Evolving syntactic structures of Baghdad: 
Introducing ‘transect’ as a way to study morphological evolution

Abstract
Most Middle Eastern cities have evolved in a spontaneous manner with a high degree of complexity. Later, many of them were expanded using modern planning concepts and models. Between the two phases, different patterns of spatial structures have formed. The main purpose of this study is to identify syntactic variations in the urban structures of different morphological phases of a typical Middle Eastern city, Baghdad, using space syntax techniques at different scales, extending from districts to quarters to neighborhoods. The study is important, because with the exception of a few studies (Hiller, 2008; Karimi, 1997, 1999; Karimi and Motamed, 2003; Rashid and Shateh, 2012), studies on the evolution of Middle Eastern cities using space syntax techniques are still rare.

Baghdad has been selected as a case study not only because it is one of the oldest cities in the region, but also because it has observed phenomenal growth and change during the last one hundred years or so. Syntactic properties of the urban structures of this city are examined both diachronically and synchronically. Diachronically, the evolution of syntactic structures of the historic core, Old Baghdad, is studied for a period that spans over 1500 years. Synchronically, the city is divided into a set of meaningful segments, called ‘transects,’ in order to make the study more manageable.

For the study, several historical maps are overlaid in GIS using georeferencing based on important landmarks and streets that did not change from one historical phase to another. Along with the shapes of the syntactic cores, two measures of space syntax – integration and choice – are used to describe syntactic properties of the study area within one transect containing Old Baghdad. Changing syntactic structures are examined and compared at the scales of quarters and neighborhoods.

Findings of the study raise interesting issues regarding syntactic properties and land use patterns at different scales, both synchronically and diachronically, in Baghdad, indicating need for further studies along this line in this and other Middle Eastern cities.

Keywords
Syntactic structure, diachronic, synchronous, transect, space syntax, Baghdad
1. Introduction

Cities in the Middle East region are different from western cities. The urban form and structure of these cities appear more complex than their western counterparts at different scales. Most Middle Eastern cities primarily have evolved in a spontaneous manner. The formation of spontaneous growth refers to the spread of various patterns of building forms without pre-planned concepts. It shapes urban forms randomly on the basis of the needs and desires of the society as well as spatial potentials in different periods of time (Kostof, 1991; Hourani and Stern, 1970). This type of growth is characterized by compact urban clusters, human scale, mixed uses, cul-de-sacs and zigzag street networks with irregular widths and is thus known as organic (Fethi, 1977; Hakim, 1986).

In contrast, the majority of modern influences in urban design and planning in this region were undertaken by the European colonial powers that re-shaped infrastructure of these cities to control and manage both social and economic resources when they occupied that region after the World War I and II (Pieri, 2008; Rashid and Shateh, 2012). Since the early periods of twentieth century, many modern planning and urban renewal programs have involved the relocation of economic cores, the demolition of existing structures, the construction of street networks, and the redistribution public services and residential clusters to manage urban development, and Baghdad is not an exception.

For aforementioned reasons, the basic spatial and physical configurations, such as, open spaces, street networks, plots, and building structures have changed and formed different patterns of urban structures from the city center to the periphery over time. In order to understand these structures, we have to explore the origins and shifts of urban forms and structures.

Space syntax literature on the morphology of the urban core, especially historic nuclei, of the Middle East cities presents studies on the logic of spatial organization in organic cities (Karimi, 1997), on urban conservation describing transformational roles of traditional structures over time (Karimi, 1999), on the comparison between organic growth and modern urban planning influences in the development of historic cores (Karimi and Motamed, 2003), and on the influences of power in reframing spatial-physical structures of the urban core (Rashid and Shateh, 2012). However, space syntax studies examining the origins, shifts, and developments of urban grids are rare (Griffiths et al., 2010; Haynie and Peponis, 2009). Similar studies of a typical Middle Eastern city, diachronically (over time) and synchronically (in the same time) are still missing. This study aims to fill in this gap. It uses space syntax techniques to develop a framework of a comparative approach based on ‘transect’ to study cities in this region. Since the study uses Baghdad as an example of a typical Middle Eastern city, a brief review of its historical evolution seems necessary in the next section.

