

Formulate Theoretical Model to Measure the Centrality of Cities (Case Study: Cities of Erbil Governorate / Iraq)

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Abstract

The cities functionality in the human and economic fields, within functional region of cities, is largely depended on the level of geographical centrality of cities in this region. The study aims to formulate a theoretical model, measures the degree of centrality of cities within the boundary of its functional region, depending on the size and location of settlements and the transport network, within a spatial framework that shows the centrality of cities. The core of the factors that inserted in the model was formulated according to a set of assumptions, using a group of spatial statistical criteria, which spatially determine the direction and distribution of geographical elements within the GIS environment. According to the theoretical model, the values of centrality index (CI) have been classified into five categories, show the levels of centrality of cities, the model was applied on the cities of Erbil governorate.

Keywords: (GIS, Spatial, Centrality, Cities, Model)

Introduction

The cities functionality in the human and economic fields, within functional region, depends largely on the level of centrality of cities in their region, centrality here is not intended strictly geographic term, but the one that involves the human and economic concepts, more than just the sum of the place dimensions (Berry & Horton., 1969; Hutchison., 2010; Smailes., 1968; Pacione., 2009; Hall., 2001). Hence the regional important role of cities is illustrated through providing all goods and services which are exchanged with the surrounding area (short., 1987; Shawarra., 2012; Johnson.,1968; Fellmann et al.2008). But the greatest part of this important arise through the central role of the city as a real nucleus for the surroundings region (Ayasra., 2009; Pacione ,2009).

The main idea of centrality of cities, derived from the geographic and economic ideas, which essentially aimed to analyze the spatial structure of economic activity or spatial economic structure of the region, starting from the planning ideas during the era of ancient civilizations (Al-Anni.,2010) , to the theoretical propositions of amateur economist J.H. Von Thunen (1783-1850) about determining patterns of agricultural production around the city, and the ideas of researchers who examined the theoretical basis of the theory of economic basis of cities, down to the leading ideas of the German geographer Walter Christaller in 1933, about the rational geographical distribution of the central places that provide goods and services for the population who evenly distributed within a homogeneous economically area, in addition to the ideas of (Myrdal ,Hirschman and Friedman) about the developing of geographical space through the principles of growth poles theory, and finally the theoretical ideas and amendments that were made by some researchers, likes (Losch , Beckmann , Philbrick, Isard,Berry and Garrison) about the foundations and theoretical concepts of the central places theory (Herbert & Thomas.,1982;Berry & Horton.,1969; Ullman., 1959; Johnson.,1969;short.,1987; AL-Jannabi.,1987; Abu Subha.,2003; Marof., 2006; Al-Anni., 2010; Ayasra., 2009; Hutchison.,2010; King & Gollodge.,1978; Berry., 1967; Kolars & Nystuen., 1974; Hagget & Arnold., 1965; Johnson.,1968).

In the light of the previous ideas and theoretical propositions, the importance of the study emerges through putting the idea of how to imagine the relation between the cities and surrounding area, according to the three principles of Christaller's theory (Marketing, Traffic, Administrative), taking into account the size and location of settlements, transport nodes, that define the spatial variation of economic differences around the place being intended to measure its degree of centrality, so this variation according to the specific factors, will play a crucial role to determine the elements of centrality's criterion and formalizing the model as whole. It is previously noted that a great variety of measures of centrality has been derived based on the various types of services inside the city (Herbert & Thomas.,1982; Short.,1987; Ullman.,1959; Abu Subha.,2003; Al-Muzaffar & Yusuf.,2010; Hagget & Arnold., 1965).

The model will focus on answering such questions as: what is the degree of connectivity and spatial interaction between the cities, to be able to describe the degree of centrality adequately?

The aim of the present study is to establish a statistical model to measure the degree of centrality of cities of the areas (settlements) nearby. According to the model, we would be able to create a spatial theoretical framework as a measure to determine the centrality characteristic of the locations of cities, within the spatial framework which supposes that the cities will provide them by their services. Accordingly the degree of centrality of cities could be measured within the spatial theoretical framework, by using distance variable or the degree of proximity from the borders of spatial theoretical framework, in addition to the economic and human importance of the surrounding area via the size and location of settlements and transportation network. The most important question that arises here is how the degree of the centrality of cities could be measured with respect to the human, natural, and economic environment within spatial theoretical framework, in the light of principles of Christaller's theory which considers the city as a service center for the surrounding area, it should be put in a central location in order to provide its services efficiently to the resident of the area.

