AN EVOLVEMENT MODEL FOR A METROPOLIS:
a case study on the evolution of spatial and functional patterns of Beijing city

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Abstract
The urban area of Beijing has sharply increased during the last decades. To better understand the mechanism and the nature of the metropolitan evolvement, this study explores and elucidates the evolution of spatial and functional patterns of Beijing, and investigates the relationship between urban spatial and functional patterns throughout this evolution process. In the thesis, spatial pattern is taken into account most, the morphology of urban network and the function pattern focused on land-use pattern. Syntactical analysis together with classical comparative methods will be used for a fundamental understanding of Beijing’s morphological evolution process. The syntactical analysis of the three phases of the metropolitan morphology, the 980s, the 1990s and the 2000s, will be conducted. By doing so, the essential changes in spatial characteristics of Beijing during its evolution will be revealed, and some valuable information about functional clusters of metropolitan area is derived. The analysis suggested syntactic difference during space evolution process may account for the different functional patterns. Moreover, certain transformations in metropolitan structure that occurred under the socialist regime are proven to have significant effects on the whole configuration of the system.

Introduction
Beijing city has a history of more than 3,000 years, and has functioned as capital for more than 850 years. What makes Beijing distinctive among the world cities is its dual characteristics of traditional grace and modern charm. On the one hand, it is the center of political, historical and cultural activities and the central node of international connections with an urban population of more than 15 million. On the other hand, it is a famous ancient capital in the world abundant with traditional heritage. As one of the metropolises in China, Beijing’s urban character and function have significant effects on urban spatial evolution, which makes the development pattern of Beijing differ from other Chinese cities to some extent.

Under the background of wide discussion and prediction about Beijing’s development, this paper aims to understand the changes of
the urban form of Beijing city during its evolution from a spatial network perspective, and to further analyze the gradual development mode of urban functions. The subject has been partly inspired by recent concerns for reconsidering Beijing's evolutionary process and its principles of development raised by the fast expansion of urban space in recent decades. Those concerns involve calling for the architectural profession to elaborate on the physical development of the city, taking into account the underlying cultural pattern of its territory, paying attention to the protection of its historical and cultural inheritance and the transition of its functional entities from a global view. Within the spatial layout of a city, the city centre is quite essential for urban functional model, but possibly the most difficult to understand due to various building forms and miscellaneous functions of a city centre. Therefore, another aim of the paper is to investigate whether the functional convergence of city centers directly relates to their spatial configuration.

Based on previous practices under the framework of space syntax theory, quantitative analysis and comparative research are integrated in the research. Space syntax is a space language to describe urban form and structure in a quantitative way and to help interpret the essence and functions of buildings and cities' space. Syntactic analysis has proved to be a valid tool to understand urban layout, which influences the evolution of land use and activity patterns of a city through their effects on movement flows. The advantage of the method chosen is that it becomes possible to reveal the functionality of urban system systematically and objectively only by analyzing urban spatial structure.

**Data and Methodology**

In the light of the main framework, the research explores the evolution process of Beijing from a diachronic perspective. In order to explain the evolution of urban space, we compare the maps of syntactical analysis in different years, in which the structure and the evolution of the old central city are clearly shown and its difference from the surrounding urban structure is outstanding. Moreover, some social and economical archives and documents are reviewed and analyzed in the research. Historical maps of Beijing city in 1982, 1993 and 2003 are mainly used as axial maps to represent the urban grid and to expound its configuration. Radius_n (global integration) and Radius_3 (local integration) are taken for the syntactical analysis of all the axial maps and each axial line is analyzed with the same radius so as to minimize the dispersing tendency (edge-effect) of the edges of spatial system and optimize the global analysis of urban space. This analysis suggests that each axial line is analyzed at the same radius, and thus the global analysis is maximized while the tendency that the edges of the system have towards segregation (edge-effect) is minimized (Hillier, 1996).

