Determination of Breaking Point for Tehran Metropolis Using Gravity Model

Rahim Rezaei
Ph.D. Student in Geography and Urban Planning
Baku State University
Azerbaijan

Abstract

No demographical center exists independently and all internal changes of human societies are resulted from belonging to those sets which based on the term case are known as geographical space, system or network. Inside the system or network, there are some relations between elements which have associated them to each other, but the degrees of their relation to each other are not the same. Tehran's municipal zone is also in the form of a network, where 52 cities surround it and have relations with it. Now, this question is set forth: to what degree is the relation of Tehran's surrounding cities with Tehran? In this paper, using the gravity model (gravitational force) and considering variables such as population, distance and access time, the breaking points between Tehran metropolis and each of its surrounding cities have been determined. It should be noted that without considering the access time, these breaking points are not precise. The obtained result suggests that the gravitation power of Tehran metropolis is higher around southern, south-western and western regions. Also, the research method is library research and study of documents and evidences.

Key words: Urban region, gravity model, surrounding cities, relation.

Introduction

The history of development of cities and urbanization is very long. After the agricultural revolution, the urban development has been the second huge revolution in human culture and following this huge revolution, the social trend caused some transformations in human interrelations. As a result of industrial revolution, the urban life was developed in different aspects, especially in Europe.

Establishment of industries and manufacturing plants inside and around cities caused cities to be converted into places for production and distribution of commodities (capital). Hence, the concentration of welfare features inside cities on the one hand, and existence of various jobs in cities on the other hand, caused a huge population to be attracted from surrounding villages. In this manner, the populations of cities increased day by day and the cities were constantly devouring their surrounding lands and villages in order to meet their demographical needs (e.g. housing). Hence, the land area of cities was increasing.

The trend of increase in population and land area of cities in industrial countries occurred slowly upon implementation of population control policies. In fact, the number and populations of cities in industrial countries increased over several decades along with industrial advancements and development of facilities.

But in developing countries like Iran, the urbanization was very fast. In other words, and population increase and the number of cities in developing countries quickly increased as a result of lack of control on population and emigration from villages to cities. Some cities attracted more emigrants because of having centrality and more facilities. Hence, some cities with special features emerged in urban hierarchies that were named as 'metropolis' by experts. The capital cities, province centers, more populated and important cities of the world were grouped in the 'metropolis' category (Behafrouz, 1995: 293-303).

Metropolises emerged and expanded around late 19^{th} and early 20^{th} century. Very large concentration of population and different activities in metropolises imposed serious crisis on them in terms of environmental, air pollution and other issues. Hence, the urban planners created some cities in different distances from metropolis to resolve this issue. In other words, the decentralization policy with respect to metropolises caused some new geographical units with different distances from them to be created as industrial, service and sometimes dormitory centers.

In this manner, the satellite cities or 'Sputnik' or 'new cities' were formed in distances of 35 to 70 kilometers far from metropolises (capitals) which had a key role in development of city networks (Farid, 1994: 73). As a result of developments in communication devices and increase of vehicles' speeds, the satellite cities, surrounding cities and metropolises were linked to other urban regions (satellite cities, towns and metropolises) and as a result of this link, a wide urban form was formed known as 'metropolis' (Shakouie, 1994:40). By increase of population and the number of surrounding cities, the metropolises were encircled by them. The concentration of capital and different economical activities inside the metropolises caused a large population from surrounding cities and suburbs to enter them for occupational purposes. In other words, the versatile and wide relations were established between metropolises and their surrounding urban centers and the surrounding cities have various functional dependencies on metropolis. This urban area was named as 'urban region' by experts.

Every day new issues and questions arise regarding the cause of existence and the mechanism of life in urban regions, such as how the urban regions are formed, on the basis of what relations they continue their life, what are the motive force and dynamism of these regions, to what extent the environmental factors are effective in their expansion and how are the relationships inside urban regions between cities and metropolis, etc. Numerous questions are set forth with regard to urban regions and the relations inside them. The bigger the city, the more complex is its relation with suburbs. A metropolis is surrounded by various small cities which reflect the different levels of recognition which are manifested by shops, industries and organizations (Johnson, James H., 1984: 144). The cities have various relations with surrounding regions and these relations are unbroken, stable and dynamic. This relation depends on environmental conditions, geographical position, urban hierarchy, role and function of the city, etc. Meanwhile, the city of Tehran is not an exception to this rule and like other cities has various relations with surrounding cities. Tehran is the most populated city of Iran. Most of services, scientific, research, military, medical, political, industrial, etc. centers are concentrated in Tehran. The country's main industries are also located around Tehran.

