Analysis of physical expansion and sprawl growth factors of Sari city using Shannon and Heldern entropy models

Mohammad Mehdi Nasiri Khalili[a*], Hamid Abya[b*], Mohsen Ebrahimi[c], Simin Tavallaee[d], Mohammad Soleymani[d] and Mousa Kamanroudi[d]

[a]*PhD student in Geography and Urban Planning, Semnan Branch, Islamic Azad University, Semnan, Iran*
[b]*PhD student in Geography and Urban Planning of geography faculty, Kharazmi University, Iran*
[c]*Phd student, Department of Management, Tarbiat Modarres University, Tehran, Iran*
[d]*Department of Geography and Urban Planning, Kharazmi University, Iran*

CHRONICLE	ABSTRACT
	Population growth and rapid urbanization growth in recent decades have not only led to unbalanced physical expansion of cities, but also contributed to growth and development of cities. The city of Sari in Iran, like many other cities is not immune from these changes. The city population has increased by 16 times over the last fifty years. Therefore, the increasing population growth has created uncontrolled physical expansion in the city. In order to prevent these inefficiencies of urban problems, the present study was accomplished to determine the factors influencing the process of expanding the city of Sari and to find out some solutions to fix and prevent this process. The method used in this study, descriptive–analytical method, to data analysis and Heldern and Shannon entropy model were used. The results show that: 82% of the physical growth of the city during the period 1977-2005 was related to the population growth and the remaining 18 percent, was associated with the horizontal growth. The city sprawl, the metropolitan area of the city had denser structure and the surrounding areas had a more dispersed structure. Also the effects of synthetic and natural factors restricting the city of Sari physical development made the city exorbitance horizontal and linearly developed. According to the findings that could help prevent the horizontal development of the city, it could be said that we could make the city vertically developed rather than horizontal expansion, improvement and renovation of old texture of implementation and more use of the land, filling the empty spaces.

1. Introduction

Industrial revolution led to rapid growth of cities, so that the world's urban population was about 3% in 1800 reached to 9.68% in 2005. In addition, many urban centers could not accommodate these sudden influx of migrants and, as a result, the cities began to develop unevenly and open spaces disappeared in recent years (Zakerian et al., 2010). Increasing the urban population in countries faced the cities involved various issues such as imbalance of spaces, price oscillation of the lands and housing,

urban creep, polarizations of society, environmental pollutions and more energy consumption. Development without planning, increased infrastructure costs, high quality agricultural lands went under construction, multiplication range of urban, low-density tissue formation at the edge of town and service problems (Sayf o Dini et al., 2012).

In our age uneven physical development of the cities has created one of the major problems in land application (Shakuyi, 2000). One of the effects of this physical development is associated with expansion margins of cities or regions in countries, beyond the administrative boundaries of cities and towns. This urban development went into the outer areas and caused changes in surrounding land use. (Shie, 1998). Therefore, horizontal growth of the cities is considered an extreme increase urban land and urban distribution, which may decrease the population density, increase the share of open spaces and unused, and consequently break segregation of urban and the spatial and ecological break (Taghvaee & Saraee, 2006).

In Iran, as long as the urban growth patterns were organic and determinants factors were the endogenous and local factors, physical development of cities was slow and urban land use was sufficient. However, when exogenous nature became the basis for the development of cities and oil revenues came into the urban economy, physical growth of cities and urban buildings took place not based on need, but based on speculation and land speculation (Majedi, 1999; Sayfo-Dini et al., 2012). The method of city distribution went outside of its normal way and anarchy took place in urban distribution, thus, it can be said that sprawl physical expansion of the cities is to blame for anarchy about the operation principles and the scientific basis of the urban terrain (Ebrahimzadeh Asmyn et al., 2010). Another point that should be noted about the physical development of cities, is that in Iran non practical growth of urbanization has led to under development and this urban population growth creates different problems such as housing issues, housing lacking facilities, unreflective growth of the city, land speculation, lack of infrastructure, lack of appropriate services, physical tissue dehiscence, and marginalization. The city of Sari in Iran is no exception from this rule and urban population growth and physical development. In fact, the population of this city has increased significantly its development has been endangered according to demographic and economic changes. Artificial and natural problems in the way of physical development of the city can be classified into three main categories as follows:

A) Barriers to an area such as: rural residential zones, agricultural zones, mountains and forest lands,
B) Linear barriers such as: Tajan River, and power transmission lines,
C) Focal obstacles such as: oil depots.

It should also be added that with continuing physical development without programming in town would make this Positioning Villages located in the vicinity of the town; namely Huvla, Zoqalchaal, Polgardan, lower Deza, upper deza, Ahidasht, upper melik, lower Melik, Sharafabad, Qoroq, come into the metropolitan area and the disorder will be more and more.