Having analyzed the historical spatial evolution of Beijing city, the study focuses on mapping what is known as the functional pattern. As far as the land use is concerned, the administrative, the cultural and the commercial functions are emphasized for Beijing as a metropolis, which are related to the governmental policy to some extent. The retail industry and marketing are also identified as major city functions, which are strongly connected to the concept of a "living centre" and bound up with "natural movement". The latter are distinguished from the main central administration function of Beijing, in terms of the specific spatial conditions required and the developed spatial environment that the conditions generate. Hence, all the external functional patterns like retail, commerce, administration and culture, are employed in this study.
Syntactical Analysis: Methods and Findings

Syntactical characteristics are analyzed to discover syntactic difference between the systems in different years by virtue of integration of lines, as discussed in previous studies (Irini, 2003). Generally axial map analysis includes the global integration rad_n and the local integration rad_3. Rad_n could represent the degree of convergence and dispersion of axial lines and other types of space in a system, while rad_3 is applied to comprehend the local grid, which can be indicative for the “living centre” of a settlement region. Since the study has drawn upon the evolution functional pattern of Beijing, its spatial pattern was analyzed as a continuous system. The syntactic analysis of different years has shown that there are some syntactic differences among these years, which are better described by the measures of syntax. Some tables (Table 1) and scattergrams (Fig 2, 4, 5) show the change of syntactic parameters throughout Beijing’s evolution process monitored in the research. The axial maps of the three chosen city plans were investigated to draw geometric and topological properties and logical structural transition of urban space at different times. These geometric characteristics of urban space configuration are consistently reflected in syntactic maps.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean global integration</th>
<th>Mean local integration</th>
<th>Mean Depth</th>
<th>Mean Depth R3</th>
<th>Mean Conn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>1.293</td>
<td>1.779</td>
<td>8.165</td>
<td>2.531</td>
<td>3.218</td>
</tr>
<tr>
<td>1993(old city)</td>
<td>1.297</td>
<td>1.772</td>
<td>7.907</td>
<td>2.535</td>
<td>3.185</td>
</tr>
<tr>
<td>1993</td>
<td>1.171</td>
<td>1.711</td>
<td>9.094</td>
<td>2.509</td>
<td>3.085</td>
</tr>
</tbody>
</table>

The axial model of 1982 appears to be “griddy” and displays very clear urban venation (Fig 1). The primary configuration of Beijing is formed by the east-west axis and the south-north axis both of which begin from the Forbidden City. Urban structure is endowed with rigorous geometrical form, and the former main south-north axis divided symmetrically the city into two parts. That is to say, the spatial properties and its expression of the historic monarchic city are imprinted continually in the urban space of Beijing. The fabric of traditional Hutong is showed legibly on the axial map 1982. As a particular identity of Beijing city, Hutong space contributes to create a fine grained, well connected, and diverse urban fabric for the traditional neighborhoods of Beijing. Most of Hutongs concentrate relatively in the north of the Forbidden City within the inner city (old city). The perpendicular intersection of urban spatial order terminates at the Hutong area, and the regular road network is decomposed into the labyrinth bystreets. From the axial map, the fabric of Beijing presents a kind of dualism, on the one hand there are clear urban axes and the main street network (the light axes in the map), on the other hand there are anfractuous micro-structure in the residential area (the dark axes in the map). From the point of view of urban transportation, the city lacked of urban trunk roads in the west-to-eastern direction through the city. The close courtyard of the Forbidden City segments the street system to some extent and influences the integrity of the street system. Furthermore, the spatial difference between the northern part and the southern part of the city is displayed explicitly on the axial map. The degree of integrity of the northern city is higher than that of the southern city, but the intelligibility and cooperation in the local space of the northern part is worse than that of the southern part.

The rad_n integration analysis of Beijing in 1982, shown in Figure 2, has suggested that its inner city is the expansion of the rad_n integration core. The axial map comprises many short lines ending at other lines, which is found both locally and globally. The rad_n integrators highlighted are not only the dominant integrators, but
almost the longest lines. For example, Chang'an Street is located in the middle of the city and transverses the whole city.

