Evaluating the consequences of supergrid developments with relation to the modernization and conservation of historic street patterns: a case study on early 20th century Seoul

Youngha Joo* and Youngsang Kwon*ab

*Department of Civil and Environmental Engineering, Seoul National University, Seoul, Republic of Korea; abSmart City Research Center, Advanced Institute of Convergence Technology, Seoul National University, Seoul, Republic of Korea

ABSTRACT
Planned supergrid developments are influential on both the modernization and conservation of historic street patterns and their spatial structures, but related discussions have so far remained largely at prescriptive or normative levels without an in-depth empirical basis. Through a case study on the historic city centre of Seoul by devising and applying a systematic framework of space syntax analysis incorporating relatively recent, less known but elaborate techniques, this study therefore empirically analysed the detailed spatio-configurational changes that occur when such plans are implemented and evaluated what their consequences may be with relation to the modernization and conservation of historic street patterns. While a variety of empirical evidence presents the spatio-configurational mechanisms of the planned supergrid consistently facilitating the historic street system’s modernization, results related to its conservation are mixed: the original spatial structure and order does become disrupted at the background and local-scale foreground levels but contrary to conventional perceptions it is spatially succeeded and expanded at the global-scale foreground level, and streets comprising the supergrid that had already existed before its development have a milder impact than newly constructed ones. Implications for the sustainable management and planning of historic street patterns and their spatial context are further discussed.

1. Introduction

1.1. Contradictory demands for both modernization and conservation of historic street patterns

Since the early modern era, the street layout of historic cities with organic and geometrically complex urban form has been subject to demands for the restructuring, or “modernization”, of its spatial configuration (Larkham 1996; Bianca 2000, 174; Gascón 2017). The needs for the spatio-configurational restructuring of the city’s street system mainly emerged from reasons such as better hygiene, enhanced infrastructure, introduction of and adaptation to new means of transportation (i.e., automobiles), and reinforcement of monumental character (Le Corbusier 1973; Bandarin and van Oers 2012; Gascón 2017). Modifications were initially implemented in a baroque style, axis-oriented boulevard development, as can be seen in Haussmann’s renovation of Paris in the late nineteenth century (Harvey 2004). As modern urban planning gradually developed and prevailed, however, modifications mainly took the form of broad avenues composing a grid pattern, the most common and universal planning layout (Lynch 1984, 378; Kostof 1991, 95), mostly being continued for the improvement of circulation and accessibility within the city’s original and historic area. Unlike the traditionally incremental and spontaneous pattern of change in urban form, these modifications are implemented in a relatively short period of time. As exemplified in Figure 1, large-scale grid systems, hereafter termed as the “supergrid,” have been superimposed upon the organic urban fabric of many historic urban areas around the world for their modernization (e.g., Bianca 2000; Whitehand et al. 2011; Millán-Gómez, Mella, and López-Moreno 2012; Alobyadi and Rashid 2017; Al-Saffar 2018), and especially in developing nations, considerations for such planning and development of supergrids over historic street patterns are still an ongoing tendency (Whitehand et al. 2011; Ibrahim and Omer 2014; Khalil, Bileha, and Mortada 2016; Xie and Heath 2017).

As acknowledged by the international community, however, the need to preserve and maintain those historic street patterns and their spatial structures has also been raised (ICOMOS 1987; UNESCO 2005; ICOMOS 2011). Reasons against the street layout’s modification can be found on a number of grounds: that long-lasting historic street patterns possess place identity and cultural heritage value as agglomerations of local culture throughout multiple generations (Sitte 1986; Kostof...
1.2. Normative literature on the essential order

Sharmin and Matthews (2012) within the street-ward (e.g., Chiang and Deng 2017; Thomas 2018) and (2) the location and performance of a city’s function, and the circulation, residence, and other socioeconomic activities of its inhabitants (e.g., Kim and Sohn 2002; Grannis 2005; Matthews and Turnbull 2007; Rifaat, Tay, and de Barros 2012; Omer and Goldblatt 2016; Takekoshi, Nishiura, and Kobayashi 2016; Summers and Johnson 2017; Sharmin and Kamruzzaman 2018), changing the network would ultimately result in disrupting the existing order and overall character of the historic city.

As seen above, the coexistence of such opposing viewpoints places historic street patterns in between the contradictory demands for both its modernization and its conservation. In light of urban conservation theories, this may be seen as another typical case of “the essential tension” between originality and alteration in the conservation of the urban built environment (Larkham 1996, 17).

1.2. Normative recommendations and relevant literature

Within such circumstances, restructuring the historic street layout through supergrid development is generally expected to radically disrupt the existing spatial context, i.e., the original structure and order of the street system, even if the traditional urban fabric is partially preserved in between the supergrid’s avenues because of the unprecedented speed and massive scale of its implementation (Bianca 2000, 173). Accordingly, recommendations when planning supergrids upon historic urban areas have been suggested, such as not allowing major streets to destroy existing communities (Alexander, Ishikawa, and Silverstein 1977; ICOMOS 1987; Bianca 2000, 203). However, these have so far remained largely at prescriptive and normative levels; few studies have taken actual empirical evidence in addressing the detailed changes in the spatial configuration of historic street patterns due to such supergrid developments, yet alone examining them with relation to the aforementioned, contrary perspectives of modernization or conservation. In line with the recent growing acknowledgement on the contribution of urban morphology to the practice of urban heritage management (Rodwell 2009; Whitehand and Gu 2010; Whitehand 2015; Palaiologou 2017), substantive research addressing those aspects between urban form and modernization/conservation would therefore provide opportune understandings within current academic discussions.

Apart from some qualitative approaches (cf. Marefat 1988; Movahed 2006), a couple of morphological studies did attempt at covering the spatial mechanisms of supergrid developments by utilizing the more systematic and analytical procedures of space syntax methodologies. Though their spatio-configurational approaches seem appropriate, some limitations are also notable; either the case project is too small in scale, comprising only a few streets (Önder and Gigi 2010), or only the average spatio-configurational transformation tendencies of several cities are examined with a sole focus on conservation aspects, thereby in lack of both addressing the more detailed changes in the historic street network and incorporating the modernization/development perspective (Karimi 2000). The space syntax methodologies used by both studies are also considerably outdated compared to the more extensive and elaborate techniques available today, limiting their capability in providing a more precise analysis of the subject.

1.3. Aims and scope of research

This study thus aims to systematically analyse the detailed spatio-configurational changes in a historic street pattern due to the planning and development of a supergrid over its organic urban form, and from its results understand and evaluate in an empirical manner what their consequences may be with relation to the street system’s modernization and conservation. Here, we refer to “modernization of the street system”
as “restructuring or rearranging the street layout and its spatial configuration to introduce a new spatial structure, mostly for the improvement of circulation within the street network”, and “conservation of the street system” as “preserving, maintaining, or preventing damage upon the original street pattern and its spatial configuration and/or structure against activities of urban development”. Accordingly, the following questions are of research interest: what are the detailed and specific spatio-configurational changes in the historic street network before and after a planned supergrid development, and how shall we interpret them? What are their consequences on either the modernization or conservation of traditional and geometrically complex urban fabric? For example, regarding its modernization, does the supergrid actually improve its circulation conditions as intended, and if so, through what mechanisms? Or else, from the conservation perspective, does the introduction of such large-scale development actually deform and sever the historic street layout’s original structure, therefore inflicting adverse impacts on its conservation as previously expected by prescriptive or normative texts? How can we systematically analyse such aspects of the street network and spatio-structural centres before and after the development of the planned supergrid?