2. Necessity and importance of the study

The lack of physical development of the city, as a basic necessity in urban development plans, indicates the importance of this issue, in Iran. One of the important steps in the process of urbanization is the rapid physical expansion of its cities. Unplanned urban growth due to irregular migration and population growth is one of the major problems. In fact, one of the problems of all cities is associated with urbanization and the consequently expansion of urban areas and the areas around it (HosseinzadehDalir & Hushyar, 2006) that has consequences such as destruction of agricultural lands, marginalization, physical tissue disruption, increasing population of cities, impossibility of answering some of the services and applications in cities, environmental problems, especially in the urban landscape. Many Iranian cities including the city of Sari, in growth and development, are faced with these problems. The study of the physical growth patterns and urban spaces at recent decades and

analysis of relationship between developments and social and economic changes at cities make it possible to recognize the role of requiring social at urban lives. On in this matter, form of city growth and spread are considered as reflection from steps of social development and changes inside cities (Yosefifar, 2006). In this study, the issue of city of Sari physical and shape expansion patterns are reviewed in order to evaluate its influencing factors.

3. Study Methods

A quantitative description of human social patterns is one of the greatest challenges of this century. (Hernando et al., 2014). According to various studies on the nature and method, in this study a descriptive – analytical method was used. At first from source documents, such as researches, local designs and sites and then physical development of Sari using Heldern and Shannon entropy models, is evaluated and analyzed. In this study, the patterns of urban development based on Shannon entropy and Heldern models, in terms of different variables such as area of regions and cities, population and net capita and gross, were used to determine the spread of the city and its influencing factors in above mentioned models.

4. Economy, social and physical developments of sari Overview

The population of the city of Sari (in the law range) from 1957 to 2012, was increased approximately 12-times and form 26 thousand person in 1957 reached to 296 thousand people in 2012. Table 1 shows index of population of sari city from 1976 to 2012.

Table 1
Demographic characteristics of sari city over the period 1976-2012

Demographic indicators	(1976-77)	(1986-87)	(1996-97)	(2006-07)	(2011-12)
Population (people)	70753	141020	195882	261293	296417
Number of households	15527	29830	44280	71564	90798
The average household size	4.6	4.7	4.4	3.7	3.26
Average annual growth (period)	-	7.1	3.3	2.5	

Also, the natural growth rate of Sari population after reduction year of before revolution went up to 3.5 percent. However, with reduction fertility and as a result of reduction rate bearing of more than 40 per thousand to fewer than 20 per thousand in period 1992-1997 and 15.1 per thousand during the 2001-2006, rate of practice growth of peace population from around the 12 per thousand was reduced to 5 per thousand. The net result is not matched with fertility reduction level of city of Sari. The main cause of this lack of compliance is non- existence of proportion between this fertility level and the rate of bearing that is because of young population, which reflects at the top amount of the natural growth. With this fertility level of Sari city women would be expected that the rate of practice growth of peace in this city lead to negative numbers. Overviews show that during the period 2001-2006, of approximately 1.9 annual growth rate from 2.9 percent of sari city population is from exchange population of this city with the other settlements of human province or out of province. Studies show that, Sari city has a structure with one central area and several weak core with patterns of relationship between the radius – ring structure (with being insufficient at ring form) that on its basis a network of centers and subjects colleague and urban supplement at space diverse are created, and it has made this city strongly ready for missions within or outside the city.

4.1. Sari city Expansion and urban growth

Geographic location of Sari city: East along 53 degrees 3 min and north latitude and 36 degrees and 34 min, and average height of the free sea surface, about 40 m, from natural view it is located in the plains region south of Mazandaran sea and only parts of the South and South West of it end to the mountains

and foothills and from sides enclosed by barriers. With citation to overviews, Sari as center province of Mazandaran, has an important history and except few periods that Amol and sometimes Babol were center area, often it had the center of the office–politic responsibilities. Fig. 1 shows the population of the city.
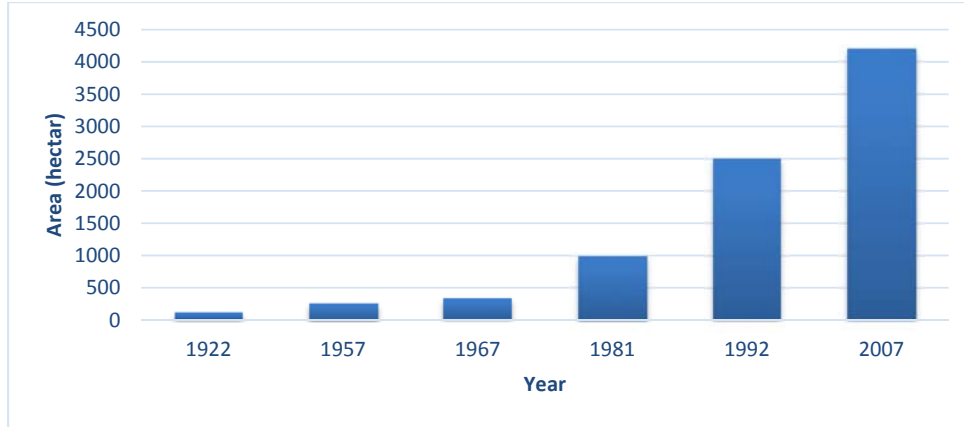

Fig. 1. Expansion of the city

At total for Sari city four applied history period described at follow can be defined;

First period: historic and ancient until time of Safaviyeh (the feudal city castle).
Second period: later (in the Sfv and Qajar) (developing networks of relationship and civilization).
Third period: contemporary - first and second Pahlavi (an administration – service urban).
Fourth period: new (Islamic republic) influenced by development of city plans.

