Role of Pre-existing Settlements in the Urban Expansion of Erbil

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Abstract: According to its approved master plan, Erbil city extends in multiple directions and overlaps with some pre-existing settlements. The role of each pre-existing settlement in urban expansion remains unknown. This study utilizes a gravitational model, which assumes the existence of forces of attraction between any two proximate urban settlements. This drawing force attracted a variety of land uses of pre-existing settlements around Erbil city. The variables of gravitational force in this study are initial population size and distance of each pre-existing settlement to the core of Erbil. The gravitational force represented by the magnitude of the urban expansion is measured by the continuously changing area covered by the urban land uses throughout a studied period from 2007–2016. Satellite images were used to depict the difference between the size of settlements before and after expansion. Computer programs were used to draw and measure urban expansion and determine its relationship to initial population size and distance to the core. This study finds that initial population size is a significant factor, but distance to the core has no correlation to the degree of urban expansion close to the studied settlements. The findings of this study will extend the knowledge about the urban expansion of Erbil and open door for further related studies.

Keywords: Pre-Existing Settlements, Erbil, Master Plan, Urban Expansion, Population Size, Distance to the Core

1. Introduction

The 2007 master plan indicates that Erbil city extends in multiple directions (KRG, 2007). This expansion overlapped with some pre-existing settlements, such as *Enkawa*, *Kesnezan*, *Bîneslawe*, *Daretû*, *Shaweis*, and other villages. The approved master plan has proposed different land uses, mainly residential land uses, close to and around pre-existing settlements. The approved master plan indicates that urban land uses can be expanded and distributed equally on different directions. Since 2007, investment projects, municipal land subdivisions, and construction activities that resulted from the goal of citizens to build their own houses show the unequal distribution of urban land use in these different directions. Built residential projects and other projects seem to be accumulated in certain areas, but they seem fragmented in other areas. To determine the cause of this phenomenon, this study suggests several forces that attract land use and encourage people and investors to build in particular areas while overlooking others.

This study attempts to use the gravitational model to test the role of pre-existing settlements in attracting land uses. This model shows that the gravitational force between two settlements is caused by population size and distance between settlements. Thus, this study hypothesizes that the pre-existing settlements of Erbil play different roles in urban expansion depending on their gravitational forces.

To prove this argument, this study collects data on two kinds of variables. The first one is independent variables, which are expected to express gravitational forces of different settlements, such as initial population size and distance from any pre-existing settlement to the center of Erbil. The second one is dependent variable, which is the actual urban expansion that occurred throughout the specified period. Actual urban expansion close to each pre-existing settlement is also hypothesized as directly proportional to initial population size but inversely proportional to distance from the core. The correlations of the two groups of variables are assumed to explain variations between the roles played by different settlements in terms of expansion. By using the gravitational model, this study attempts to determine the causes of unequal spatial distribution of land use in Erbil city between 2007 and 2016 close to and around pre-existing settlements. This issue has not been studied in previous research.

2. Literature Review

Since the beginning of the 20th century, many theories and models have been considered to explain the spatial distribution of urban land uses and explore the factors of influence in this regard. Sinclair (1967) stated that the theme of modern cities is urban expansion given their growing population; he described the patterns of urban growth along linking roads and those that spread around the nodes, such as commercial and industrial ones.

This issue should be examined to understand the nature of forces and factors that affect the rapid and huge urban expansion in cities (Davis, 2013). Location theory was used in the pioneer study of Thünen (1783-1850), who explored the spatial distribution of land use for agricultural purposes around a German town and how economy and profit played a leading role in this development. This theory of agricultural location remains important in urban studies. He stated that the pattern of land use depends on the competition between various types of agriculture for the use of a special part of the land. The controlling factor in this competition was land rent. By assuming that the area is flat and the mean of transportation is constant, he concluded that transportation cost was the determinant of economic rent, which increases with distance. Hence, economic rent of any land use can be expressed as a function of distance from the market.

Alfred Weber (1868-1958) utilized industrial location theory and a mathematical equation to explain how industrial firms are optimally located between two towns, depending on economic reaction. His theory of industrial location attempted to explain and predict the locational pattern of the industry on a macro-scale by emphasizing that firms seek a site of minimum transport and labor cost. Walter Christaller then concluded that people gather in settlements to share goods. In his model, he assumed an isotropic plain region where goods and population density are distributed equally; however, this model neglects the impact of physical barriers and obstacles that effect and reshape the movements of people and distribution of goods. Doran and Fox (2015) then used central place theory to develop a central flow theory by studying the flow of information instead of goods.