For real-world data acquisition and analysis on such questions, a case study was conducted on the supergrid development experience that the Historic City Centre (HCC) of Seoul, South Korea went through. Space syntax methodologies were applied to examine and compare the street network’s spatial configuration before and after supergrid development, but not without improvements; a more comprehensive and detailed understanding was sought by devising a systematic framework of space syntax analysis with the incorporation of elaborate and relatively recent techniques. Regarding practical implications, the study’s results would provide both guidance and empirical evidence for future planning and development of historic urban areas with traditional street patterns, especially those in the present-day developing world that still need to balance the two contradictory demands of the area’s modernization and conservation. From a methodological perspective, the study would also contribute in that it presents both (1) a demonstration of the actual application of less known but elaborate and useful space syntax techniques and (2) a systematic framework of analysis applicable to other future studies addressing the street patterns of cities, whether historic or not.

The direct examination and analysis of this study focus on the physical change of historic street systems induced by planned supergrid developments. However, functional and socioeconomic aspects of the urban spatial structure are also reported to be affected by the change in its physical street network, since the spatio-configurational dimension is the very framework of the overall urban environment (e.g., Wu and He 2005; Sharifi and Murayama 2013; Shen and Karimi 2018). Therefore, although the study’s scope is concentrated on the street system’s physical transformation, the functional and socioeconomic aspects affected by supergrid-induced street network changes are not completely neglected but addressed at a supplementary level by discussing our results in relation to those of other studies that have examined those non-physical aspects of Seoul HCC’s supergrid development. By combining such primary and supplementary examinations, the morphology-oriented study is expected to extend its contribution in helping the development of the broader research area which encompasses both the tangible and intangible aspects of the historic city and its urban spatial structure.

2. Materials and methods

2.1. Study area and its procedure of supergrid development

The HCC of Seoul, South Korea, where a large-scale supergrid has been planned and developed over the original historic street layout for its modernization, was selected as the study area; literature has noticed such contrast between the historic and the planned (e.g., Jacobs 1993, 268; Sim 2010; Henry 2014). Seoul was initially planned and constructed in 1394 as a walled capital city of the Joseon Dynasty, and over the following 500 years, its traditional urban form was shaped by gradual and mostly spontaneous development (e.g., Kwon, Jeon, and Kim 2015). The original HCC consisted of a city wall with seven gates, a water system with Cheonggyecheon as its main stream, a few palaces and shrines, several government institutions, and a multitude of streets and other general buildings comprising the rest of the organic urban fabric (Figure 2(a)). Eventually, however, three supergrid plans were implemented on the historic city throughout the first half of the twentieth century, which resulted in the transformation of its street system.

The first and most influential plan was the “District Rearrangement Programme” implemented from 1911 to 1928 during the Japanese occupation of Korea (-1910–1945) (Son 1990; Kim 1995; Lee and Shim 2013). To ensure both (1) the improvement of sanitary and circulation conditions (particularly, the north-south connection) of the city through street network modernization, and (2) the facilitation of colonial rule over the capital by gaining control of its spatial structure, the Japanese colonial government initiated a programme to rearrange the urban form within the city walls into a supergrid system of regularity and geometrical order (Figure 2(b)). Although some of the avenues
comprising the supergrid were formed by straightening or widening existing streets (e.g., Jong-ro, the main east-west thoroughfare), most were newly constructed and generally irrelevant to the existing morphological context. Though not all of the planned routes were implemented, the programme led to the introduction of a supergrid structure in Seoul’s HCC.

The second plan was the “Programme for Open Space against Flame Spread,” which was again planned by the Japanese colonial government in
1945 (Son 1990; Goto 1993). Toward the end of the Second World War, the Japanese government prepared open spaces (mostly through demolition) in the form of broad streets in many of their major cities, including Seoul, as a precaution against incendiary bombing raids. Additional straight avenues were delineated across the HCC (Figure 2(c)), and a number of such planned routes were implemented just before the withdrawal of the colonial government at the end of the war, which contributed to the expansion of the supergrid structure.

Finally, the third plan was the “Post-war Reconstruction Programme” implemented by the Korean government from 1952 to 1957 after the Korean War (Jang 2002; Son 2003). Apart from ensuring overall city restoration, the programme utilized the war as an opportunity to carry out further street layout plans that conformed to, but amended the colonial aspects of, the two earlier supergrid plans, this time with the intention of completing the HCC’s modernization. A selection of previously planned but not implemented routes was incorporated into the programme in modified form, and together with a few additional streets completed the supergrid structure (Figure 2(d)).

The three plans resulted in an organic, geometrically complex street pattern being overlapped by a planned, large-scale grid system. Although many years have passed since its planning, the supergrid structure embedded upon the traditional urban fabric remains distinct in the present-day urban form of Seoul’s HCC (Figure 2(e)).

2.2. Research materials

According to such history, changes in the historic street system of Seoul’s HCC due to its supergrid modernization can be obtained by comparing its street network before Japanese colonial influence and after post-war reconstruction efforts. Hence, historical maps depicting the street layout of each period were used as base research materials. Although the official beginning of the first supergrid plan is recorded as 1911, the Japanese influence had already been exerted on the city’s street system from 1907 onward, when a partial demolition of the city wall was carried out (Choi 2009). Therefore, the 1903 map Hanguk-Gyeongseong jeondo (Map of Korea and Gyeongseong), which is the map depicting conditions closest to those prior of 1907, was selected as the base material for the “before” state (Figure 3(a)). Similarly, the 1958 map Jibeonip Seoul teukbyeolsigajido (Street Map of Seoul with Street Numbers), which depicts conditions closest to those toward the end of the post-war rebuilding plan in 1957, was selected as the base material for the “after” state (Figure 3(b)).

2.3. Spatio-configurational analysis through space syntax methodology

2.3.1. Concise summary of space syntax methodology

Since the seminal work by Hillier and Hanson (1984), space syntax methodology is a particularly well-established research method representative of the configurational approach to urban form studies (Kropf 2009). Using maps drawn from “axial lines,” which are the longest straight lines that can be drawn within the street area of a map (Hillier and Hanson 1984), or “segment lines,” which are axial lines that are disaggregated at each intersection (Turner 2001; Hillier and Iida 2005), the methodology computes a set of measures for each line describing its syntactic status within the street network. Here, the two measures “integration” and “choice” are most significant. Integration calculates the mathematical “closeness” value, or accessibility (how close a line is to reach) from all other lines within a given system, and represents the “to-movement” potential of the line as
a destination; choice calculates the mathematical “betweenness” value, or how likely one is to pass through a line upon trips of shortest distance within a given system, and represents the “through-movement” potential of the line as a route (Hillier 2009, 4; Hillier, Yang, and Turner 2012, 155–156). The measures can be calculated under three different definitions of “distance” between lines (topological, least turn; angular, least angle change; and metric, least number of metres), and at varying “radii,” ranging from the local scale (a few turns/angles/metres; the radius can also be defined as topological, angular, or metric) to the global scale (the entire network).