Assumptions of Model

Before accessing into the main model-building procedures, it is worthwhile to highlight the most prominent assumptions which take into account in the process of the theoretical model building, as following:

1. The city offers services within a specific administrative boundary, so it is supposed to look at the degree of centrality within a specified spatial framework, whether it is specified forcibly, like administrative or political boundary, or if it follows the natural frame, like the boundary of river basin or plain, or any other frame could be suitable for determining the degree of the city centrality.
2. The existing settlements (Rural or Urban) within a spatial frame will be the most important points that receive the city services, and are the essential nodes or elements that form overall structure of the functional region of the city.
3. The transportation network that connects the city with settlements within the spatial framework, are the lines which identifies the general structure of the functional region of the city, and arteries through which the city interacts with the nearby settlements. While the transportation nodes are the points for linking the elements of functional region. So the settlements "points" and the routes "lines" are the main factors which together determine the overall structure of the functional region of the city in both sides spatial and functional.
4. Size of settlements (population) is the content that identifies the extent of spatial variation of functional gravity of the region, it affects the degree of centrality of the city within the specified spatial framework.

Model Building Procedures

Supposedly that the model includes as large number of factors as possible, that are in charge of determining the degree of centrality, whether they affect the characteristics of centrality directly or indirectly, explicitly or implicitly, and whether these factors have a spatial-geometric, economic or human nature. But increasing number of factors will lead to additional implications (complications) may be related to statistical issues, in terms of the mechanism of formulating the role of the factors from a statistical standpoint, or procedural and operational problems of how to convert the role of factors affecting, from the practical reality to theoretical reality according to the statistical values compatible with the model building procedures. Nevertheless, the model will try to formulate the role of the three main factors to identify the degree of centrality of cities.

It is possible to add influences of other factors, if it is possible to solve the previous complications, these factors are:

- a. Transportation network (transportation nodes).
- b. Location of settlements (purely geographic location).
- c. Functional contents of Settlements (population).

In order to formulate the role of those factors within the model, a set of steps was conducted by using a group of spatial statistical criteria that usually measure the spatial trends and distribution of geographical phenomena, in terms of dispersion and concentration, in the light of the spatial centrality concept (Sankary., 2008; Shahada., 2002; Shahada., 2011; Hirori., 2012; Mitchell., 2001; Lee & Wong., 2001; Abdullah., 2006; Al-Jamal., 1985; Dudley Stamp., 1965). The steps involved are as follows:

1. Compute the mean center (Spatial mean)(symbolized as A) for all settlements(cities and villages), located within the spatial theoretical framework which affects on determining the degree of the city centrality, by using the computational tools for geographical distributions within GIS environment (ArcGIS 10.2)by using the following equation.(McGrew & Monroe.,1993):

$$\bar{Y} = \frac{\sum_{i=1}^n y_i}{n} \quad \bar{X} = \frac{\sum_{i=1}^n x_i}{n}$$

Where: \bar{X} \bar{Y} mean center of X/Y, x_i y_i are the coordinates of feature i , n equals the total number of features.

2. Compute the weighted mean center (symbolized as W) for the same settlements (cities and villages), located within the same spatial theoretical framework, by using the same previous computational tools. Weight is the size of population of each settlement, it is possible to use other criteria beside or instead of this criteria. (McGrew & Monroe.,1993):

$$\bar{X}_w = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i} \quad \bar{Y}_w = \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i}$$

Where \bar{X}_w \bar{Y}_w weighted mean center of X/Y, w_i is the weight of feature i .