Theorists developed several models to describe and explain the spatial distribution of land uses in 20th century cities, such as the concentric zone model of Burgess in 1925 and the sector model of Homer Hoyt in 1932. According to François Perroux's growth pole theory in 1955, the area with strong economic potential drives development and attracts land use and human activities. Morris (1968) adopted a sociological approach and focused on three processes that played a role in deciding the spatial distribution of land uses; these processes are concentration and dispersion, centralization

and decentralization, invasion and retreat.

Communication theory emphasizes that social reaction plays a role in this regard because the city is a place of social reactions. This theory suggests that communication and transportation are means of those reactions.

Based on Alfred Weber's industrial location theory and the way firms are agglomerated to each other, others scholars found that the core city and its surrounding towns seem to agglomerate with each other given that the sites between every two towns is likely to attract urban expansion. Tai defined agglomeration as a densely populated area that consists of the city, suburbs, and continuously settled commuter areas (Tai, 2016). Most large cities seem agglomerated due to urban population growth and development of transportation infrastructure. Uchida and Wilson studied the agglomeration index based on this development; they assumed three factors that affect this index, namely, population size, population density, and travel duration. They found that population density at the outskirts of the city varies according to the quality of roads. (Uchida & Nelson, 2008)

The metropolitan area is formed when the city and its surrounding settlements expand. Metropolitan area is defined by UNICEF as a formal local government area that comprises the whole urban area and the attached commuter areas (UNICEF, 2012). Downs (1989) suggested four factors or "pillars" that led to the rise of American metropolitan development; these factors are related to the desired lifestyle of American households. In terms of planning and urban design purposes, others considered the metropolitan region that covers several classic types of regions, such as political, biophysical, socio-cultural, and economic regions (Steiner & Butler, 2006)

The formation of the metropolitan region of many urban centers creates a polycentric structure. Champion argued that a polycentric structure could be formed in three different cases; he identified three models that describe these developments, namely, centrifugal model, incorporation model, and fusion model (Parente & Pessoa, 2009). Given the effect of urban economics, investments projects usually settle near or within the urban area where certain required services are available (O'Sullivan, 2003).

The gravitational theory suggests that the gravity between neighboring towns is responsible for the interactions between these two towns, such as daily trips, immigration, and exchange of goods and services. The simple gravitational model was built based on Newton's model of gravitational theory in physics. Newton's model of gravity is described in mathematical form, where the gravitational force between two masses *i* and *j* is directly proportional to the product of their masses (m_i* m_j) and inversely proportional to the squared distance (d^2) between them.

G_{ij}= K m_i*m_j/ d^2 ……..……...……... (1)
Where *K* is a constant, m_i and m_j are the masses of two objects *I* and *j*, and *d* is the distance between them.

William Reilly (1931) developed a Newton's model for city attraction of trade. Reilly described his model as: "Two cities attract trade from an intermediate town in the vicinity of the breaking point, approximately in direct proportion to the population of the two cities and in inverse proportion to the squares of the distances to the intermediate towns" (p.9). He assumed that the geography of the area is flat and consumers are homogenous. The model helps find the limit of catchment area, which is highly important in urban studies to find the area covered by a service. The model is also useful in finding the forces of attraction of two neighboring towns to determine the point where the two

opposite forces are equal.

2.1 Previous Studies

Urban expansion is a particularly wide and important subject. Cities are currently expanding twice their population growth rates and now cover almost 0.5% of the land area of the planet (Angel, Parent, Civco, Blei & Potere, 2011). A rich body of literature can be found on this issue. However, only a few studies examined the causes of urban expansion, such as the natural population growth or the population growth due to immigration, rising incomes, and falling commuting costs (Brueckner, 2000). To distinguish between urban growth and urban sprawl, Wassmer (2008) listed many causes of urban growth, as shown in Table 1; he labeled the factors are 25 variables, which starts with population growth and ends with the desire of households to live in large plot size.