Figure 1:
The Axial Map in 1982
Showing Global Integration Pattern

Beijing’s urban area has expanded greatly in the 1990s (Fig 3) because of the development demand of city itself and the influence of China’s reform and open policy at that time. The spatial change of Beijing could be presented by comparing the axial maps of 1982 and 1993 during the past ten years. Although the built up area had been growing, the structure of the old city was maintained because of the urban development mode of concentric circles. The structure of the old core consisted of some main streets existing for several hundreds years such as Chang’an street, Wangfujing street and Xi’dan street, and has been the dominant integrators whether in the global or local structure. At the same time, some areas in the old city lost their effects gradually at a global scale and transformed into local centers. From a holistic perspective, the pattern of typical single centre in Beijing was presented distinctly, compared to the urban configuration in 1980s. And the courtyard configuration emerges in the syntactical map which
was a special spatial form at the Development Stages of Chinese Socialism. The contemporary settlements around the old city seemed to have grown under the different rules from those formed in the old city. Thus, the axial lines outside the old core have inconsistent geometrical features with those of the old core. However, the old center had a weak connection with the surrounding grid. The “old” and the “new” grid were mainly connected through several ring roads and radial roads.

Compared with the axial maps of Beijing in 1982, one can notice that between 1980s and 1990s the axial density decreased in the old city, and the global integration and the intelligibility of the old city increased because of the disappearance of part of the labyrinthic Hutong (Fig 4). Nevertheless, the global integration and the intelligibility of the axial map in 1993 decreased in the whole city (Fig 5), and it means the whole city had grown more and more complexed and unintelligible in terms of spatial configuration and way-finding performance with the increase of city size.

Figure 3:
Axial Map in 1993 Showing Global Integration Pattern

Figure 4:
Scattergrams showing the correlation between integration and connectivity (intelligibility) of the old city in 1993
The development of Beijing in 2000s decelerated in some sort compared with in 1990s. There are some reasons for this phenomenon and one of important reasons may be the macro-control policy of the central government on land use. The syntactic map (Fig 6) of Beijing in 2003 shows that urban space was maintained and almost intensified its development pattern of typical single centre, though the global topological structure was presented as a form of radiate wheel (Yang, 2006). From the analysis result of urban structure and the local-global relationships based on the analysis map in 2003, we found that the centre of integration, the distribution of integration and the part-whole interrelationship kept least change as well as the spatial difference between the southern and northern parts of the urban system. It is suggested that the spatial pattern of Beijing's historical core of was hold and further the basic framework of the old city was preserved and continued.

The analysis map also demonstrates such a trend of the change in both morphological and configurational measures that morphological simplification results in an incremental process rather than sudden changes. As to micro structure, the spatial transformation of the old city in Beijing, weakens not only the hierarchy of traditional space elements, but makes them considerably more secluded in the whole spatial system. Especially, Hutong fabrics in the historical core were seriously destroyed, and the spatial extent was enlarged much greatly than before. In the whole city space, many small circular roads located between the central radiate streets and the main ring roads (the third and the fourth ring roads) have enriched the city structure. Some of the main ring roads have evolved into the new axes of Beijing city. However, what seems to be interesting regarding the contemporary settlements is that the “living centre” of the urban settlement remains within the old city, the historic core of the city, which comprises more short axial lines intersecting obliquely than the outside grid does. Other long and strong axes, such as Chang'an Street with its prolonged line and Xi'dan Street with its prolonged line etc, connect the old city and the new settlement areas.