3. Compute the mean center of transportation nodes (symbolized as N) derived from the network transportation, within the same previous spatial theoretical framework, according to the same context shown in the first step.
4. Compute the mean center of points (A , W , N) (symbolized as F), within the same previous spatial theoretical framework ,and according to the same contexts shown above, to represent the center of the optimal circle, if the city has situation inside this circle, it could be described as having a central location. While the average distance between (F) and (A, W, N) will represent the radius of the optimal circle (symbolized as dF).
5. In order to formulate the relationship between the above factors within the theoretical model, its value represents the degree of centrality of cities , an index was formulated could be called (Centrality Index)(CI) is the square root of the average distance between the city and points (A,W,F), divided by the average distance between (F) and (A, W, N) multiplied by (100), and the formulation of model is:

$$CI = \sqrt{\frac{dA + dW + dN}{3 \cdot dF}} \times 100$$

Where CI is the centrality Index, dA the distance between the city and (A), dW distance between city and (W). dN distance between city and (N), dF average distance between (F) and (A,W,N). The greater the value of the index is, the farther the city will be from the optimal circle, and the less the degree of centrality will be. The lower the value of the index is, the closer the city will be from the center of the optimal circle, and the more degree of centrality will be.

Classification Model of (CI) Values

Determining the value of the centrality index according to the previous model, is not sufficient to detect the degree of centrality of city, so it is necessary to adopt adequate measurement tool to classify index values, based on the categories of the classification, the cities will be classified into cities which have a central location, moderate centrality, marginal, very marginal and extremely marginal location .

Let us assume that the center of first circle shown in the Figure (1) represent the mean center of points (A,W,N) and these points are distributed around its center in equal distance along its perimeter, and assume also that the average distance between (F) and (A,W,N)(the radius of the first circle) is (10 km).According to the previous assumptions, the value of centrality index will differ depending on the variation of city's location between the center and perimeter of the circle ,and thus we can distinguish between five classes of centrality index values ,each class indicate specific level of centrality ,the classes are (Table 1):

1. If the city situated on the center of the first circle, the same site of point(F), thus the values of the numerator and denominator will be equal in the model , then the value of centrality index will up to (100%),but if the average distance between the city and points (A, W , N) increased gradually, by about the length of radius of first circle (and reached twice) then the value of centrality will reach up to (140.9%) , so if the value of centrality index ranged between (100 to 140.9%) then the city has central location within the spatial theoretical framework, in this case it is probable theoretically according to Figure (1) that the city sites between the center of first circle and perimeter of second circle.

Table 1: Indications of Centrality Index

Classes	Average distance between city and points (A, W, N) in terms of radius of first circle	Location type
100 – 140,9	1	Central location
141 – 199,9	4	moderate centrality
200 – 244,9	6	Marginal location
245 – 282,9	8	Very marginal location
283 and more	More than 8	extremely marginal

2. If the average distance between city and points (A, W , N) increases gradually, by about twice length of radius of first circle (and reaches four times) then the value of centrality will reach up to (199.9%) , so if the value of centrality index ranges between (141 to 199.9%) then the city will have moderated central location within the spatial theoretical framework, in this case it is probable theoretically according to Figure (1) that the city sites between the perimeter of second and third circle.
3. If the average distance between city and points (A, W, N) increases, also by about twice length of radius of first circle (and reaches six times) then the value of centrality will reach up to (244.9%), so if the value of centrality index ranges between (200 to 244.9%) then the city will have marginal location within the spatial theoretical framework, it is probable theoretically that the city sites between the perimeter of third and fourth circle.
4. With more increasing distance between city and points (A, W, N) as the previous increasing value, about twice length of radius of first circle (and reached eight times) then the value of centrality will reach up to (282.9%), so if the value of centrality index ranges between (245-282.9%) then the city will have very marginal location within the spatial theoretical framework, it is probable theoretically that the city sites between the perimeter of fourth and fifth circle.