2. Forming urban structures of Baghdad

Baghdad, Iraq has been selected as a case study not only because it is one of the oldest cities in the region, but also because it has observed phenomenal growth and change during the last century or so. Though the emergence of Baghdad has a complex history (Al-Ashab, 1974), this study will focus on reviewing important changes and shifts of the city. Baghdad has nearly always maintained its supremacy as the most important urban center in Iraq. It is one of the most significant remaining examples of Arab-Islamic cities that contain valuable variety of traditional fabrics and artifacts indicating different historical phases of Muslim Civilization (Fethi, 1979). It was primarily founded with a high sense of geopolitical planning that later underwent spontaneous growth and finally expanded with modern planning concepts (Al-Ashab, 1974; Pieri, 2008).
The Round City of Baghdad is clearly a good example of a planned city (Figure 1). It was founded by Caliph al-Mansur in 762 CE as a capital for the Abbasid Caliphate (750–1258 CE) for geopolitical, socioeconomical, and cosmological reasons. The city plan contained four main gates, huge double walls with ditches and cylinder towers, circular-residential sectors, streets, and bazaars (Hourani and Stern, 1970). Today, the Round City no longer exists. In 772, Caliph al-Mansour ordered the bazaars to move from the city to the suburbia area that became al-Karkh and which, in turn, became a global commercial place. The growth expanded to surround the Round City and continuously occupied new lands on the East bank of the River Tigris to form what was called later al-Rusafa in the eleventh century. Both al-Karkh and al-Rusafa are considered to be the original roots of current Baghdad (Al-Ashab, 1974; Fethi, 1977). To illustrate the process of evolution of these roots, four historical morphological phases have been identified for diachronic examinations. In contrast, the synchronic examinations have been limited to the current phase of Baghdad.

- **Formation (1055):** In this period, the final shape of urbanization and the walls of Old Baghdad was accomplished, and the city fringe belts were formed outside of the city walls in the east. However, the city size was reduced significantly in the west (Al-Ashab, 1974).
- **Densification (1055-1854):** After the city form and walls were completed, commercial buildings, bazaars, and residential neighborhoods had spread irregularly and rapidly from important landmarks, including mosques and shrines, to the city edges (Fethi, 1977).
- **Modernization (1920s-1940s):** The most important characteristic of this period included the building of modern street networks by the colonial power. These streets re-structured the city. They passed through traditional urban fabrics and connected the city edges with the center. By the end of the World War II, the inner city was gradually connected to the suburbs after the city walls were removed (Pieri, 2008).
- **Modern Expansion (1950s-2000s):** The rapid modern growth has continued and occurred in a rectilinear direction and perpendicularly on the East bank of the Tigris. The growth during al-Ba’ath regime period (1968-2003) was characterized by increasing grid patterns in different directions and shaping new residential neighborhoods.
- **Urban Explosion (2003-present):** After democracy arrived in 2003, significant morphological changes happened in the city. Many open spaces, parks, orchards, and green areas have been removed by the Municipality of Baghdad and instead they are now built areas. Streets have been widened at the expense of sidewalks and pedestrian paths. Many urban squares have...
been modified to become traffic intersections or bridges. In addition, many urban squatters have been built in the north, northeast, and southwest suburbs. A state of urban chaos ensued because of changes in land use patterns and physical structures.

3. Research framework for the present study

Among the scientific methods that serve purposes of this study, first we discuss the ‘transect’. Transect, as a technique, was initially introduced by Geddes (1915) as a natural law that can be observed anywhere and everywhere. It is a cut system that forms a path along which one observes and records occurrences of the phenomena of study. For example, different patterns of spatial layouts including streets and open spaces can be precisely observed by walking from city center to the periphery. Recently, it was re-introduced by Duany as an instrument of design (Duany and Talen, 2002).

For this study, transect provides the means of a comparative approach between urban structures at different scales over time for a better understanding of the patterns of growth and the process of formation (Conzen, 1960; Southworth and Owens, 1993). In this regard, our morphological study at the scales of districts, quarters, and neighborhoods hopes to show how the spatial morphology of Baghdad has changed at different scales from its center to the periphery over time.