Initially, axial analysis with topological distance and radius served as the standard method; however, once its limitations were recognized (Ratti 2004), segment analysis techniques with angular distance and metric radius (a.k.a. Angular Segment Analysis (ASA)) were developed and preferred within the space syntax community (Hillier et al. 2007; Hillier 2009; Xia 2013; Haq and Berhie 2018). Meanwhile, several prominent studies have also reported that street-centre lines are more than sufficient in generating segment maps for segment analysis (Turner 2007; Liu and Jiang 2012). The present study therefore applied ASA methods on segment maps derived from street-centre lines, which were in turn redrawn from the base historical maps of 1903 and 1958.

2.3.2. Framework of space syntax analysis

The study devised a systematic framework for applying ASA methods to analyse and compare in detail the street networks and their spatial configuration before (1903) and after (1958) supergrid development. The framework distinguishes street network “structure,” the form and spatial configuration of the street network, and street network “properties,” the characteristics of the network itself as a consequence of that particular form and spatial configuration (Figure 4).

Analysis of the network structure was conducted based on the “generic city-dual system” concept (Hillier 1996 2007, 2009). It proposes that all cities generally constitute a “foreground network,” which maximizes movement and links spatial centres (similar to an arterial system), embedded in a “background network,” composed of low-movement and mainly residential space (hence forming the majority of the city’s area). The foreground network can be identified through ASA integration and choice measures (Hillier and Vaughan 2007; Hillier 2009). Here, the product of the integration and choice values was used to capture both to-movement and through-movement potentials in a single combined measure (Al-Sayed 2014, 91). Additionally, to examine the spatio-structural centres of the network in greater depth, analysis of the foreground network was further divided into global and local scales; the “global core,” consisting of segment lines that have the top 10 per cent integration × choice values with respect to the entire network, and the distribution of “local centralities,” depicted as segment maps of the combined measure calculated within a pedestrian shed of 500 m radius. Meanwhile, the revelation and analysis of the background network can be conducted through a technique that is relatively recent within the space syntax community. It is visually highlighted as a “patchwork” pattern (Hillier et al. 2007; Al-Sayed 2014) where the urban space is interpreted as being a self-organized and naturally differentiated set of semi-discrete local spatial areas, or “patches,” which differ according to block size and shape. Patches are identified by calculating metric mean depth; whereas different radii of calculation generate different patchworks, appropriate scales are known to reveal patches that are, to some extent, indicative of residential neighbourhoods (Al-Sayed 2014; Haq and Berhie 2018). Here, a 500 m radius scale was used again in accordance with both the aforementioned local centralities analysis and the conventional neighbourhood unit walking distance of 400–500 m.

Street network properties were analysed with respect to space syntax concepts of (1) “intelligibility” and “synergy” and (2) mean/maximum values of “Normalized Angular INtegration (NAIN)” and “Normalized Angular CHOice (NACH).” Intelligibility is the correlation coefficient between axial connectivity (the number of axial lines connected to a certain axial line) and axial global integration within a given system. It represents the ease of comprehending the complete spatial structure of the system from a local position, or in other words how “readable” the whole is from the parts of the system (Hillier et al. 1987; Al-Sayed 2014).

![Figure 4](image_url)  
Figure 4. Outline of the framework for space syntax analysis. NAIN, normalized angular integration; NACH, normalized angular choice.
Synergy is the correlation coefficient between the local scale (a topological radius of three turns, denoted as R3) and global scale (a topological radius of n, denoted as Rn) axial integrations within a given system. It represents how well the internal local structure is related to the global structure in which it is embedded (Hillier [1996] 2007). In contrast to the study’s general use of segment analysis methods, axial analysis methods were exceptionally used when calculating these two measures since they are derived from the latter.

The mean/maximum values of normalized angular integration (NAIN) and choice (NACH) are another set of more recent, elaborate, but less known syntactic measures also available in describing the characteristics of the street network (Hillier, Yang, and Turner 2012). Before the application of the normalization technique, the absolute values of an individual system’s integration and choice are relevant to that system alone, and in a strict sense are thus unavailable for direct comparison across different systems (i.e., different segment maps). Hence, the term “normalized” comes from the fact that the numerical values of integration and choice have been modified to enable such direct comparison. For both NAIN and NACH, the mean values are associated with the characteristics of the background network since a greater number of segment lines in a system form the background, and the maximum values are in turn associated with the foreground network. Therefore, in the case of NAIN, similar to the familiar syntactic sense of unnormalized integration, the mean and maximum values serve as indicators of the overall ease of accessibility in the background and foreground networks, respectively. NACH, on the other hand, differs slightly from NAIN in its interpretation of mean and maximum values. The mean NACH indicates “the degree to which the background [areas form] a continuous [system] … rather than being broken up into discontinuous sub-areas,” whereas the maximum NACH indicates the degree to which the overall spatial configuration of the system is dependent on the core structure of the foreground network (Hillier, Yang, and Turner 2012, 170).

All space syntax analyses were conducted using UCL DepthmapX-0.6.0 software (Turner 2004; Al-Sayed 2014). Edge effects may be a concern when analysing the network’s integration and choice measures (e.g., Al-Sayed 2014). However, in the case of Seoul’s HCC, since it had been a walled city from the beginning and continued to retain most of its walls as of 1958, and therefore, movement within the city was restricted to its boundaries, it was thought acceptable to interpret the results without considering edge effects as a major issue (in line with Kwon 2003, 225). Further, there is evidence that for angular distances such as in ASA, integration and choice measures are generally stable, regardless of the size and position of a system’s edge (Gil 2017).

2.3.3. Examining space syntax analysis results from modernization/conservation perspectives

Through an examination of its analysis results on the historic street pattern’s detailed spatio-configurational changes after supergrid development, space syntax methodology enables the evaluation and/or interpretation based on actual empirical data – not just at the individual street level, but at the overall street system level – of (1) whether the traditional urban fabric’s modernization is achieved or conservation is adversely affected by the supergrid and (2) its relevant network-wide mechanisms. For street network structure, the changes in the shape or distribution/pattern of the foreground global core and local centralities and background patches were examined by comparing ASA results before (1903) and after (1958) the implementation of the planned supergrid. The spatial changes in each aspect were then evaluated and interpreted in relation to the original street system’s modernization and/or conservation. For street network properties, whether the values of the various indicators increase or decrease after supergrid development was observed and, similar to the network structure, what their meanings could be regarding the original street system’s modernization and/or conservation were discussed.

3. Results and discussion

3.1. Changes in street network structure and their consequences on modernization/conservation

3.1.1. Foreground network analysis

3.1.1.1. Global core. Analysis results on the street network structure reveal that the original 1903 global core of the foreground network seems to be affected by supergrid development. Observations are obtained by comparing maps that depict the segment lines with the top 10 per cent integration × choice values. Segment colours are assigned to represent the relative size of the product values, increasing from blue to red, which in turn indicates the segment’s relative significance as both a route and a destination within the whole system (Figure 5).