Regarding the above-mentioned items, the following question can be set forth:

- How much is the gravitation power of Tehran metropolis over different surrounding cities? In other words, how much are the relations between Tehran metropolis and surroundings?

To find an answer to the above question, a hypothesis is outlined as follows. Does the amount of relations between Tehran metropolis and surrounding cities depend on population and the distances between them? The aforesaid hypothesis is explored based on library data and using gravity model.

Methods for determination of influence field

One of the methods employed for determination of influence field is the method of Iso-influence lines. After recognizing the centrality of the city, the simplest statistical method for determining the urban gravity field is to use the following formula: $2I=p/d$.

In this formula, I represent the city's gravitational intensity on a point of its surrounding space and is proportional to the mass population of that city, p, divided by the reversed square of the distance between that point and the city, namely 2d.

Here, mass population means the active population in the third section of social jobs. Having performed such calculation on all geographical units with respect to central city, the Iso-influence centers are related to each other using some curves. The thickness and orientation of the curves are truly representative of the intensity and action of city on the region and region's geographical units (Farid, 1993:74).

The flow analysis method is another method which is used to determine the urban region relations. In this method, the orientations and intensities of flows between one demographical center and its surrounding demographical units are determinants of limits and boundaries of functional region. Intensity of each flow decreases by going away from one center and increases by approaching another center. Considering this feature, the limits and boundaries of an urban region (a demographical center) is a place whose intensity reaches the minimum value. The flows are of different types, but often encompass various economical activities which are categorized in terms of type (like the traffic of passengers, commodities, road or railway) and /or purpose (like the daily shopping or daily commuting to workplace).

Meanwhile, the flows may have social nature (like the daily flow of pupils or patients), political nature (like the flow of state costs) or communication nature (like telegraph, telephone or newspaper) (Rafiei, 1992: 15). In fact, the flows of information, human beings, goods and energy are taken into consideration. The basic theory for using this method is the graph theory (Razavian, 1997:35).

Other methods employed for determination of influence field are as follows: Seven Goland method based on retail and services and the Lush's theory of economical space based on price curve and demand curve (Talaminaei, 1974: 34), Von Tannen method based on land use pattern or agricultural goods prices (Saberifar, 1999:33) and the Central Place Theory of Walter Christaller (Papoli Yazdi and Rajabi, 2003: 132).

The gravity model

The gravity model (inspired from Newton's law) is one of the methods used for determination of urban influence field**.** Based on this model, once can determine the breaking point between two cities (Farid, 1994: 85).

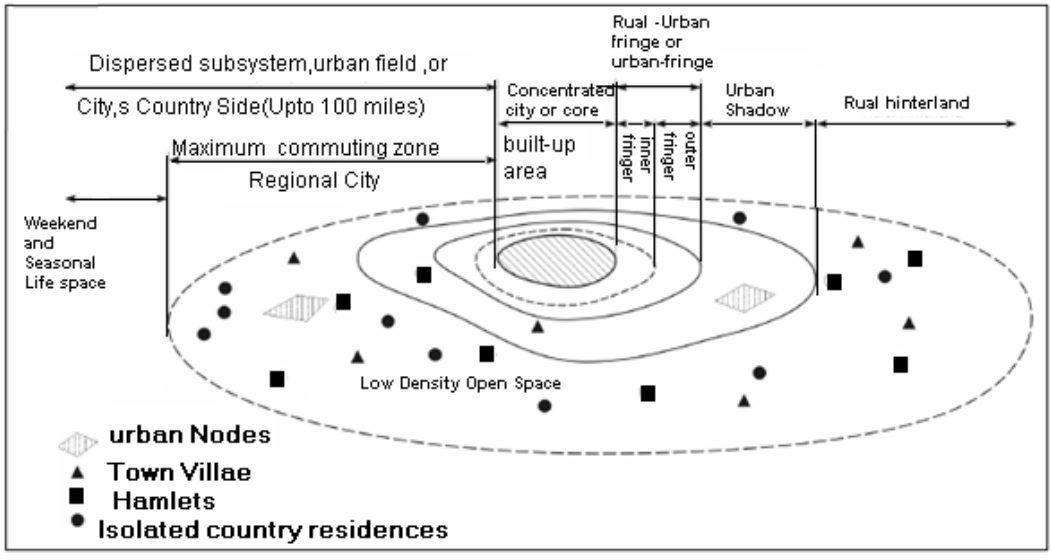
The first theory that investigates the interrelations of some of human activities in territorial spatial organization is the gravity model. The gravity model is one of the most important deposits extracted from physics by geographers (Hekmatnia and Mousavi, 2006: 134).