To further enhance our study, we use ‘space syntax’, which provides a set of theories, techniques, and measures used for studying the syntactic structure of the networks of physical spaces. It was developed by Hillier and Hanson (1984), and was later elaborated by Hillier (original1996; reprint 2007). The important techniques of space syntax that have been applied to describe various relationships between spatial layouts and movement, social forms, building structures, plots configurations, and land use distributions are the axial and segment map analysis. Both techniques represent spatial networks by generating an axial map that includes a set of minimum number of interconnected straight lines that cover all streets and open spaces. This map also can generate another map called the segment map, which is formed by breaking down each axial line at the intersections with other lines. After this, software program such as depthmapX can be used to determine such syntactic measures as connectivity, integration, choice, and entropy of each line and the map.

Integration, an important measure of space syntax, indicates how accessible/connected a line is in relation to all other lines in the map. Therefore, high integration values indicate lines that have better connections, while low values indicate lines that have fewer connections with other lines. Integration values are represented graphically on the map by using colors that range from the red colors referring to highly integrated streets to the blue colors referring to the segregated lines in the axial map. Integration values can be computed at different radii. For example, the integration value at radius-3 (R3) of a line uses only those lines that are three steps away for the given line; the integration value at radius-5 (R5) uses only those lines that are five steps away for the given line; and so on. The integration value at radius-n of a line considers n-steps (Rn) needed to cover all the lines in the whole system. Therefore, the integration value computed at a lower radius describes more local syntactic property than that computed at a higher radius. Note, however, that the most local of any syntactic property of a line is its connectivity value, which is the number of lines directly connected to the line.

Another key measure of space syntax is choice. Unlike integration, choice gives the degree to which a line lies on simplest paths from one line to another line in the network system. While the choice value of a given axial line is determined by dividing the number of the shortest paths between any two lines in the axial map containing the given line divided by all the shortest paths between any two lines in the map, the choice value of a segment is calculated by replacing shortest paths with paths that have the
lowest angular cost for each possible origin and destination pair of segments on the given segment (Turner, 2007).

In simple words, integration measures how easy it is to go one line to all other lines of the network system, thus indicating the potential of a line for to-movement. In contrast, choice measures how likely is it for a line to be chosen on paths from one line to another in the network system indicating its potential for through-movement (Hillier, 2005). Clearly, what is implied here is that in to-movements people want to maximize their accessibility to all spaces and in through-movements people use a space to get to another space with minimum efforts.

4. Morphological Analysis

For the purpose of this study, as noted before, five historical phases of the growth of Baghdad were identified that show significant morphological variations at different scales of the city. Since Baghdad is a huge city, it was divided into historically meaningful segments called transects, each almost 21 kilometers (13 miles) long, for this study. The first transect, extending from the northwest to the southeast, includes the historical development located along the two banks of the River Tigris. The second transect, extending from the northeast to the southwest to represent the rapid modern expansion, includes areas which was started in the late 1950s and was mostly completed by the middle of the 1990s. Both transects intersect in the Old Baghdad area, and thus each one is divided into two new parts: northwest transect (NWT), southeast transect (SET), northeast transect (NET), and southwest transect (SWT) (Figure 2).

Significant urban variations with regard to spatial and physical forms, plots, and land use distributions are found in the aforementioned four transects. For example, historic urbanized areas that were primarily founded in the eleventh century and gradually developed until the middle of the eighteenth century such as al-Kadhimiya, al-Adhamiyah, al-Karkh and al-Rusafa are found in the NWT. Areas that were primarily established in the early periods of the twentieth century and then were expanded during the 1940s are found in the SET. Areas mostly established by the middle of the 1950s and rapidly developed by the end of the 1990s appear inside the limits of the NET. Finally, the SWT accommodates most areas that were developed after the 1960s. The latter transect also includes a set of quarters that are characterized by modern networks, monumental architecture, large size of plots, and a good infrastructure expressing a sense of prosperity.