While the global core had resembled a dendritic structure in 1903 consisting of Jong-ro (the main east-west thoroughfare) as its main trunk and a few other branches, it had been transformed into a highly distinct supergrid structure in 1958. The form follows quite accurately the actual three supergrid plans developed upon the historic street pattern, namely the north-south connections and east-west passages. In other words, the supergrid itself becomes the new foreground core structure, realizing its planning intentions of rearranging the organic spatial structure into a network of well-connected streets with high to- and through-movement potential at the global scale.
Conforming to the reports of other previous studies that the superimposed grid becomes the new main structure at the global scale (Karimi 2000; Movahed 2006), such observation provides empirical evidence that the superimposition of a planned supergrid system actually succeeds in introducing a new spatial structure upon a historic city’s street layout supportive of better traffic conditions, and thus guides its modernization.

Regarding such transformation in structure, one general perception is that it is achieved at the expense of the street layout’s traditional spatial context and order. Contrary to such convention, however, it seems that the original configuration does not undergo radical deformation by the supergrid at the global core scale. Closer examinations reveal that even after the large-scale restructuring of the foreground network, the status of being a “core street” has been conserved for almost all parts of the original 1903 dendritic core in an absorbed form within the new 1958 supergrid core. While the streets comprising the original 1903 core that also happened to be included in the three supergrid plans (cf., Figure 2(b–d)) would naturally become part of the new supergrid core, those that were not included in the plans are found to equally perdure within the updated core as well. Moreover, with the exception of the 1903 “tail” near Namdaemun (the south main gate), the relative significance of most original core streets is found (through observations of their colour changes) to have remained high, or become even higher, after supergrid implementation. Therefore, despite the notable changes in shape, the large-scale supergrid development could be interpreted in essence as to spatially succeed and expand rather than radically deform and damage the original global core. In a certain sense, this could be further interpreted as conforming to earlier discussions on street layouts being the most enduring morphological element of the city – although the outward shape of the street layout’s core may change, its spatio-configurational context and status are maintained even after undergoing rapid and large-scale adjustments. That being said, it can be summarized that even while the planned supergrid facilitates the modernization of a historic street pattern, it surprisingly may not hurt the conservation of its global core-level original spatial structure.

Meanwhile, an example of supergrid development affecting the further functional and socioeconomic aspects of the urban spatial structure can be found by interpreting the global core’s changes in conjunction with a study by Yu and Kim (2017). The study describes the development of the north-eastern area of Seoul’s HCC throughout the Japanese occupation period, during which the establishment of public facilities (a hospital, an imperial college, and some schools) led to the first plan to construct or improve major thoroughfares in the area, which in turn increased both movement to the area and its housing demands. Consequently, an originally underdeveloped, low-density area with a population composed mainly of Korean farmers became a moderate-density district with not only Korean but also Japanese middle- and upper-class residents. The results of these non-physical aspects are in line with the increase in the relative significance of the two core routes in the direction of Dongsomun, the east small gate, as shown by the comparison between Figure 5(a,b).

3.1.1.2. Local centralities. The original distribution of the foreground network’s local centralities also seems to have been changed by the superimposition
of a planned grid. Analogous to global core maps, segment maps of integration × choice at the local level are assigned colours, such that the product values, and hence, the segments’ relative centrality within a walking range increases from blue to red (Figure 6). Whereas some of the original centralities along Jong-ro do not show changes in relative centrality (e-e’ and f-f’ in Figure 6), some centralities to the north and west of Jong-ro have remarkably lost their significance (a-a’ through d-d’ in Figure 6). New centralities have also emerged to the south and east of Jong-ro, particularly in areas where the supergrid pattern is intensified (g-g’; h-h’ and its vicinity in Figure 6). This seems to indicate an opposing trend compared to the foreground network’s global-scale core; the local-scale centralities of the foreground network are largely subject to spatio-configurational transformation when supergrid development takes place, rather than retaining their original context and spatial order. Therefore, while the development of a supergrid may not have adverse effects on the conservation of the historic spatial structure at the global scale, it does seem to raise such concerns at the local scale.

Some of these spatio-configurational changes in the distribution of local centralities are found to coincide with the results of several other studies examining the spatial changes in Seoul HCC’s political or socio-economic functions during the same period. Originally, the Jeong-dong area in front of Deoksugung palace of the Joseon Dynasty (c-c’) was the political centre of Seoul’s HCC during the early twentieth century; however, it prime residential district of government officials and aristocrats; however, during the colonial era, this place gradually lost its prominence as the sociodemographic centre shifted from the predominantly Korean sectors located north of Jong-ro, to areas south of Jong-ro composed mainly of Japanese population (Lee 2007; Oh and Kim 2015). One such example, the area denoted as h-h’ in Figure 6 and its vicinity also happens to be both one of the new commercial districts (Park and Kim 2012) and light-industrial clusters (such as food production, printing, and furniture manufacturing) (Oh and Kim 2015) that emerged in the 1920s. Though such coinciding examples alone do not confirm any causal relationship, together with the above global core example, they do seem to indicate certain interrelations among the transformation of the historic street layout through supergrid planning, its spatial configuration, and its further functional/socioeconomic aspects of urban spatial structure. Therefore, such correspondence between the tangible and intangible aspects suggests that although this study takes a spatio-configurational approach and focuses primarily on the physical conservation and modernization of historic street patterns, discussions on its results can possibly be expanded to a broader level without being limited to purely morphological interpretations.

3.1.2. Background network analysis
The background networks at the 500 m radius scale before (1903) and after (1958) supergrid development are depicted as the respective patchwork patterns in

Figure 6. Integration × choice maps of Seoul’s historic city centre at the local scale (R500 metric radius) for 1903 (Figure 6(a)) and 1958 (Figure 6(b)). Each map represents the respective local centralities of the foreground network. Segment values increase from blue to red, which in turn indicates the increase in a segment’s relative centrality within a 500 m pedestrian shed. Arrows and alphabets are marked to ensure ease of comparison between the two maps.

Figure 7(a). (For reference, the foreground network global core of each year is also faintly drawn underneath in light brown). The pattern after supergrid development displays some differences from the
pattern before its development, thereby implying the supergrid’s influence on the background network. To identify its influence in more detail, both patchwork patterns are re-examined in Figure 7(b) with respect to the actual, final supergrid layout of 1958.\textsuperscript{1} The final supergrid was identified by comparing the three development plans of Figure 2(b–d) with the two actual street maps of Figure 3(a,b). Of the streets comprising the three supergrid development plans, those that had already existed since 1903 (i.e., before the implementation of the plans) and incorporated into the plans by means of widening, repair, etc. are drawn in green, whereas those that were newly constructed according to the plans are drawn in blue for differentiation. Planned streets that were never implemented were excluded from the final supergrid.

