results showed that the administrative dong in the southern part of the Kangnam district were relatively less developed, suggesting where to develop first in terms of facilities, road infrastructure and building density. Also, it was shown how the land price was affected.

Based on the space syntax that quantifies spatial configurations of urban area and has a strong explanatory power regarding accessibility to roads, the research is expected to provide a useful guideline for future urban development through integrated analysis of land uses in consideration of building density. Further studies are called for that can enhance explanatory power of vertical building density to provide a more practical spatial analysis.

Acknowledgement

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (No. 2011-0009601)

REFERENCES

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

Hillier, B. 1996. *Space is the Machine*. Cambridge University press.

Hillier, B., R. Burdett, J. Peponis, and A. Penn. 1987. "Creating life: Or, does architecture determine anything?" *Architecture and Behaviour* 3(3): 233-250.

Kim, H K., and D W. Sohn. 2002. "An analysis of the relationship between land use density of office buildings and urban street configuration." *Cities* 19(6): 409-418.

Kim, H Y., Y J. Joo, and C M. Jun. 2011. "A study on transformation of urban layout patterns through analysis of spatial relationships with urban street configurations." *International Journal of Urban Sciences* 15(1):25-34.

Kim, Y W. 2003. "A study on the relationship between properties of spatial configuration and patterns of space use using space syntax." *Asian pacific Planning Review* 38(4): 7-17.

Peponis, J., C. Zimring, and Y K. Choi. 1990. "Finding the building in wayfinding," *Environment and Behaviour* 25(5): 555-590.

Yun, Y W., and Y O. Kim. 2007. "The effect of depth and distance in spatial cognition." *6th International Space Syntax Symposium.*