The study described here examines only the historic nucleus of the city, Old Baghdad, with a history spanning over a period of 1500 years. All the historical maps of Baghdad since its establishment were digitized and were overlaid onto each other using georeferencing based on important landmarks and streets that did not change from one historical phase to another (Figure 2). However, it should be noted here that some parts of these maps do not match onto each other entirely because of the differences in the projection coordinate systems; as a result, remains as a limitation of the study.
As noted earlier, this study uses the following three scales: districts, quarters, and neighborhoods to examine syntactic structures found in Old Baghdad. The diachronic examination is confined at the district scale of four morphological phases because of a lack of historic data and details of quarters and neighborhood. Synchronic examinations of morphological properties are conducted at the scales of quarters and neighborhoods of the current morphological phase. A brief description of these morphological studies at each of the three spatial scales is given below:

- The district scale analyses large areas of urban structures to see how they grew and developed at different periods. At this scale, we explore developments of spatial and land use patterns to show the evolution and direction of the city (Figure 2). This scale includes an area, Old Baghdad and its peripheral areas, measuring 441 sq. km (169 sq. miles). Since movement, accessibility to and between urban spaces, is a key factor in defining urban structures in the city, the axial segment analyses can be used to define the syntactic properties of these spatial structures.
- Next, we observe how quarters are characterized by spatial forms and structures, which are divided as organic, transitional (hybrid), and modern types. These quarters are defined by the political-administrative borders of the Municipality of Baghdad.
- At the lowest level we study neighborhoods. The neighborhoods are characteristically classified into three sets: organic, transitional, and modern in relation to the patterns of streets, plots, and buildings. The axial and segment analyses focus on residential neighborhoods, defined based on political-administrative boundaries of the Municipality of Baghdad.

5. Results and discussion

Results are divided into two main groups: the first group includes the results of the diachronic studies of the four historic phases of Old Baghdad; and the second group includes the results of the synchronic comparisons between different sets of quarters and neighborhoods of the current phase of the city of Baghdad.
5.1. Diachronic evolution of land use patterns

During the diachronic evolution of four morphological phases, we observe two distinct patterns of land use, which are described below:

Strip Commercial and Fragmented Residential: The beginnings of the first urban clusters of Baghdad in the two early historic phases show relatively similar patterns of land use. The first phase, in 1055, indicated that the commercial distribution for both bazaars and small shops occupied the strip areas on the two banks of the River Tigris. Institutional and religious buildings were limited at that time and distributed in a scattered manner (Figure 3). Residential neighborhoods in the second morphological phase expanded and included more institutional and religious entities, which are illustrated by both the rapid growth and increased population. Large areas of handicraft markets, animals’ markets, and seasonal transactions have taken place next to the walls of the old city and shaped a huge fringe belt (Figure 3). Patterns of commercial and mixed use are still located close to the river, but increased gradually at the expense of adjacent residential clusters and open spaces. New patterns of commercial activities have concentrated around certain main paths within large subdivisions. This development was occurred in the north, which is far away from the riverbanks.

Concentrated Commercial and Continuous Residential Patterns: The last phases that span from the 1920s to the middle periods of the twentieth century are good examples of modern land use planning (Figure 4). The separation of land use is formed by adopting city planners zoning concept during new extensions started in the early 1940s and continues to date. Commercial activities take place around the main streets in the Central Business District (CBD) in and around the historic fabrics in Old Baghdad. Many residential clusters that are adjacent to the CBD have changed to mixed uses in the 1950s. A scatter pattern of institutional, cultural, and religious entities are distributed in the CBD and around its edges. Open spaces and urban squares are created for social interactions and are used as transitional areas between mixed-use areas. Improvements in transportation and communication cause the old fringe belt of industrial activities to grow towards the northeast and to include new small factories, car workshops, and warehouses. Numerous residential neighborhoods with their schools and cultural centers have rapidly filled in next to the fringe belt and towards southeast and northeast.
According to the results, the Old Baghdad includes a range of complementary land uses, including residential functions occupying upper floors, small shops and cafes, bazaars, religious entities, and urban squares for gathering people. The distribution of mixed land uses are encouraged by compact clusters, including short twisted blocks and zigzag street networks, and the walkable environment. In contrast, a separation in land uses can be seen in modern urban areas at the center, at the periphery, and in the in-between spaces.