In the Friedman and Miller's formula for gravity, a new environmental unit has been considered around the metropolis in which the daily travel (commuting) between the metropolis and its surrounding is about 2 hours (64 to 80 km) with respect to city center (Friedman, J., Miller, J: 1973: 79).

The relation in urban region is a multi-dimensional space formed from surrounding function and both of them (urban influence field and urban region) can have three separate main dimensions (Coppack, 1988: 25).

The first dimension is combined from the concentration of maximum land use, the dispersion of human activities among fields and the undeveloped regions. The second dimension is related to urban centers which exist in two forms, namely the physical flow of goods and people and non-physical flows of information and money. The third dimension is the frequency of performing the relations inside the urban influence field and urban region whose daily rhythm is different (figure 1).

Figure 1: the shape of urban region and urban influence field (Bryant, Coppack, 1991: 220)



The 'internal' and marginal 'external' regions can be recognized by apparent transformation due to large urban influence and feeling of change in all environment categories. The external regions of the suburbs can be recognized as 'influence region of the city' based on dependencies on central city and also effects and pressure of the city (Bryant, Russwurm and Mclellan, 1982:58).

As shown in figure 1, the limits of the urban influence field include urban region too. In other words, the urban region is located inside the urban influence field. But not all cities have such situation.

The influence field of Tehran includes throughout the country in addition to urban region or one can say the metropolises (like Tokyo, London, New York, Paris, etc.) enjoy universal influence fields in addition to urban region and throughout the country. The continuous traffic of passengers from throughout the world is indicative of this fact.

"Gravity model" is of paramount importance as one of applied models especially for determining the urban region relations. This method has been introduced by 'William Riley.' 'Riley' believed that there is much similarity between 'urban field' and 'gravitational field.' Here, the gravitational field has been used as Newton's concept (Azimi, 2002: 97). In this model, Riley has supposed that the amount of referrals of a crowd to shops of a city has inverse relation with the distance between that crowd and the desired city. Also, it has a direct relation with the population of that city. From this hypothesis, he suggested a point known as breaking point that relates to two variables, i.e. distance and mass (population). If two cities have the same size and area in urban network, the breaking point would be exactly in the middle of two cities, but if these two cities do not have the same size and area, the larger city would have more power to attract the consumers than the smaller one. In this case, the breaking point would get away from the larger city and would approach the smaller city in proportion to the size of the larger city. This means that the gravitation power of the larger city for attraction of consumers will be higher. In order to obtain the breaking point between two cities, 'Riley' has suggested the following formula:

Distance from breaking point to city A = $\frac{d_{AB}}{1+\sqrt{\frac{p_B}{p_A}}}$

Where d_{AB} is the distance between two cities of A and B and p_A denotes the population of city A (Azimi, 2002:105).

The breaking point obtained from Riley's model is not precise, because the region topography (being mountainous) and the conditions of communication ways such as autobahn, highway, railway and subway affect the separation or breaking point. This also applies to breaking point of Tehran metropolis. In southern, south-western and western regions of Tehran, the breaking point is favored toward Tehran because of various communication ways (highway, autobahn, metro) and also various vehicles (bus, passenger cars, subway) and the city is more affected by Tehran's gravitational power, but eastern regions of Tehran, namely the Tehran-north route (Firuzkuh-Damavand-Rudehen,…) and the northern Tehran (Lavasan, Fasham,…) is less affected by gravitational power of Tehran metropolis because of mountainous regions and lack of communication ways such as subway.