Changes in the patchwork patterns reveal that while the original 1903 patches located at the periphery of the network and thus are more or less just “clinging” onto the supergrid remain relatively the same,\textsuperscript{2} those located inside and thus are spatio-configurationally more associated with the supergrid are less resilient to alteration. In other words, though the following trend may not always apply, a majority of the original patches that are either penetrated or intersected by the supergrid streets are observed to be relocated/divided (circled in red solid lines) or diminished (circled in red dotted lines), whereas the others that are away from or simply adjacent to the supergrid system are mostly intact. Since the distortion or loss of patches demonstrate that the historic urban fabric’s original structure and order has been disrupted to some

---

\textsuperscript{1}Though many parts of both the foreground network global core and the actual supergrid layout overlap since the supergrid itself becomes the main foreground structure (as examined in the previous section), the former drawn in Figure 7(a) for simple reference is not to be confused with the latter drawn in Figure 7(b).

\textsuperscript{2}Some peripheral patches do show changes such that their area or the number of streets that form them increases, but being mainly attributable to the simple expansion of the city along the fringe ensuing its growth during modern times, their mostly growth-related changes can be assumed as relatively small or negligible compared to those of the inward patches that undergo further alterations.

---

\textbf{Figure 7.} (a) Background network patchwork patterns for 1903 (left) and 1958 (right) at the 500 m radius scale, with the foreground network global core of each year faintly drawn underneath in light brown for reference. (b) Background network patchwork patterns for 1903 (left) and 1958 (right) re-examined with respect to the actual supergrid layout of 1958. Streets that had already existed since 1903 (i.e., before supergrid development) are drawn in green, whereas those that were actually constructed according to the three supergrid plans (cf. Figure 2(b–d) are drawn in blue for differentiation. Solid and dotted red circles respectively indicate patches that have been either relocated/divided or diminished by the supergrid streets that run through them.
extent, such tendency therefore suggests that the planned supergrid eventually exerts adverse effects on the spatial order’s conservation at the background level as well.

Interestingly, while the supergrid basically relocates/divides or diminishes the patches, the trend seems more prominent in the blue-coloured, newly constructed streets comprising the supergrid compared to the green-coloured ones that had originally existed before the supergrid’s development. This difference could be interpreted as presenting the possibility that careful exploitation of already existing streets might be able to mitigate the damage caused by supergrid development – constructing the supergrid with streets already in place may reduce the relocation/division or diminishment of background network patches.

Meanwhile, since the patches derived by ASA techniques can be considered analogous to residential neighbourhoods, the disruptions as a result of supergrid development are not just concerned with the spatio-configurational conservation aspect, but may be seen as further concerned with the relocation or loss of existing local neighbourhoods, or “communities,” within the historic urban area. Relatedly, Sim (2010) actually notes some newspaper articles of the time reporting how the residents of Seoul’s HCC protested against the demolition of their towns for road construction; another study by Abramson (2008), though different in terms of its detailed study area and aims, addresses similar concerns regarding the disruption of communities by Corbusian, superblock approaches in the redevelopment of historic urban areas.

### 3.2. Changes in street network properties and their consequences on modernization/conservation

An evaluation of the changes in street network properties reveals that the characteristics of the network itself have also been affected by the planned supergrid development. Table 1 shows the results pertaining to intelligibility and synergy. Both intelligibility and synergy of the entire network have increased by approximately 22.4% and 30.3%, respectively. It can be inferred from these increases that after the restructuring of the street system, the whole of the street layout can be better understood from its parts, and the local structure is better related to the global structure. Higher intelligibility can further be interpreted as a proxy for better wayfinding, since the concept is related to people’s spatial cognition, or comprehension, of a street layout’s spatial configuration (Penn 2003). Therefore, this increase in both measures provides empirical insight that restructuring a historic, geometrically complex street layout through means of a planned supergrid actually can achieve its modernization by improving its circulation conditions, particularly its wayfinding, based on spatial comprehension (intelligibility), and the relatedness between the parts and the whole (synergy).

Meanwhile, partly inspired by the studies of Karimi (2000) and Millan-Gómez, Mella, and Lópezmoreno (2012), intelligibility was further calculated for the global core alone to understand the changes in the readability of the street system at the core level as well. While the absolute values 0.358 and 0.523 for the global core alone before and after supergrid development, respectively, are clearly higher than the corresponding values 0.232 and 0.284 for the entire network, the increase is also considerably higher at approximately 46.1%. The higher values of intelligibility seem supportive of the general perception that the core structure of a street layout is typically much easier to “read” compared to its entirety, or vice versa, that the street system can be understood more easily through the core structure than by the network as a whole. The higher increase in intelligibility seems to indicate that the restructuring of a historic street pattern through a supergrid plan has a more direct effect on improving the comprehensibility of the core structure compared to the entire network. Therefore, in conjunction with the previous examination on the foreground network’s global core, it could be said that whereas the development of a planned supergrid is found to expand the original core in a spatial sense, it is also found to imprint the resultant core in people’s minds in a cognitive sense by considerably enhancing its comprehensibility.

Table 1. Changes in intelligibility and synergy before (1903) and after (1958) supergrid development. In the case of intelligibility, the measure was calculated for both the entire network and the global core alone.

|               | Entire network | Global core |
|---------------|----------------|-------------|
|              | 1903 | 1958 | 1903 | 1958 |
| Intelligibility | 0.232 | 0.284 | 0.358 | 0.523 |
| Synergy (Rn-R3) | 0.452 | 0.589 | - | - |

Higher values between the years 1903 and 1958 are highlighted in bold.

Unlike intelligibility, however, synergy for the global core alone was not analysed since distinguishing the local (R3) and global (Rn) scales for the calculation of synergy within such a limited system (i.e., the global core alone) was considered as not applicable.
Table 2. Changes in the mean/maximum values of NAIN and NACH before (1903) and after (1958) supergrid development.

| Normalization | Values        | 1903 | 1958 |
|---------------|---------------|------|------|
| NAIN          | Mean          | 0.793| 0.875|
|               | Maximum       | 1.355| 1.373|
| NACH          | Mean          | 0.800| 0.739|
|               | Maximum       | 1.593| 1.470|

Higher values between the years 1903 and 1958 are highlighted in bold.

between streets regardless of background or foreground network, which eventually leads to higher possibilities of each street being accessible as a destination within the street system.

The decrease in mean NACH indicates that the background patches become more discontinuous (i.e., isolated) after rearranging the street structure. At first glance, such an increase in discontinuity among local background areas following supergrid development may seem contrary to either the increase in overall accessibility for both background and foreground networks (mean and maximum NAIN), or the increase in relatedness between local and global structures (synergy). On reflection, however, the two situations are not necessarily incompatible; even though newly constructed main thoroughfares may provide more connections for the local areas to the global structure, they can nevertheless separate neighbouring local areas from each other if developed in an irrelevant manner with respect to the surrounding morphological context (cf., Hillier et al. 2007, 18). In conjunction with the previous background network analysis results (Figure 7(b)), this points out once again that supergrid development has an adverse impact on the conservation of the background network’s original spatial structure – this time by isolating each of the patches.

Finally, the decrease in maximum NACH indicates a decrease in the street system’s spatio-configurational dependence on its foreground global core. This is a somewhat unexpected result, since the core structure becomes more noticeable after modernization, both spatially and cognitively, and yet the reliance upon that core declines. Although requiring further verification, this decrease in the dependence on, or dominance of, the global core may possibly result from the pervasiveness of its new supergrid structure, where the number of route choice alternatives are higher than the original dendritic structure. Such interpretation, while unverified, again implies easier movement and better circulation within the historic urban area after supergrid development.