The most intuitive geometric differences explained by the characteristics also lead to different syntactic values, which reflect the degree of strong or weak relations of all parts in the urban system. The dualism of Beijing city's fabric demonstrated in the syntactic map continued in 2003. On the one hand, the trunk axes of the whole city that form the urban basic configuration are of high integration comparatively, and on the other hand there are some short labyrinth-like axes of low integration in the new settlements. It is suggested that those new settlements outside the old city have been connected well with the wide roads around, but the inner structures within them are quite complex.
According to space syntax theory, spatial configuration is a reflection of social inputs and configurational differences between structures resulting in spatial analysis are affected by social ideology or policy. The spatial decisions of urban network explored in such studies should be embedded in the logics of understanding and planning city and further city reforms. The morphological analysis on the central areas of Beijing city reviewed in this paper allowed to extract many of the features which can summarize the difficulties and compatibility issues encountered by the old city.

**Functional Analysis: Methods and Findings**

Having analyzed the spatial structures of Beijing during its evolution process, the study focuses on what its functional patterns are and how they transformed or remained almost unchanged over time. Due to limited historical data, the study attempts to investigate the functional aspects of “urban centrality” and “living centrality”, to map the locations of different categorized buildings, like administrative, cultural, commercial buildings, bank and retail shops. Only the distribution of land uses in Beijing city in 1981 and 2003 is studied, since there was no clear evidence of the functional pattern during the 1990s.

The functional analysis of Beijing has shown that the old city remains its dominant and significant role in terms of urban functions and life. The old core has been the main area aggregating urban functions for several centuries since the Ming and Qing Dynasty. According to historical records in the 15th century, the administrative centre, today’s Forbidden city, co-existed with the “living centre” of the city and both were developed along the same axial lines. Meanwhile, the “living centre” of Beijing in 1980s, remains inside the old core and is developed around the historical focal point, and this could be presented in the syntactical map. This kind of distribution of urban functions is influenced by the policy of central government of the time (Fig 7).
As a metropolis, the dominant function of Beijing is its political function which could be revealed in the city layout. The national administrative center Zhongnanhai is located almost in the city's geometrical centre. Some important governmental and commemorative large-scale buildings (such as The Palace of the People, National Historical Museum and many ministries) surround the Tiananmen Square, one of the most famous but the biggest central congregation square for people in the world. Many other administrative and cultural buildings and banks were arranged along the strong lines, i.e., Chang'an Street which is one of the main axes of urban structure and the main artery in city's transportation system, and has the highest global and local integration. It is accordant with Hillier's theory that the syntactical axes with the highest global and local integrator value are of the strongest function of social activity in the city. There are lots of industries distributed dispersedly in the old city, some of which belong to contaminative industry. The commercial land uses do not gather in a large scale, but scatter in different parcels, namely "unit yard". This phenomenon could be explained primarily by the influence of governmental planned economy at that time. And the unit yard is
essentially a living unit primary for people working in one big organization and provides people with all daily facilities including commerce, education, entertainment. The mixed land-use of administration, retail, commerce, residence and industry is the typical land-use pattern for Beijing of that time. Although the function pattern of Beijing in 1980 showed the profound mark of socialistic governmental policy to some extent, it could still be explained by the “movement economy” theory from the point of view of the whole city.

The function pattern of Beijing in 1990 was intensified. Its “living centre” was still located in the old city. Those most important buildings, such as administrative buildings, cultural buildings and banks, were still located on Chang’an Street along with some commercial buildings and tourist shops. Chang’an Street remained to be the main axis that connected the “living centre” of the city and was of the historical and political significance. Urban economy developed rapidly by virtue of the governmental reform at the beginning of 1990s and some commercial streets were developed along with the economic development. For example, Wangfujing, the traditional street has been reconstructed successfully which is located in the global integrator of Beijing. Other important commercial streets, such as Xidan street and Qianmen street, have also been developed, which retain their high integration and significance during urban evolution. What is significant to the functional pattern of Beijing in the 1990s is the fact that there were still streets along which the functions related to the centre were developed, despite the tendency became more centralized in shape due to the intensification of the grid that occurred in and around its centre during its evolution process.