5.2. Diachronic evolution of syntactic structures

One cannot understand the development of a city without taking into account its earlier forms of evolution that goes back to original ones, or their traces. Origins of forms can reveal linkages with their components or with other aspects of the processes of formation over time and across space (Mumford, 1956). As such, the configuration of space can be used to study urban structures in relation with land use distribution over a span of time (Rashid and Shateh, 2012). To illustrate the point, space syntax analysis is used to model the spatial configurations of urban spaces of Baghdad. Four maps for the historic phases of the city are generated in order to show how the patterns of integration and choice of syntactic structures change from one phase to another.
Figure 5: Analysed maps using integration ($R_n$) and choice ($R_n$) of syntactic structures of the diachronic evolution including four historical phases: 1055, 1854, 1944, and 1958.
In the first phase, the axial map, colored using integration measures at the global level (Rn), shows that the well-connected streets are limited and concentrated in al-Rusafa region, near the riverbank. The bridge between the two areas, al-Rusafa and al-Karkh, is defined as the most connected road in Old Baghdad. The segment map analysis shows similar results that defined the bridge as the path with the highest choice value. Streets with high integration and choice in the areas contain commercial and mixed uses, and are characterized by short and twisted street networks (Figure 5).

In the second phase, the axial map analysis shows a significant increase in the number of connected streets in the same area because of development and expansion occurred due to rapid growth in economy and population. Streets with high values of integration and choice measures are distributed between commercial and mixed uses with the exception of some streets in the segment map that connects residential clusters with commercial mixed uses. The axial map showed that the integration core has moved slightly to the northeast side, and most connected streets are centered in al-Rusafa region only (Figure 5).

With modern expansion during the third phase, straight modern roads that connect Old Baghdad with modern clusters, particularly in al-Rusafa, become very well-connected streets. In addition, the old bridge becomes, once again, one of the most integrated streets. In this phase, streets with high choice values mostly include long modern streets that pass through historic clusters, the old brigade, and a group of highways streets, which pass along outer boundaries of historic clusters in the two parts of the city. According to the land use maps, while integrated streets (i.e., roads with high integration values) are distributed between or around commercial and mixed uses, streets with high choice values are used to connect residential areas in suburbs with the commercial cores (Figure 5).

Integrated streets in the fourth phase move, for the first time, from the historic core into new modern areas. They divide and connect quarters of Old Baghdad, and extend towards modern extensions in the southeast. Bridges connecting the two parts of Old Baghdad become very integrated in the axial map. The segment analysis shows that the chosen streets remain in their original locations linking the two parts of the city on the riverbanks and surrounding the original historic clusters in al-Rusafa. Few streets with high choice values, however, are found towards north and west in the new suburbs. Streets with high values of integration are located on the borders of mixed uses’ zones in Old Baghdad (Figure 5).

5.3. Synchronic examinations of syntactic structures

Since the beginning of the 1990s and to date, though the majority of the physical infrastructure and historic clusters of Old Baghdad has remained constant, significant changes at the scales of quarters and neighborhoods are observed in the axial and segment maps when colored using integration and choice measures. The study area in the current phase of Old Baghdad now contains organic, transitional, and modern quarters and neighborhoods based on shared urban characteristics of streets, spaces, and plots (Fig 6).

These sets at the scales of quarters and neighborhoods are divided into organic, and transitional (hybrid), and modern. Organic sets are characterised by irregular patterns of urban structures including twisted streets, various configurations of plots, compact buildings, and short urban blocks. Modern sets are characterised by a grid pattern of streets that form various patterns of rectangular urban blocks. Translational sets include both organic and modern patterns.
Figure 6: Selected neighborhoods and quarters in the current map of Baghdad

Figure 7: Land use distribution (left), integration Rn (middle), and choice Rn (right) at the scale of quarters in Baghdad
Syntactic properties of urban structures at the scale of quarters show same values, in terms of accessible and inaccessible places, of integration and choice of different quarters, whether organic, transitional, and modern. The axial map of organic quarters, set 1 (Figure 7), indicates that the well-connected streets with high values of integration are mostly modern roads that surround, divide, and connect historic clusters with other quarters. The segment analysis identifies the same integrated streets as easiest roads for movement in the street networks (Figure 7).

The axial and segment maps of transitional quarters, sets 2 and 4, also indicate that the streets with high integration are mostly the same streets with high choice. While streets with high integration and choice shows a super block pattern in the set 2, the deformed pattern is the main feature of these streets in the set 4. Integrated streets in the set 2 located between the commercial cores in Old Baghdad and industrial zones of modern extensions towards northeast, while in the set 4 they are placed at the edges of organic urban clusters and pass around large urban subdivisions of institutional, administrative, and industrial activities in the southwest (Figure 7). In the modern quarters, a set 3, integrated and choice streets are same in the axial and segment analyses. Streets with high values in the set 3 form super block patterns.