4. Conclusion

Planned supergrid developments are influential on both the modernization and conservation of historic street patterns and their spatial structures, but related discussions or recommendations have so far remained largely at prescriptive or normative levels without an in-depth empirical basis, let alone address specifically its effects on the two contradictory demands. Through a real-world case study on Seoul HCC by devising and applying a systematic framework of space syntax analysis incorporating relatively recent, less known but elaborate techniques, this study hence achieves an empirical understanding and evaluation on the consequences of developing a planned supergrid over a traditional and organic street network with relation to both its modernization and its conservation, thereby making it distinctive from previous studies. Adopting a spatio-configurational approach using space syntax methodologies especially enabled evaluations and/or interpretations based on actual empirical data not just at the individual street level, but at the overall street system level.

Rudimentary findings of the study would be “the detailed spatio-configurational changes in the historic street pattern before and after the development of a planned supergrid” itself. The direct measurement, identification, and visualization of the changes in the street network’s structure and properties in a systematic manner provide a readable and tangible depiction of the supergrid’s spatio-configurational impact with hierarchy and organization. It also serves as a factual basis for the subsequent evaluations/interpretations and accommodates an opportunity to match and discuss the morphological dimension’s interrelationship with other functional/socioeconomic aspects of urban spatial structure.

Further findings specify the consequences of supergrid development with relation to the historic street network’s modernization and conservation, along with its network-wide mechanisms as well. Regarding modernization, a variety of results consistently show that the planning of a supergrid actually does contribute to the organic street system’s achieving it, as intended. Empirical evidence is obtained that restructuring the street layout by superimposing a supergrid system upon it successfully introduces the supergrid as the new global-scale foreground structure, which in turn is supportive of better circulation conditions such as wayfinding, the relatedness between the parts and the whole, and overall accessibility within the network. Contrarily, the spatio-configurational reliance of the overall street network upon the planned supergrid after its development is unexpectedly low, but this might be because many route choice alternatives have become available by virtue of the supergrid’s pervasiveness, which again implies easier movement within the historic urban area. On the other hand, results regarding conservation do not appear to converge towards a single course. Conventional perceptions are that introducing a large-scale supergrid system would radically deform the whole of the
historic street layout’s original spatial structure and order, but it seems that it is not necessarily so. At the background and local-scale foreground levels, the original spatio-configurational context does become disrupted by supergrid development, and therefore adverse impacts on its conservation are inflicted as per general expectations. However, at the global-scale foreground level the existing spatial structure, despite its alteration in its outward shape, seems to be in essence spatially succeeded and then further expanded, instead of being totally lost. Additionally, even at the background level, it is found that streets comprising the supergrid that had already existed before its development and incorporated into the plan certainly seem to have a milder impact on the original spatial context than those that were newly constructed.

From such results that encompass both the contradictory demands of modernization and conservation, practical implications can be drawn for future sustainable management and planning of historic urban areas with traditional street patterns. For the public sector to fully exploit the advantages of the supergrid while minimizing its disruptive effects on the existing spatial order, procedures to first analyse and identify the street network’s present spatio-configurational global core is recommended above all. This is because the global core can be succeeded within and expanded by the supergrid while retaining most of its original spatial context. Afterwards, with reference to the identified global core, careful planning measures designating already existing streets as to constitute the supergrid as much as possible would be most ideal since it would integrate most of the original spatial configuration within itself and reduce the introduction of new thoroughfares irrelevant to the original morphological context. By doing so, the planned supergrid would minimize its adverse effects on the conservation of the historic street system at both the global foreground and background/local foreground levels, while still facilitating the various mechanisms for its modernization. Guidance and empirical evidence put forward from this study are expected to be of use especially for developing nations or municipalities in need of balancing the tension between originality and alteration, or strict preservation and full-scale development.

Owing to the intrinsic limitations of a single case study, generalizing its understandings and interpretations may be debatable. Therefore, while this study may still serve as an exploratory attempt in empirically evaluating the effects of supergrid development on historic street patterns, further identification of the similarities and differences between multiple cases under different conditions would provide a more elaborate understanding on the subject. Another limitation is that although the study did not altogether neglect the consequences of supergrid development on the intangible aspects of the historic city’s urban spatial structure (i.e., the functional and/or socioeconomic dimensions), they were addressed in an indirect manner due to the study’s focus on the physical street pattern with relation to its modernization/conservation issues. While excepted from this already long and complex paper, future studies directly examining the non-physical aspects would generate further, solid accounts on the interrelationship between the spatio-configurational transformation and overall sustainable management of urban cultural heritage.

Acknowledgments

The early version of this article was presented as a conference paper at the “2018 International Conference of Asian-Pacific Planning Societies (ICAPPS)”, in the University of Architecture of Ho Chi Minh City, Ho Chi Minh, Vietnam.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Creative-Pioneering Researchers Program through Seoul National University (SNU), the Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Education (NRF-2018R1D1A1B07048832), the Smart City R&D project of the Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Ministry of Science and ICT (Grant 20NSPS-B151375-03), and the Integrated Research Institute of Construction and Environmental Engineering at Seoul National University.

Notes on contributors

Youngha Joo is a postgraduate student (Ph.D.) at the Department of Civil and Environmental Engineering, Seoul National University. His research interests are mainly in urban morphology, urban greenery, and urban street environments within the Urban Design field.

Youngsang Kwon is an associate professor of Urban Design at the Department of Civil and Environmental Engineering, Seoul National University. His research interests are mainly in urban history, urban structure, sustainable urban development, smart city, and urban resilience.

References

Abramson, D. 2008. “Haussmann and Le Corbusier in China: Land Control and the Design of Streets in Urban Redevelopment.” Journal of Urban Design 13 (2): 231–256. doi:10.1080/13574800801965700.

Alexander, C., S. Ishikawa, and M. Silverstein. 1977. A Pattern Language: Towns, Buildings, Construction. Oxford: Oxford University Press.

Alobaidi, D., and M. Rashid. 2017. “A Study of the Morphological Evolution of the Urban Cores of Baghdad
in the 19th and 20th Century." In Proceedings of the 11th International Space Syntax Symposium, 38.1–38.12. Instituto Superior Técnico, University of Lisbon: Lisbon, Portugal.

Al-Saffar, M. 2018. "Urban Heritage and Conservation in the Historic Centre of Baghdad." International Journal of Heritage Architecture 2 (1): 23–36.

Al-Sayed, K. C. 2014. Space Syntax Methodology: A Teaching Guide for the MRes/MSc Space Syntax Course (Version 5). London: Bartlett School of Architecture, UCL.

Bandarin, F., and R. van Oers. 2012. The Historic Urban Landscape: Managing Heritage in an Urban Century. Chichester: Wiley Blackwell.

Bianca, S. 2000. Urban Form in the Arab World: Past and Present. Zurich: vdf Hochschulverlag AG.