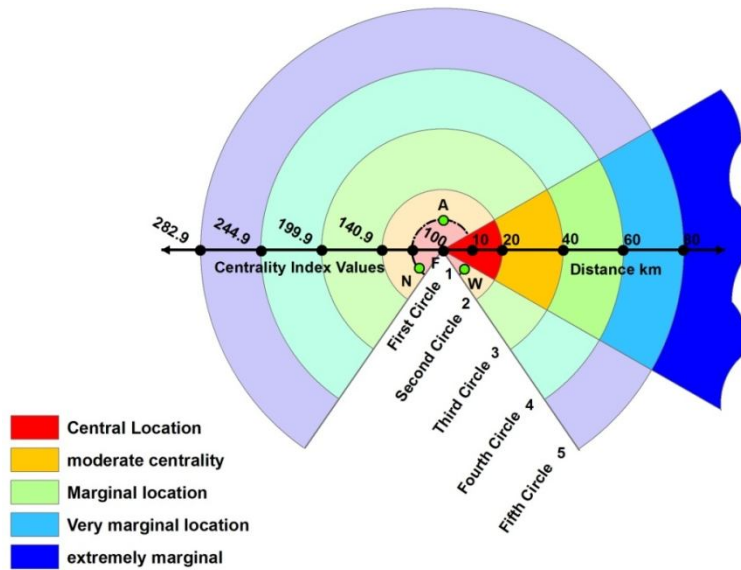


Fig 1: Theoretical Model for Classifying Centrality Index Values

5. With more increasing distance between city and points (A, W, N) as the previous increasing value, about twice length of radius of first circle (and reached eight times) then the value of centrality will reach up to (282.9%), so if the value of centrality index ranges between (245-282.9%) then the city will have very marginal location within the spatial theoretical framework, it is probable theoretically that the city sites between the perimeter of fourth and fifth circle.
6. If the distance between the city and points (A, W, N) increases and exceeds eight times the length of first circle radius, then the value of centrality will reach up to (282.9% and more) so the city will have extremely marginal location, and theoretically, the location of city will be determined behind the perimeter of fifth circle.

The Practical Study

The practical case study was conducted on cities of Erbil governorate in Iraqi Kurdistan Region, the study area occupies extremely north parts of Iraq, and central parts of Iraqi Kurdistan Region, lies between latitudes (35°,25',33" N) (37°,19',13" N) and longitudes (43°,20',35" E)(44°,04',55" E), covers an area of (15000 km²) and total population (1717284) inhabitants in 2009 , the bulk portion of population of about (76,5%) inhabit in urban areas in (44) cities , the remainder (%23,5) inhabit in rural areas in (1185) villages, Figure (2).

The administrative boundaries of the governorate were considered as spatial framework which affects when detecting the degree of centrality of cities, and the transportation nodes within the road network in governorate were converted to point file within (ArcGIS 10.2) environment, in order to detect the mean center of transportation nodes, as well as the mean center of total settlements (urban and rural) were detected, while the size population of the settlements represents the weight field when detecting the weighted mean center for the settlements, all this procedures were conducted within (ArcGIS 10.2).

The previous methodology was implemented on the cities of governorate according to the steps that have been mentioned above. In the light of the information displayed by Figure (3) and Table (2) which together represent the results of applying the centrality index (CI) the following notes can be concluded:

1. The mean center of settlements and transportation nodes and weighted mean center of settlements are located within a circle with a radius of about (9.5 km) in the northeastern parts of Erbil city, (between Erbil and Salahaddin city).
2. Roughly, about quarter of total cities of the governorate characterized as central location and moderate central location, six of total eight cities of this category are situated within the central part of the Erbil plain.
3. Two-thirds of cities are classified as marginal locations, while (18) of total cities of about (40%) classified as extreme location, most of them are located in north and north east parts of the governorate, which are mainly composed of complex relieves .