According to the industrial policy of the market economy at the beginning of 1990s, a majority of industry has been transferred out of the old city and these central districts of high integration have been occupied gradually by the third industry which requires favorable area for their development. For some important national and civil building projects have been positioned in the northern city, such as Yayun Village located besides the northern third ring, the difference between the northern and southern part still exists and has a tendency to be intensified. The integration core of the whole city maintains stabilized comparatively in the 2000s. By comparing with the axes of global integrator of Beijing in different years, it is found that some main axes are of high integration all the time which forms the integration core, such as Chang’an street, Wangfujing street and Xidang street. And they are of the core functions of Beijing city, and they bear many important functions and social activities (Fig 8). The old city has been occupied by the land use of the third industry including commerce, culture, information industry, which becomes the dominant function in addition to administration in urban core.

Although the scope of urban space has expanded continuously and the built-up area has gone beyond the boundary of the central city, the primary urban centre functions are still kept in the central city. It means that the core functions of the city did not decentralized with the development of new settlements around the periphery of the old city, but intensified within the extent of the city center. This resulted in the demands for the development of heavy density and intensity in the heart of the city, thus led to the spatial exploitation in three-dimensions including the utilization of urban land use, underground space and space on air. The old city, incorporated into multi-purpose and multi-functional complexes, has become more complex in spatial three-dimension with the increase of size and functional diversity. The current development tendency has been shown to be in conflict with preserving the old city. The function of some main streets with high integration has been changed because of the movement of urban
network during the evolvement. On the one hand, the scale of the centre function is beginning to expand from the old city to the third ring, and on the other hand, some streets of global integrator are strengthened or weakened. An example is the Lóngfūsì Street, whose declining process has to be understood in a large context. Instead, Wángfǔjīng Street has occupied far more strategic location, which is one topological step from Chāng’ān Street, and become a flourishing commercial center with a combination of multiple networks including metro system. Along with some ring and radiate roads being built, the syntactic map shows that the original tree-structure pattern of integration core has turned gradually into the wheel pattern of integration core. It means that these new built roads have evolved into the main axes of high integration with important functions. And the integration is distributed along the newly constructed arteries either hosting representative functions or encircling micro-districts, breaking the organically evolved shape of a “deformed wheel” described by Hiller (2001).

Furthermore, similar to other socialist plans for sub-areas, the new development areas in the city, containing administrative buildings and other facilities for recreation, education, health and commerce, are more segregated and less possible to function as a generator of local movement economy, which goes against planners initial intentions. With a global view to look at land use pattern in urban space, the distribution of land use is strongly related to the pattern of integration in Beijing. The map of the standard land price for commerce shows that the highest land price is located in the Chāng’ān street, Wángfǔjīng and Xīdān street, which are all within the integration core. There is a tendency that land price falls from urban center to urban periphery in accordance with the representation of the syntactic theory. The relation between spatial structure and land use could be explained by the role of movement patterns generated by the morphology of the urban grid.

**Figure 8:**
Land Use Map of Beijing in 2003. The darker area is the concentration of administrative and commercial land uses

It is worth mentioning that the development of the old city in Beijing becomes one substantial part of the settlements of the whole city. Its significance in term of the functions of the whole city can be traced to its history, the interrelationship and the intensification of urban grid,
which have happened during the last decades. Beijing has expanded greatly during the 20th century. The morphology of the grid of the old city is clearly different from that of the new part of the city. The historical core is connected to the new city through the ring roads and radiate roads which have been constructed in recent years. In conclusion, the study suggests that it is the city’s size, density, and its connections to the new city that cause the historical core in Beijing to function as a “city within a city”. During the urban evolution, there are also other characteristics in the old city, which substantiate the influences of spatial structure on the fate of historic cores. Retail activity, for instance, shows a strong dependence on the integration value of urban spaces. Therefore, when the traditional structure is preserved, the important traditional spaces remain economically viable. But when the old structure is destroyed, the spaces to preserve may lose their economic significance and consequently, lose their viability to be productive.