Chiang, Y.-C., and Y. Deng. 2017. "City Gate as Key Towards Sustainable Urban Redevelopment: A Case Study of Ancient Gungnæ City within the Modern City of J’ian." Habitat International 67: 1–12. doi: 10.1016/j.habitatint.2017.06.007.

Choi, I.-Y. 2009. "The Introduction and Role of Electric Car in the Outer Area of Dongdaemun: Focused on the Line of Cheongryangni and Wangsimni (in Korean)." The Journal of Seoul Studies 37: 83–115.

Corbusier, L. 1935. The Athens Charter. Translated by Anthony Eardley. New York, NY: Grossman.

Gascón, M. 2017. "Gustavo Giovannoni on Planning in Historic Towns." Context 152: 29–31.

Gil, J. 2017. "Street Network Analysis "Edge Effects": Examining the Sensitivity of Centrality Measures to Boundary Conditions." Environment and Planning B: Urban Analytics and City Science 44 (5): 819–836.

Goto, Y. 1993. "A Historical Study on the Construction of Street Network in "Keijo" (Seoul: At Present) (in Japanese)." Historical Studies In Civil Engineering 13: 93–104. doi: 10.2208/journals/1990.13.93.

Grannis, R. 2005. "T-communities: Pedestrian Street Networks and Residential Segregation in Chicago, Los Angeles, and New York." City & Community 4 (3): 295–321. doi: 10.1111/j.1540-6040.2005.00118.x.

Haq, S., and G. Berhie. 2018. "Space Syntax Investigation of Lubbock, a Grid-like American City and Some Insights into Isotropic Layouts." Journal of Urban Design 23 (1): 5–22. doi: 10.1080/13574809.2017.1369872.

Harvey, D. 2004. Paris, Capital of Modernity. New York, NY: Routledge.

Henry, T. 2014. Assimilating Seoul: Japanese Rule and the Politics of Public Space in Colonial Korea, 1910–1945. Berkeley: University of California Press.

Hillier, B. [1996] 2007. Space Is the Machine. Cambridge: Cambridge University Press.

Hillier, B. 2009. "Spatial Sustainability in Cities: Organic Patterns and Sustainable Forms." In Proceedings of the 7th International Space Syntax Symposium, K01:1–K01:20. Royal Institute of Technology (KTH): Stockholm, Sweden.

Hillier, B., R. Burdett, J. Pepponis, and A. Penn. 1987. "Creating Life: Or, Does Architecture Determine Anything?" Architecture & Behaviour 3 (3): 233–250.

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

Hillier, B., and S. lida. 2005. "Network Effects and Psychological Effects: A Theory of Urban Movement." In Proceedings of the 5th International Space Syntax Symposium, 553–564. Delft University of Technology (TU Delft): Delft, Netherlands.

Hillier, B., A. Turner, T. Yang, and H.-T. Park. 2007. "Metric and Topo-geometric Properties of Urban Streets Networks: Some Convergences, Divergences and New Results." In Proceedings of the 6th International Space Syntax Symposium, 001:01–001:21. Istanbul Technical University (ITU): Istanbul, Turkey.

Hillier, B., and L. Vaughan. 2007. "The City as One Thing." Progress in Planning 67 (3): 205–294.

Hillier, B., T. Yang, and A. Turner. 2012. "Normalising Least Angle Choice in Depthmap: And How It Opens up New Perspectives on the Global and Local Analysis of City Space." Journal of Space Syntax 3 (2): 155–193.

Ibrahim, M., and O. Omer. 2014. "Evolution and Changes in the Morphologies of Sudanese Cities." Urban Geography 35 (5): 735–756. doi: 10.1080/02723638.2014.919798.

ICOMOS. 1987. Charter for the Conservation of Historic Towns and Urban Areas (The Washington Charter). Paris, France: ICOMOS.

ICOMOS. 2011. The Valletta Principles for the Safeguarding and Management of Historic Cities, Towns and Urban Areas. Paris, France: ICOMOS.

Jacobs, A. 1993. Great Streets. Cambridge, MA: MIT Press.

Jang, S. 2002. "Korea War and Urbanization in Seoul (in Korean)." City Research 8: 154–191.

Karimi, K. 2000. "Urban Conservation and Spatial Transformation: Preserving the Fragments or Maintaining the 'Spatial Spirit'." Urban Design International 5 (3–4): 221–231. doi: 10.1057/palgrave.udi.9000012.

Khall, H., E. Bileha, and H. Mortada. 2016. "Urban Conservation of the Historic City of Jugol, Ethiopia: A Syntactic Approach." WIT Transactions on the Built Environment 159: 149–160.

Kim, H.-K., and D.-W. Sohn. 2002. "An Analysis of the Relationship between Land Use Density of Office Buildings and Urban Street Configuration: Case Studies of Two Areas in Seoul by Space Syntax Analysis." Cities 19 (6): 409–418. doi: 10.1016/S0264-2751(02)00071-9.

Kim, K. 1995. “Study on the Urban Planning of the Early Stages of the Japanese Occupation Period: Focusing on the District Rarrangement of Gyeyongsong (in Korean).” The Journal of Seoul Studies 6: 41–66.

Kostof, S. 1991. The City Shaped: Urban Patterns and Meanings through History. Boston, MA: Bulfinch.

Kropf, K. 2009. "Aspects of Urban Form." Urban Morphology 13 (2): 105–120.

Kwon, Y. 2003. "The Spatial Structure of ‘Hanseongbu’ in Late Joseon Dynasty." Unpublished doctoral diss. (in Korean), Seoul National University, Seoul.

Kwon, Y., B. Jeon, and S. Kim. 2015. "The Seventeenth-century Transition of Seoul’s Spatial Structure to Functional Pragmatism." Journal of Asian Architecture and Building Engineering 14 (2): 419–426. doi: 10.3130/jaabe.14.419.

Larkham, P. 1996. Conservation and the City. London: Routledge.

Lee, E.-A., and J.-H. Shim. 2013. "The Relationship between the Urban Policy during Japanese Ruling Era and Its Actual Influence to Seoul’s Urban Structure (in Korean)." Journal of the Urban Design Institute of Korea 14 (2): 71–80.

Lee, J.-S. 2007. "Neighborhood and Population Changes in Seoul during the Period of Japanese Colonization: Focusing on Residential Segregation by Ethnic Groups from 1925 to 1935 (in Korean)." Seoul and History 69: 301–348.

Liu, X., and B. Jiang. 2012. "Defining and Generating Axial Lines from Street Center Lines for Better Understanding of Urban Morphologies." International Journal of Geographical Information Science 26 (8): 1521–1532. doi: 10.1080/13658816.2011.643800.

Lynch, K. 1984. Good City Form. Cambridge, MA: MIT Press.
Marefat, M. 1988. “Building to Power: Architecture of Tehran 1921–1941.” Unpublished doctoral diss., Massachusetts Institute of Technology, Cambridge, MA.

Matthews, J. and G. Turnbull. 2007. “Neighborhood Street Layout and Property Value: The Interaction of Accessibility and Land Use Mix.” The Journal of Real Estate Finance and Economics 35 (2): 111–141. doi:10.1007/s11146-007-9035-9.