Table 1: Causes of urban growth that may result in compact and/or sprawled growth (Wassmer, 2008)

Causes of urban growth	Compact growth	Sprawled growth
Population growth	•	•
Independence of decision		•
Economic growth	•	•
Industrialization	•	•
Speculation		•
Expectations of land appreciation		•
Land hunger attitude		•
Legal disputes		•
Physical geography		•
Development and property tax		•
Living and property cost		•
Urban		•
Demand of more living space	•	•
Public regulation		•
Transportation	•	•
Road width		•
Single-family home		•
Nucleus family	•	•
Credit and capital market		•
Government developmental policies		•
Lack of proper planning policies		•
Country-living desire		•
Housing investment		•
Large lot size		•

Other studies focused on the form of urban expansion, which may take many forms. Expansion would sometimes reach a density equal to, lower than, or greater than the initial density of the settlement. Expansion happens either by infill of vacant open spaces in built-up areas or as new "greenfield" projects, which can either be attached to existing built-up areas or leapfrogged away from them, thereby encroaching on sensitive environments.

Some studies explored the spatial distribution of different densities of urban expansion and the cause for different land uses to be distributed in a certain way within the space. Households are generally inclined to reside near markets, roads, river banks, and even temples (Prasad, 1985). Urban expansion is usually attached to main arterial roads because of minimal commuting costs. Others found that the growth of income played a powerful role in China's urban expansion (Deng, Huang, Rozelle & Uchida, 2008). According to them population, traffic conditions, industrialization, and policy are the major factors that influence urban expansion. Urban expansion that occurs on the best environmental lands tends to increase attraction of these places. Urban expansion on low-price lands minimizes the initial construction costs of projects. Cost also pushes urban expansion to sites with available infrastructure (Kozlowski, 1968). Population classes and ethnic groups tend to live in specific places, which cause urban expansion due to the varying concentrations of groups.

Cities expand on sites due to the decisions of planning and municipal authorities, which leave households with no other choice to select a preferable site to build their dwelling units. Given that expansion is led by authorities, it occurs regardless of the potential of settlements. However, the central decisions in Erbil city are made according to positive potentials and internal characteristics to accelerate and facilitate urban development. More than 60% of investment licenses are issued according to the request of investors for location priorities according to the director of Erbil urban planning (Sadraldeen, 2016). When the real estate market provides alternatives, the attractiveness of some locations may push households to seal their own plots and buy another plot at a better location. Economic competition is a pivotal cause of urban expansion, wherein households leave their dwelling units close to the city center for commercial or industrial land uses where rent is high.

The gravitational model is an old model, but it is still being applied widely in urban studies. This model is still used in transportation studies on trade and movement of people. Nandi tried to find the breaking point between two towns in the northern part of West Bengal, where two major shopping centers are located on the highway between the two main cities. Nandi applied Reilly's model on these two towns, where the distance between Siliguri and Jalpaiguri is 12 km; the population of Siliguri is 765,813, whereas that of the latter is 266,823; Nandi found that the breaking point from the city of Siliguri is 7.54 km (Nandi, 2016). Others used the gravity model to determine the level of spatial interaction that occurs among city clusters in one of the most rapidly urbanized regions in China ,Wuhan urban agglomeration, (Tan, Zhou, He & Xu, 2016). Empirical results indicate that the spatial interaction among city clusters is one of the main drivers of urban growth. This study finds the effects of spatial interaction as the only socioeconomic factor that affected the spatial expansion from 2005 to 2010.

GU and Pang (2008) used the gravity model by focusing on the spatial relations in the inner urban system; they classified the ranks of spatial combination areas of Chinese urban system with different values of distance-friction coefficients. Liu and his colleagues (2014) extended the use of the fitted gravity model to explore and analyze the patterns of trips and spatial interactions of half a million individuals within 370 Chinese cities. They found that the observed spatial interactions are governed

by a power law distance decay effect.

3. Research Problem

Many new residential neighborhoods and other investment projects have been built since the adoption of Erbil master plan by the regional government. Urban expansion has been attracted close to these pre-existing settlements at different rates. The role of each of these pre-existing settlements in attracting urban expansion, as well as the causes of these roles, remains unknown. Thus, the research problem here could be the unidentified role of pre-existing settlements, which were previously located outside Erbil city and are now included within the Erbil master plan and shows effectiveness in attracting land use.

4. Research Questions

This study attempts to focus on a particularly limited question: Why does urban expansion of Erbil city occur in certain places or what encourages land use to expand in some places more than others? This study explores the underlying causes of the spatial distribution of urban expansion. The Erbil master plan of 2007, which suggests that the city expands in multiple directions to include some surrounding pre-existing settlements, provides a suitable case study to test the gravitational forces of the core and small neighboring towns.