In Beijing, as mentioned earlier, in further development and the newly opened street revealed as the most integrated space by the axial analysis were occupied by administrations, commerce, banking sectors and public spaces, proposing that as an active space, which is similar with the study in most cities in the world. Such a hypothesis could be further analyzed if more old land use maps could be constructed according to written evidence, which was not possible within the time frame of this paper. And if proven correct support the proposal that, the old city grew maximizing the spatial conditions for the functioning of the productive area of the city, using space properly.

**Discussion and Conclusion**

The study has tried to pinpoint the evolution of Beijing in terms of its functional and spatial patterns. The spatial analysis has revealed that Beijing followed some rules of growth, which was reflected in the morphology of its grid, manifested by the syntactical analysis of contemporary settlements. The syntactic analysis of Beijing in several years showed that its old city has retained its significance as a focal point of the city. The grid inside the inner city is part of the extensive integration core of the whole city. Having been built around the old city, the ring roads have been evolved gradually as important axes of the whole city. As some scholars have pointed out in the studies of other cities, the change of Beijing is not only in the morphological shape but also in the spatial significance of the parts of the city to the rest of it, a phenomenon of “urban evisceration”, and the integration cores having to rely on trans-spatial means of attraction. Syntactic measures have additionally concurred to the diagnosis of un-intelligibility of the city centre and of the city as a whole. During the evolution of Beijing, the old city is becoming more intelligible to strangers, whereas the whole city is becoming more unintelligible. Spatial patterns have been suggestive for the functional patterns. The function pattern of Beijing during the decades from the 1980s to the 2000s describes the old city as the place where the urban buzz is located. Unlike other historical cities, Beijing retains its historical core as its main functional core, and also its “living center”. Though the development of Beijing has been influenced by socialistic governmental policy in China, the functional core that is still associated strongly with natural movement was described by the integration analysis of Beijing during its evolvement. This true-to life spatial pattern seems to have been very suggestive for the functional and current movement patterns of the city.

The study shows that if in an organically development city spatial configuration had the essential role of providing a necessary basis for the functioning of the city as an economically sustainable centre, socialist modernization and urbanization caused a power relationship
between centre and servant local structures, where the ideology is the force that overcomes space as generator of social interface. In light of the present study and in the context of previous known concerns as the competition launched having as a subject the development of the city centre, it could be stated that the city’s structure needs to and could be improved and particularly, local strategies may be developed to support the global supergrid structure. According to the studied cases regarding the centrality of the new centres it was conclude by Jiang and Peponis (2005) that a logic of evolution applied equally to planned centrality and emergent district centrality, includes further fragmentation of the system. For Beijing, the study is worth of being referenced for building multi-centre in urban space. It also could be concluded that a finer scale of the grid closer to the neighbouring central structure might be beneficial.

With the growing concerns about the sustainability of urban environments in an urbanizing world for Beijing, the conservation for the old city is another very important problem. Space syntax has been presented as a new approach to the concept of urban conservation by prioritizing the issue of urban context and spatial transformation. Urban conservation in recent decades has been more attracted toward dynamic conservation which aims to preserve the physical characteristics of the old cores as the focal point of history, polity and culture in the modern cities as well as the centre for creating life, activity and social-economic viability. Thus conservation is not only about the individual building and places and it is more about the relationship between the spatial components of urban system. The essence of these relationships, the “spatial spirit” is an invisible power which controls the organization and utility of the historic core (Karimi, 1999). For the development of Beijing in the future, a very important step is protecting the unique spatial system of the old city, or the “spatial spirit”, which creates the relationship among the component and functions of the urban system. The important lesson from history is that before engaging in any detailed process of conservation, a basic knowledge of the spatial harmony between the past and present is needed, otherwise the past loses it logic, and consequently its viability to be conserved, or the new cannot find its appropriate place to function.

Acknowledgment: This paper is supported by the Science Foundation for Post-doctor of China (20060400064), Beijing Natural Science Foundation (4063038), and Tsinghua University Sustainable Urban Mobility Project.

Reference


i. The syntactic map of Beijing in 2000s is referenced the analysis of Yang