Millan-Gómez, A., F. Mella, and D. López-Morenro. 2012. “Organic and Inorganic Overlapping in Old Barcelona.” In Proceedings of the 8th International Space Syntax Symposium, 8035:1–8035:20. Pontificia Universidad Católica de Chile (PUC): Santiago de Chile, Chile.

Movahed, K. 2006. “The Mechanism of Transformation of Shiraz City from past to Present.” In Proceedings of the 42nd ISoCaRP Congress (page numbers not given). Yıldız Technical University: Istanbul, Turkey.

Oh, C. and Y. Kim. 2015. “Spatial Patterns of Industrial Activities in Seoul under Japanese Colonial Powers: Based on Ethnically Segregated Residential Distribution (in Korean).” Journal of the Korean Cartographic Association 15 (3): 91–100. doi:10.16879/jkca.2015.15.3.091.

Omer, L. and R. Goldblatt. 2016. “Spatial Patterns of Retail Activity and Street Network Structure in New and Traditional Israeli Cities.” Urban Geography 37 (4): 629–649. doi:10.1080/02723638.2015.1101258.

Önder, D. and Y. Gigi. 2010. “Reading Urban Spaces by the Space-syntax Method: A Proposal for the South Halîç Region.” Cities 27 (4): 260–271. doi:10.1016/j.cities.2009.12.006.

Palaiologou, G. 2017. “Urban Morphology and World Heritage Practice.” Urban Morphology 21 (1): 83–96.

Park, H.-Y. 2014. “A Study on the Power and Change of Space: With Focus on Jeong-dong from the Korea Empire Period to the Japanese Colonial Period (in Korean).” Studies in Urban Humanities 6 (2): 245–288.

Park, W.-S. and Y.-O. Kim. 2012. “The Transformation of Relationship between Spatial Configuration and Commercial Area in Modern Seoul (in Korean).” Journal of the Architectural Institute of Korea - Planning & Design 28 (10): 291–299.

Penn, A. 2003. “Space Syntax and Spatial Cognition: Or Why the Axial Line?” Environment and Behavior 35 (1): 30–65. doi:10.1177/0013874302238864.

Ratti, C. 2004. “Space Syntax: Some Inconsistencies.” Environment and Planning B: Planning and Design 31 (4): 487–499. doi:10.1068/b3019.

Rifaat, S., R. Tay, and A. de Barros. 2012. “Urban Street Pattern and Pedestrian Traffic Safety.” Journal of Urban Design 17 (3): 337–352. doi:10.1080/13574809.2012.683398.

Rodwell, D. 2009. “Urban Morphology, Historic Urban Landscapes and the Management of Historic Cities.” Urban Morphology 13 (1): 78–79.

Shafii, A. and A. Murayama. 2013. “Changes in the Traditional Urban Form and the Social Sustainability of Contemporary Cities: A Case Study of Iranian Cities.” Habitat International 38: 126–134. doi:10.1016/j.habitatint.2012.05.007.

Shamarin, S. and M. Kamruzzaman. 2018. “Meta-analysis of the Relationships between Space Syntax Measures and Pedestrian Movement.” Transport Reviews 38 (4): 524–550. doi:10.1080/01441647.2017.1363101.

Shen, Y. and K. Karimi. 2018. “Urban Evolution as a Spatio Functional Interaction Process: The Case of Central Shanghai.” Journal of Urban Design 23 (1): 42–70. doi:10.1080/13574809.2017.1337496.

Sim, K.-M. 2010. “The Change of Urban Fabric Resulted from the Urban Planning in Jongno Street, Seoul in the 20th Century.” Unpublished doctoral diss. (in Korean), University of Seoul, Seoul.

Sitte, C. 1986. City Planning according to Artistic Principles. Translated by George Collins and Christiane Collins. New York, NY: Rizzoli International.

Son, J. 1990. Study on Urban Planning during the Japanese Colonial Era (in Korean). Seoul: Iljisa.

Son, J. 2003. Tales on Urban Planning of Seoul: A Record of Tumultuous 50 Years (in Korean). Seoul: Hanul.

Summers, L. and S. Johnson. 2017. “Does the Configuration of the Street Network Influence Where Outdoor Serious Violence Takes Place? Using Space Syntax to Test Crime Pattern Theory.” Journal of Quantitative Criminology 33 (2): 397–420. doi:10.1007/s10940-016-9306-9.

Takakoshi, M., S. Nishiura, and T. Kobayashi. 2016. “Quantitative Evaluation of Space Structures Defined by Space Syntax Theory and Categorized by Indexes of Compactness: Analysis of the Data of the Cities Whose Population Is More than 100,000 (in Japanese).” Journal of the City Planning Institute of Japan 51 (3): 459–465.

Thomas, R. 2018. “Conservation, Heritage and Urban Morphology - Further Thoughts.” Urban Morphology 22 (1): 71–73.

Tourner, A. 2001. “Angular Analysis.” In Proceedings of the 3rd International Space Syntax Symposium, 30.1–30.11. Georgia Institute of Technology: Atlanta, GA, United States.

Turner, A. 2004. Depthmap 4: A Researcher’s Handbook. London: Bartlett School of Graduate Studies, UCL.

Turner, A. 2007. “From Axial to Road-Centre Lines: A New Representation for Space Syntax and A New Model of Route Choice for Transport Network Analysis.” Environment and Planning B: Planning and Design 34 (3): 539–555. doi:10.1068/b32067.

UNESCO. 2005. Vienna Memorandum on “World Heritage and Contemporary Architecture - Managing the Historic Urban Landscape”. Paris: UNESCO World Heritage Centre.

Whitehand, J. W. R. 2015. “Conservation, Heritage and Urban Morphology.” Urban Morphology 19 (2): 115–116.

Whitehand, J. W. R., K. Gu, S. Whitehand, and J. Zhang. 2011. “Urban Morphology and Conservation in China.” Cities 28: 171–185. doi:10.1016/j.cities.2010.12.001.

Whitehand, J. W. R., and K. Gu. 2010. “Conserving Urban Landscape Heritage: A Geographical Approach.” Procedia Social and Behavioral Sciences 2: 6948–6953. doi:10.1016/j.sbspro.2010.05.047.

Wu, F., and S. He. 2005. “Changes in Traditional Urban Areas and Impacts of Urban Redevelopment: A Case Study of Three Neighbourhoods in Nanjing, China.” Tijdschrift Voor Economische En Sociale Geografie 96 (1): 75–95. doi:10.1111/j.1467-9663.2005.00440.x.

Xia, X. 2013. “A Comparison Study on A Set of Space Syntax Based Methods: Applying Metric, Topological and Angular Analysis to Natural Streets, Axial Lines and Axial Segments.” Unpublished master’s thesis, University of Gâvle, Gâvle.

Xie, J. and T. Heath. 2017. “Conservation and Revitalization of Historic Streets in China: Pingjiang Street Suzhou.” Journal of Urban Design 22 (4): 455–476. doi:10.1080/13574809.2016.1176587.

Yu, S.-K., and K.-M. Kim. 2017. “The Process of Being a Middle-upper Class Town of Northeastern Areas within Seoul City Wall during the Japanese Colonization Period (in Korean).” Seoul and History 97: 161–213.