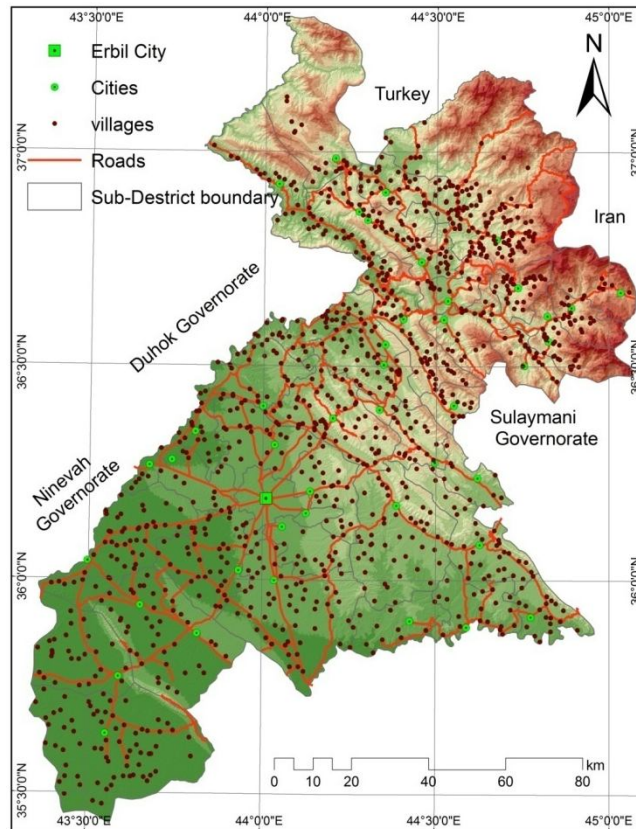


Fig. 2: Study Area

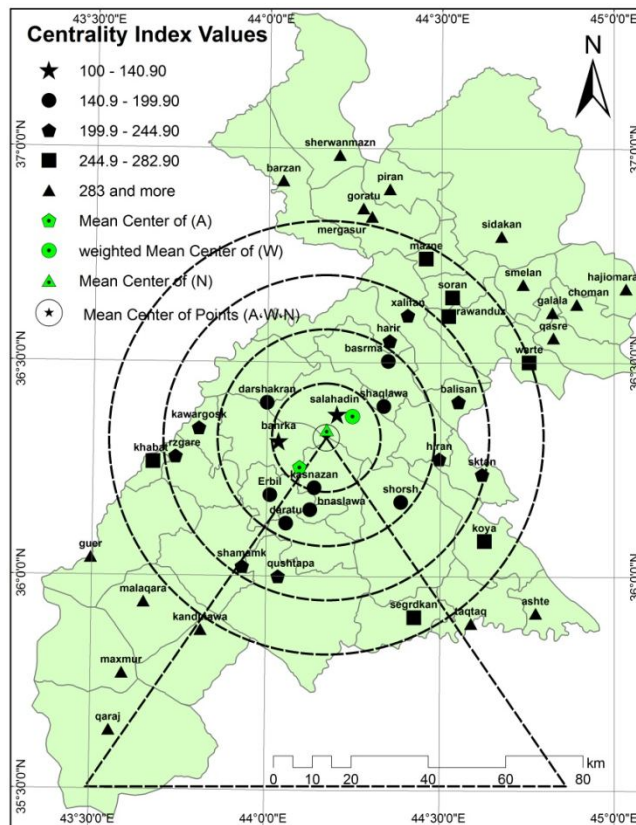


Fig. 3: Erbil Governorate Cities According to Centrality Index

Table 2: Results of Centrality Index of Cities in Erbil Governorate

Classes	Location type	No of cities	%	Average distance between cities and mean center for points (A·W·N)
100 – 140,9	Central location	2	4,5	9203
141 – 199,9	moderate centrality	8	18,2	20418
200 – 244,9	Marginal location	9	20,5	36061
245 – 282,9	Very marginal location	7	15,9	49750
283 and more	extremely marginal	18	40,9	69323
The value of (<i>dF</i>) in Erbil governorate is (7022 km)				

4. Erbil city, as administrative and economic capital of the governorate has a moderate central location.

Conclusion

The proposed model is a good tool to measure the degree of the centrality of cities within the spatial framework in the field of regional planning and analyzing the urban systems. It is also a good tool to highlight an important part of the spatial structure of economic activity in the region, as long as the model considers the locations of cities in a spatial context, as well as the economic and human factors that could affect the degree of importance of cities. There is a possibility to evaluate the effects of additional factors, in case there is a possibility to solve the complications and obstacles (statistical and operational issues) that might appear in application, in a form that is compatible with the model building procedures. This model can be used in different spatial levels to assess the growth potentials of cities, and realize or visualize their roles to achieve sustainable and urban development within the cities themselves, or at the regional level. Furthermore, this model could be a good tool to evaluate the potentials and the possible role of cities in achieving the sustainable and rural development.

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