In fact, the 'access time' should be considered in gravity model in order to properly obtain the breaking point.
Hence, in order to specify the breaking point between two cities, the Riley's suggested model should be modified as follows.

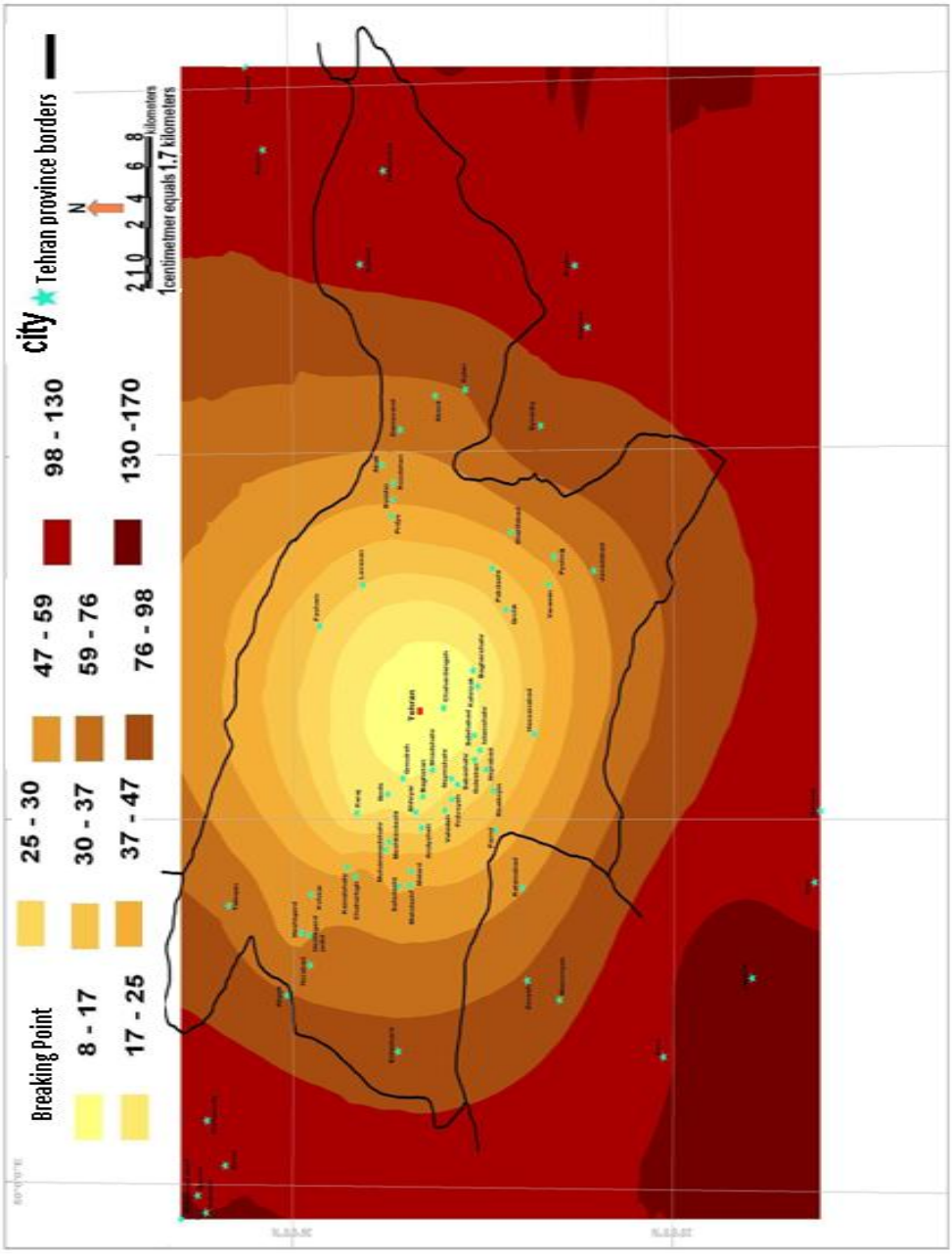
The suggested (modified) gravity model is as follows:

$$X = \frac{Zij \times T}{1+\sqrt{\frac{pi}{pj}}}$$

Where,
X: separation point; T: access time; Z_{ij}: distance between two cities; p_i: population of the larger city; p_j: population of the smaller city.