5. Research Hypotheses

Based on the research problem, this study hypothesizes that the pre-existing settlements of Erbil city play different roles in urban expansion depending on their initial population sizes and their locations, specifically their distances from the core of the city. The force of attraction between the city (*i*) and the core (*j*) is directly proportional to their initial population sizes and inversely proportional to the squared distance between them. Therefore, the equation could be written as shown below. This study assumes that the gravity or force of attraction of an area is expressed by the area of the urban expansion close to any given settlement. Investment projects would develop in the area to gain the benefit of a growing attraction to their businesses. However, the attractive force of a settlement will be low if the population size of the settlement is small or if its location is far from the core because the city would be unlikely to stretch out to such a settlement. Gravitational equation (1) above could written as

$$G_{ij}=k\ P_i*P_j/\ d^2, \quad \ldots\ldots (2)$$

Where G_{ij} is the gravitational force between *i* and *j*, *K* is a constant, and *d* is the distance between them, which could be modified as

$$E_{ej}=k\ P_e*P_j/\ d^2, \quad \ldots\ldots (3)$$

Where E_{ej} is the magnitude of the urban expansion that occurs on the sites between *i* and *j*, P_e represents the initial population of Erbil city, and P_j represents the initial population of the pre-existing settlement.

The initial population of Erbil is similar to the situation when the equation is applied to find the magnitude of expansion of urban land uses close to each settlement and *K* is a constant. Thus, E_{ij} is directly proportional to P_i, and E_{ij} is inversely proportional to the distance to the core. Therefore, the

secondary hypotheses are as follows:

5.1 In light of the gravitational model, the amount of urban expansion close to any pre-existing settlement within Erbil master plan is directly proportional to its initial population size.
5.2 The magnitude of urban expansion close to any pre-existing settlement within the master plan is inversely proportional to its distance from the core of the city.

This hypothesis may be defective because initial population size can illustrate the force of settlement gravity in the first year, but the situation will be different during the next years due to population growth. Changes in population size in the second year may create a new magnitude of attraction, and urban expansion will further take place. This study finds that most of the expansion close to these settlements represents investment projects, which are mostly under construction. Furthermore, investment licenses have been dormant from 2011 to 2016, which means that the observed urban expansion has been taking place as a result of gravitational forces caused by the hypothesized variables (population sizes and distances to the core) from 2007 -2010. Moreover, the population size of the studied pre-existing settlements did not change sharply as most of the investment projects are not yet occupied. Thus, most of the urban expansion that took place is due to the attraction of the initial population size. However, this hypothesis will not be valid in other circumstances.

6. Research Objectives

The objectives of this study are as follows:

6.1 To find the variation in areas of urban expansion close to the pre-existing settlements adjacent to Erbil city core from 2007 to 2016
6.2 To find the relationship of the initial population size of pre-existing settlements adjacent to the core of Erbil city and nearby area of urban expansion
6.3 To find the relationship of distance between any pre-existing settlement and the core of Erbil city to nearby area of urban expansion

7. Methodology

Many indicators can be used to assess urban expansion. Sun and Zhou used spatio-temporal modeling method to find the pattern of change through pixel-based imaging (Sun & Zhou, 2016). By using remote sensing, (Kantakumar, Kumar & Schneider, 2016) measured urban expansion by means of quantitative variables, such as expansion contribution rate, percentage of change in expansion, and annual expansion rate of each administrative area, to explain the dynamics of urbanization of Pune metropolis. The area occupied by urban land uses seems the simplest and most sufficient indicator that will be measured. The actual expansion in this study is considered a dependent variable, whereas initial population size and the distance from the core were considered as independent variables. Satellite images from (mapcreator, 2016) and (Zoom Earth, 2016) were used. The area of urban land use or land cover was measured regardless of the nature of the land use itself. Computer programs, such as (earthpoint, 2016), AutoCAD and Adobe Photoshop, are used to calculate the area and distances.

Data about the population sizes were collected from available sources using Excel 2013. Simple analysis was conducted to determine the relationship between the two groups of variables. The midpoint of distance between every two adjacent pre-existing settlements was identified to measure

the area of urban expansion close to each settlement. The lines that join the midpoints to the center of Erbil city were drawn to form different sectors as shown in Figure 1. Any urban land use that occurs in a sector is assumed to be a result of the gravity of the pre-existing settlement in this sector.