**Figure 8:** Land use distribution (left), integration Rn (middle), and choice Rn (right) at the scale of neighborhoods in Baghdad.
At the scale of neighborhoods, the axial and segment analysis show that integrated and choice streets are, once again, the same though the characteristics of urban structures of neighborhoods are different. Streets with high values of integration and choice are the long modern streets that pass through the historic organic neighborhoods in the set 1, while they form deformed patterns in and around urban clusters of transitional neighborhoods in the sets 2 and 4, (Figure 8). However, in the modern neighborhoods, a set 3, integrated streets are distributed along the main streets inside and in the borders of neighborhoods, while choice streets are slightly moved next 2 to 3 steps away from integrated streets in the network; they try to connect resident with other urban clusters in the urban structure (Figure 8).

6. Conclusion

This study using space syntax provides a framework for diachronic and synchronic studies of large metropolitan areas in the Middle Eastern region using transects. Transects are historically and/or functionally significant areas of a city that show distinct morphological characteristics. These areas are often purposefully selected making detailed morphological study of a very large city possible.

This study uses Baghdad, a typical example of a Middle Eastern city, to illustrate how transects can be used along with space syntax to derive useful conclusions regarding urban form and land use patterns at different scales of a complex city that defies a comprehensive morphological analysis of the Conzenian kind (Conzen, 1960). Though the study identifies five transects for a comprehensive morphological understanding of Baghdad, here we present the morphological analysis and findings of one transect only. This transect contains Old Baghdad that was founded in the eleventh Century AD.

The diachronic study using space syntax and historical land use patterns of the transect containing Old Baghdad reveals strong influences of the structure of spatial networks on the commercial cores of Old Baghdad. According to this study, for a long period, extending from the formative stages of the city to the 1940s, the syntactic core of the city remains within Old Baghdad showing a strong correlation with its commercial core. This correlation is disrupted after the 1940s, when due to modern developments, the syntactic core of the city moves outside Old Baghdad. Consequently, we see the formation of a new commercial core along this new syntactic core in addition to the old historic commercial core.

The diachronic study of the city using space syntax also reveal a strong correlation between the syntactic core defined by the streets with high integration and that defined by the streets with high choice. Again, this was the case for a long period extending from the formative stages of the city to the 1940s. In other words, the structures defining to-movements and through-movements remained the same in this historic city. Hillier (2005) argues that to-movement patterns help generate and support socio-cultural aspects and that through-movement patterns help generate and support the economy of the city. According to our findings, therefore, the social and economic aspects of Old Baghdad were dependent on one another before the 1940s. However, with modern developments after the 1940s and 50s these patterns become separated indicting that the economy of the city might no longer be dependent on the social aspects of the city.

The synchronic study of the city involving quarters, and neighborhoods of the city reveals different syntactic structure at the local levels of the city. In some cases, the structures show a pattern similar to a super-grid. In some cases, they show linear patterns. In some other cases, they radiate or branch out from one or more highly integrated streets. Yet, in other cases, they remain on the periphery of the local areas. The different shapes, size, and locations of the cores of these syntactic structures may be
indicative of the differences in the social and economic aspects of these quarters and neighborhoods; therefore, requires further studies.

The synchronic study involving the syntactic structures of the quarters and neighborhoods of the city in relation to land use patterns also show significant differences. Since the land use patterns of these quarters and neighborhood are significantly different from each other, a more careful study of the relationship between syntactic structures and land use patterns in each area is needed. In such a study, we must ask: if a local area contains only residential uses, then are there differences in the residential functions on the more integrated streets and that on the less integrated streets? Are these differences reflective of economic classes? Do these differences exist in all residential areas? Etc.

While this study of one transect reveals significant findings and interesting issues, it is hoped that the future studies involving more transects of Baghdad will help not only to validate what we have already found here but will also help generalize the morphological types of Middle Eastern cities at multiple scales.

References

Fethi, I. (1977), ‘Urban Conservation in Iraq: The Case for Protecting the Cultural Heritage of Iraq with Special Reference to Baghdad including a Comprehensive Inventory of its Areas and Buildings of Historic or Architectural Interest’. University of Sheffield.
Hillier, B. and Hanson, J. (1984), The social logic of space: Cambridge university press.