Suppose two cities A and B in urban region which have the same distance to metropolis and city A has mountainous roads and lacks highways which the vehicle speed does not exceed 50 km/h and city B has highways and the vehicle speed exceeds 120 km/h, then the time to reach from city A to metropolis would be more than the time from city B to metropolis. In these cases, the Riley's model does not exactly show the breaking point. Therefore, using the suggested model, the breaking point of two cities can be determined more precisely by taking into account the time duration.

Using the suggested formula, the breaking point and gravity domain of Tehran metropolis were specified and the obtained numbers were converted into map over some stages and for better illustration (map no.1). Firstly, all distances between all surrounding urban points and Tehran metropolis were specified and the population in 2006 was set as base population of surrounding cities and Tehran metropolis. Then, the aforesaid formula was defined in the software Excel. Hence, different numbers were obtained in terms of distance, access time and population of surrounding cities and Tehran which were defined in GIS again, so that the map no. 1 was obtained and this map showed that how the breaking point of Tehran metropolis varies in terms of distance, access time and population.



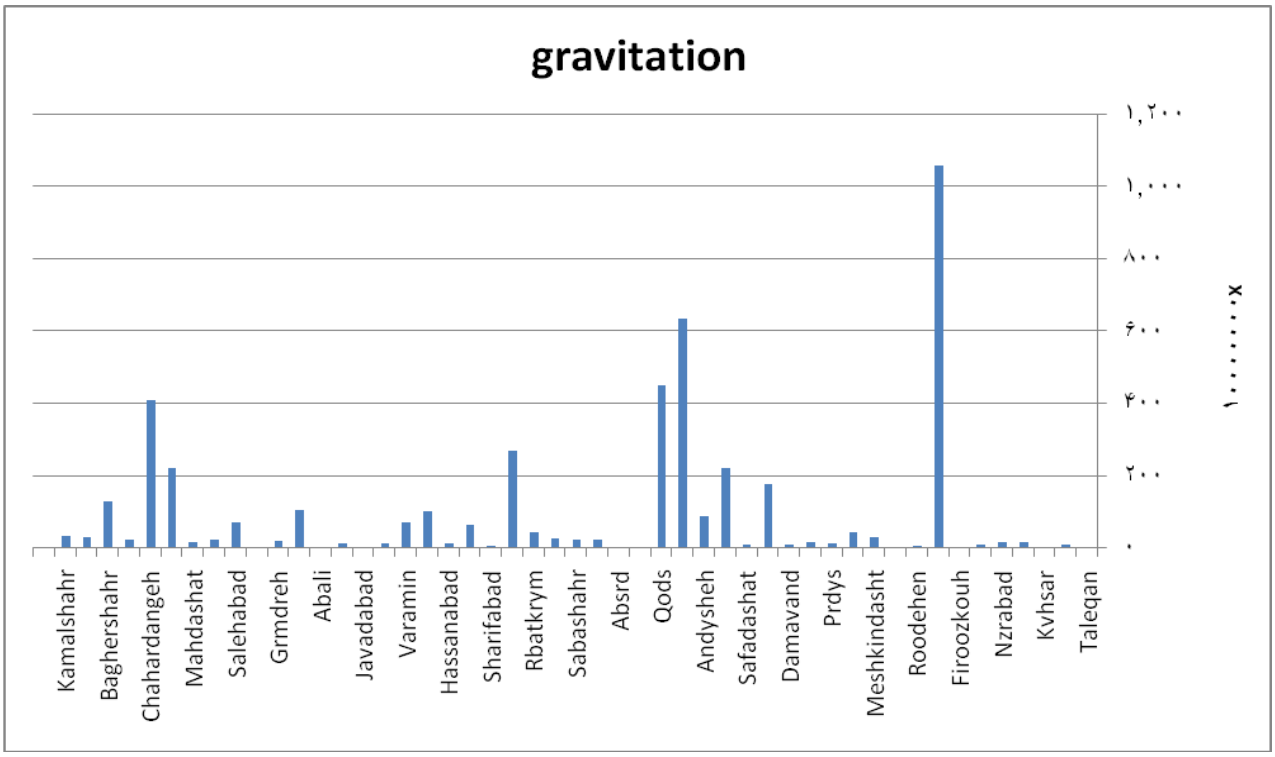
To investigate the relation between the metropolis and the surrounding cities inside the urban region, the flows (the traffic of population, exchange of goods, …) existing between metropolis and surrounding cities should be studied.