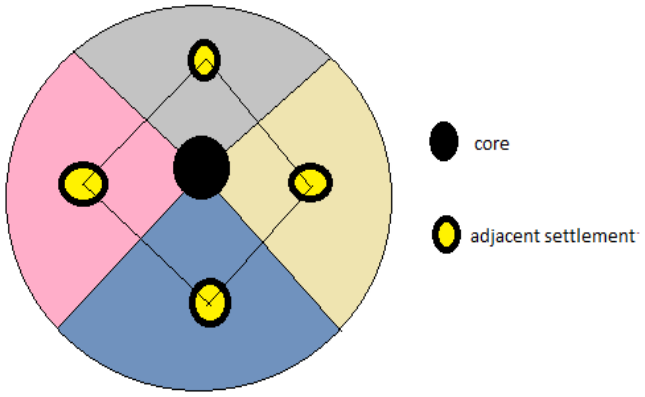

Figure 1: Method of measurement of the area of expansion close to pre-existing settlements as prepared by researcher

8. Case Study

Erbil governorate consists of 10 districts and 34 sub-districts. Most of these districts are too distant and will not be involved in this research. The studied adjoining districts and sub-districts are all of *Deshti Hawler* (*Bîneslawe*, *Kesnezan*, and *Daretû*), in addition to the *Enkawa* and *Behirke* sub-districts and the *Shaweis* municipality (Erbil Governorate, 2016). The population of *Enkawa* as an administrative sub-district consisted of approximately 40,000 inhabitants in 2007. According to the Erbil master plan, the population size of *Kesnezan* in 2007 was 50,000 inhabitants, 48,000 inhabitants for *Bîneslawe*, 45,000 inhabitants for *Daretû*, and 21,000 inhabitants for *Shaweis* (KRG, 2007).

The areas occupied by urban land uses close to each settlement in 2007 and 2016 were drawn and measured by applying the mentioned procedure. The measurements are shown in Figure 2, Figure 3, and Table 2. The studied settlements are located at different distances from Erbil city core. The distance of each settlement from the core was measured from the center of settlement to the center of Erbil citadel by the researcher using the mentioned above programs.

Table 2: Collected data related to independent and dependent variables

Variables	***Enkawa***	***Kesnezan***	***Bînesle***	***Daretû***	***Shaweis***
Administrative level	Sub-district	Sub-district	District	Sub-district	Village
Initial population size	40,000	50,000	48,00	45,000	21, 200

Initial area occupied by urban land uses in hectares	244	163	300	214	95
Distance from the core in km	4.275	12.200	10.160	9.120	9.215
Area of urban expansion in hectares during the studied period	2186	2427	2169	2129	1171

9. Results and Discussion

This study applied the method mentioned above to determine the area occupied by urban land uses in 2007 and 2016, as shown in Figures 2, 3, and 4. Some mathematical modifications were performed on the original figures of Table 2 to make the graphs noticeable. For example, the initial population sizes of all settlements were divided by 10,000 and the initial areas occupied by urban land uses in hectares of all settlements were divided by 100.

Figure 2: Erbil city: area occupied by urban land uses in 2007

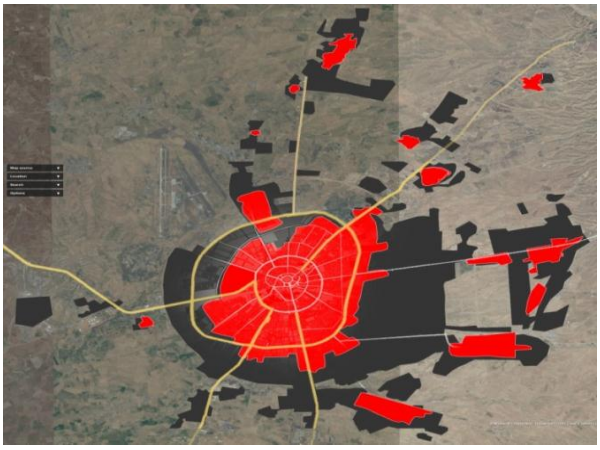

Figure 3: Erbil city: area occupied by urban land uses in 2007 and 2016. Red: 2007, Black: 2016

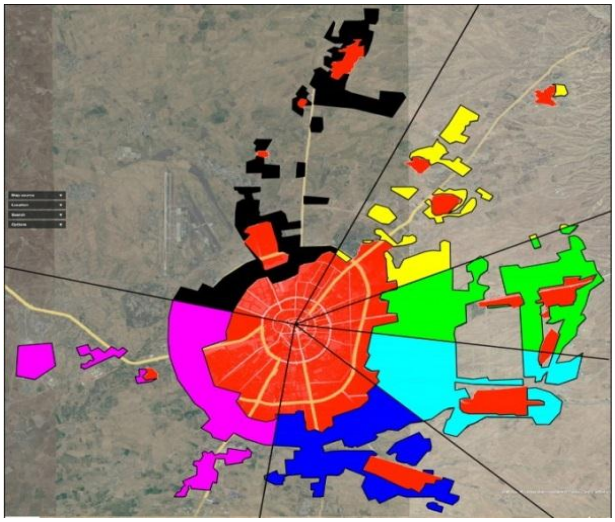

Figure 4: Erbil city: area occupied by urban land uses close to each studied settlement
Black: *Enkawa*, yellow: *Shaweis*, green: *Kesnezan*, light blue: *Bîneslawe*, blue: *Daretû*, pink: *Tûraq*. Note: Expansion toward *Tûraq* was ignored in this study because it is a small village and no available records on its population size were found.

The survey showed that the administrative level did not affect the magnitude of urban expansion. The breadth of urban expansion varies in the same administrative level. For example, the expansion of *Kesnezan* is greater than that of *Bîneslawe*, although the former is a sub-district and the latter is a district. The initial population sizes of the studied settlements in 2007 showed a significant relationship to the area occupied by urban land uses during the study period, as shown in Figure 5. Figure 6 shows that the correlation of these two variables is too strong because R^2 is equal to 0.92.

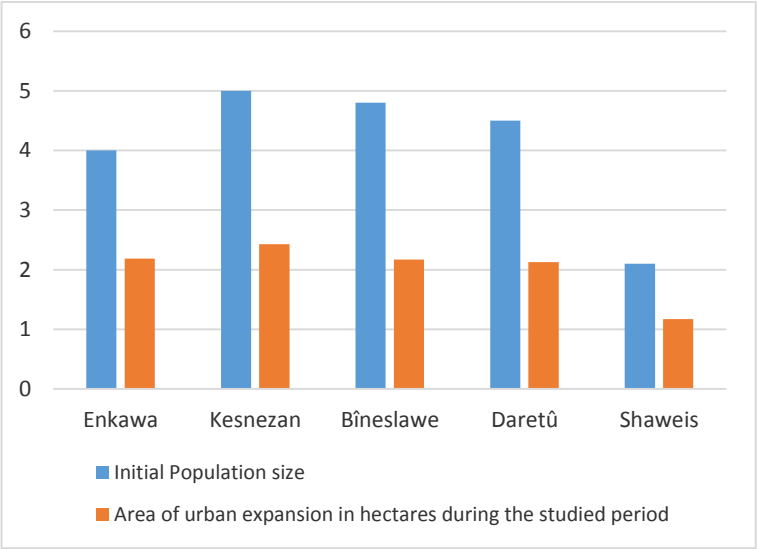

Figure 5: Relationship of urban expansion area to initial population size

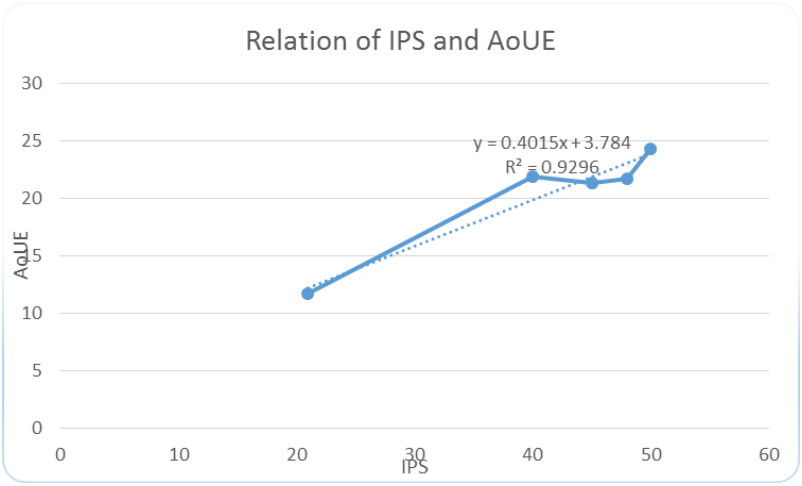

Figure 6: Correlation of urban expansion area to initial population size

The relationship of population size of a settlement and its gravitational force is explained as follows. A bigger population size reflects a variety of available services in the settlement, thereby encouraging more people to dwell close to this settlement. Alternatively, certain identifiable characteristics caused accelerated the growth of big settlements from the outset and have been working to attract more investments and dwellers since then. However, these factors are responsible for the lack of progress in other smaller settlements and still keep the urban expansion slow in those areas, thereby upsetting the balance of the several ongoing expansions.