The flows of population, goods and information between two cities depend on the size of cities and the distance between them. The flow between two cities is directly proportional to the product of their populations and is inversely proportional to the distance between them. This idea is shown by formula (1) as follows:

$$t_{ij} = k[\frac{p_i p_j}{(d_{ij})^2}]$$

Where,
K: constant value which is generally equal to unity; t_{ij}: the amount of flow between two cities of i and j; d: distance between two cities; p: population (Taghizadeh, 1997: 151) (diagram 1)
This model is based on Newton's theory of gravity. In this method, the emphasis is on the potential flow between centers. It is assumed in this model that the mutual effects of two demographical centers have a direct relation with masses of these two centers and have an inverse relation with the distance between them.

Diagram no.1 shows the gravitation intensity of Tehran metropolis in urban region over surrounding cities.



Since the relation or flow (goods-population) between two cities depends on some factors such as existence of communication way (highway, autobahn and metro), so the aforesaid formula is not true in all cases. In other words, to investigate the flow between two cities, the region's conditions (being mountainous, etc.) should be considered. For example, although the city of Saveh is farther from Tehran compared to Damavand and Firuzkuh, the traffic between Tehran and Saveh is higher because of existence of autobahn (without having hazardous turns). So for precise investigation of the flow between two cities, the above formula should be modified as follows:

$$M_{ij} = k\frac{p_i p_j}{dij \times T},$$

Where, M_{ij}: the amount of flow between two cities of i and j, d_{ij}: distance between two cities, K: constant value and is generally equal to unity, p_i, p_j : populations of two cities, T: duration of access time.

In this manner, each urban point would have a good potential regarding three variables population, distance and access time and regarding the coefficient k which can be a basis for drawing the iso-potential lines. Diagram 1 shows the gravitation power of city Tehran with respect to its surrounding cities. Regarding diagram 1, 'gravitation power' depends on the population, distance to that city and the access time. The gravitation power for each of the surrounding cities was obtained based on the modified formula that different numbers were found. Regarding diagram 1, the gravitation power of the metropolis of Tehran in cities of Karaj and Islamshahr is higher in comparison with other cities.

The next ranks go to the cities of Golestan, Chardangeh, etc. The least gravitation powers with respect to the metropolis of Tehran belong to the cities of Taleghan, Arjmand, Kuhsar, Abali, etc. The cities located in western and southern regions of Tehran metropolis have more relation with it because of easier access to it. In other words, most of flows (population, good, etc.) are established between them, while fewer flows are established between Tehran metropolis and cities located in northern and eastern regions of Tehran, because of being mountainous and lack of easy access to western and southern regions.

Conclusion

In studies conducted on breaking point and also the impact of a metropolis on its surrounding cities, the access time should also be considered along with variables population and distance. The Riley's suggestion for determining the breaking point of two cities using the Newton's gravity formula applies to those regions in which all cities are almost the same in terms of access time. In other words, all cities enjoy communication ways and vehicles in the same manner or the access time is considered in Newton's gravity formula. Otherwise, the obtained breaking point would not be correct. It is manifestly clear in the urban area of Tehran.

Communication ways of Tehran metropolis with respect to suburbs in southern and south-western regions differ fundamentally from those in eastern and northern regions. Tehran metropolis in southern and western regions has wide relations with surrounding cities via metro in addition to highways and autobahns, while the eastern and northern regions are not only devoid of metro, but also are devoid of such various and hazardous turns-free highways. So the relation of Tehran metropolis with eastern and northern cities is not similar to that of southern and western cities.

So, in order to determine the breaking point of the cities more exactly, the variable time (i.e. duration of access time) should be considered.

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