The area occupied by urban land uses of the studied settlements in 2007 seems particularly significant in Bîneslawe, Daretû, and *Shaweis*, as shown in Figure 7, where the measures of the areas in 2007 and 2016 follow the same trend in all three settlements. However, the measurement showed an insignificant relationship with the area occupied by urban land uses in 2016, as R^2 is only 0.41, as shown in Figure 8. The measures of *Enkawa* and *Kesnezan* show unmatched trends. *Kesnezan*, which had a relatively small area in 2007, attracted more urban land use. The low urban expansion close to *Enkawa* did not match its relatively large urban area in 2007 compared with those of *Kesnezan* and *Daretû*. This relatively inhibited expansion of *Enkawa* could be explained either by the large area that Erbil International Airport occupies or by the special homogenous society living in *Enkawa*, which was an independent municipality and had a weak relationship with local authorities until 2011. This special situation may have also played a role in restricting the growth.

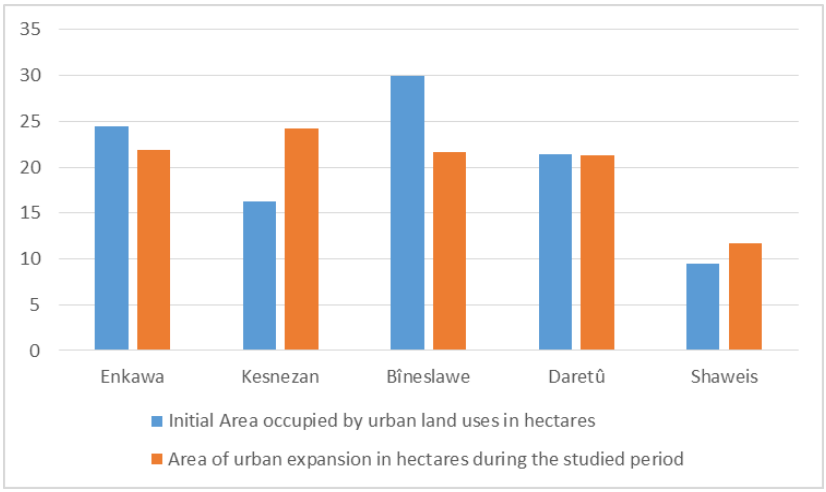

Figure 7: Relationship of urban expansion area to the initial area occupied by urban land uses

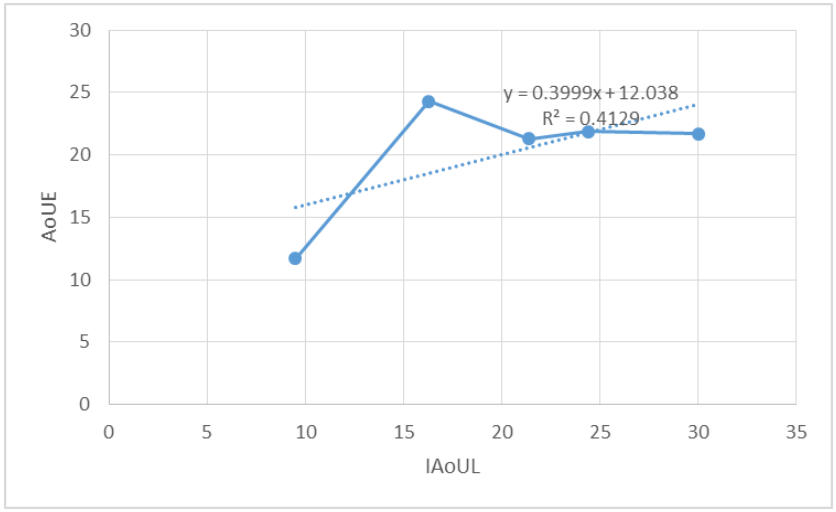

Figure 8: Correlation of urban expansion area to initial area occupied by land uses

The second hypothesis is that the degree of urban expansion close to any pre-existing settlement within Erbil master plan is inversely proportional to its distance from Erbil city. However, results show that the location of each settlement did not play a significant role in determining nearby urban expansion (Figure 9). The correlation of these two variables is equal to zero, as shown in Figure 10. A reasonable urban expansion can be found in the settlements that are near to the core, such as *Enkawa*, but the results show that the urban expansion of *Enkawa* is minimal. By contrast, *Kesnezan* and *Daretû*, which are relatively far from the core, seem to be relatively more expansive than that of *Enkawa*.

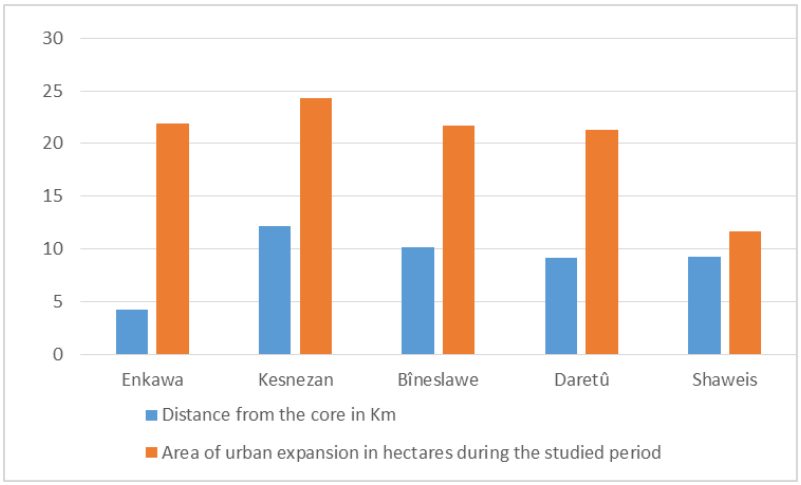

Figure 9: Relationship of urban expansion area to the distance from city core

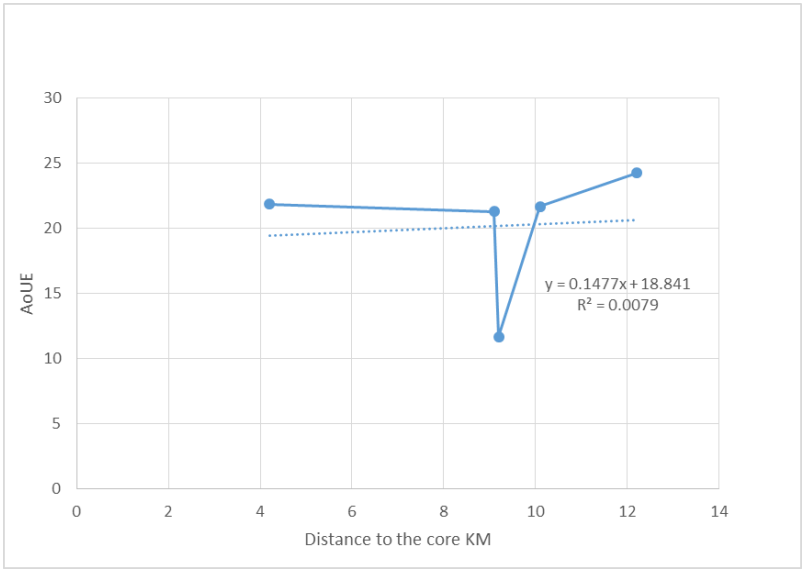

Figure 10: Correlation of urban expansion area to initial area occupied by urban land uses

10. Conclusion

This study hypothesized that the pre-existing settlements of Erbil play different roles in urban expansion, depending on their population sizes and their locations, specifically their distances to the core of Erbil city. The main research hypothesis was validated based on this premise. The secondary research hypothesis was tested. This study concludes that initial population size plays a significant role in attracting urban expansion close to pre-existing settlements. Pre-existing settlements attracted varying spaces for land uses regardless of their distances. This finding could be attributed to the influence of other unstudied factors, such as regional linkages, quality of roads, availability of services, or environmental characteristics. This study concludes that the area occupied by urban land uses in the beginning of the study period partially played the same role as the initial population size. Urban expansion has occurred close to each pre-existing settlement regardless of administrative level. Moreover, sub-districts, such as *Daretû*, attracted more urban land uses than other districts.

The survey shows that the studied pre-existing settlements display different patterns of urban expansions as *Kesnezan*, *Bîneslawe*, and *Daretû* showed continuous and coherent urban expansion, whereas other settlements showed fragmented expansions. Cities in the whole Iraq in general and Kurdistan region have grown rapidly during the last decade. Only a few studies focused on this issue. The present study may open the way to further studies. The current study may be beneficial to the municipality of Erbil city and other related authorities. The findings may also benefit decision makers by helping them control and manage urban expansion to achieve the economic, social, and environmental goals of urban development.

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