During mentioned period's maturity process, growth and development of the city has been formed at facilities' line and proportional with time. Output of mentioned periods; development of city is considered - feudal castle until development network of the relationship and civilization and later city role development of administration- services. Fig. 2 shows the spread of the city during different years.
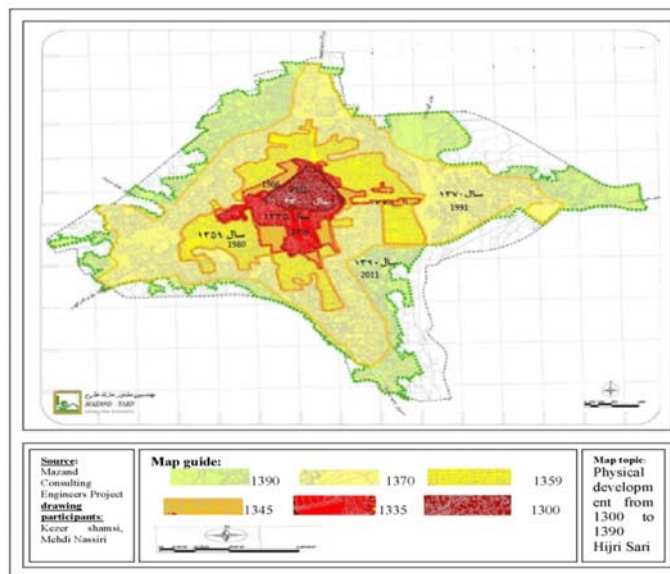

Fig. 2. Expansion of the city during the past half century
Source: Master Plan Sari (Mazand Consulting Engineers Project)

5. Theoretical principles

The event of Industrial Revolution in the 18th century and the 19th century brought a big change in urban areas where the most important was the population growth of cities. The most important result of the increase in population, was associated with the stress. The high demand for accommodation and related services, on the earth and the pressure caused by the uncontrolled growth of population, creates more challenging problems (Samat, 2006).

After World War II, a major industrial city pattern was an urban growth pattern. Patterns that occur in low densities and a lot of poor outcomes, as the destruction of agricultural lands have created some service problems (Rahnama & Abbas Zadeh, 2008; Mashhadizadeh Dehaghani, 2003).

5.1. Definitions

Scattered low-density development and urban areas in developed countries named as Urban sprawl because of the numerous and destructive effects on the environment in urban areas, reflecting the attention scholars and the policy makers of issues and prompted them to resort; increase in density and distribution deal with growing urban areas, has devoted the bulk of the discussion to sustainable development in the last decade (Poormohammadi & Qorbani, 2012). "Horizontal expansion of the City" is a term that in the past half century has come in the literature (Hess, 2001. Quoted from: Rahnama & Abbaszadeh., 2008).

5.2. Distribution of cities in Iran

Uneven development and distribution of cities in Iran is worse than many developed countries. In reviewing the history of urban development in the country it can be said that the cities have two urban growth scenarios in the organic model up to Pahlavi, especially before the land reforms in spatial development happed in the form of mostly endocrine of the population. In this process structural changes were generally in contents and the growth pattern of the city had been remained compact. Another scenario of the cities of Iran associated with the last quarter century gone through stages of growth has been inorganic growth model. This process is much faster than population growth and spatial development of cities and towns have a real need to expand the surface. (Taghvaee & Sarayi, 2006). The problem of rapid growth and horizontal expansion in Iran perhaps is worse than most of the developed countries or developing. This problem has become more complex during the Islamic Revolution. The causes of this phenomenon in cities can be classified in the following format:

- Lack of principles of land use, has made the system of cities chaotic in the country.
- Urban population growth in recent decades has been an upward trend.
- Ground rules of the city during the revolution, probably has been one of the most influential factors in the urban fabric.
- In most cases, the method of preparing the land concession and the governing body of the city has been directed toward expansion of city (Azizi, 2005).

In fact, we can say that the traditional pattern of urban development projects because of the lack of system attitude and lack of attention to strengths and weaknesses points of natural and potentials of city has been unsuccessful. Thus, physical expansion of sprawl city in the country, in most cities is the result of not having plan in the utilization of scientific principles and on the basis of the city's lands. (Ebrahimzadeh Asmyn et al., 2010).

6. Physical development of the City Survey with Shannon's entropy Model (SHANNONS ENTROPY MODEL)

This model is used to analyze and to determine the uneven growth of city. The overall structure of the model is based on Shannon Entropy as follow, (Hekmatnia and Mousavi, 2006),

$$H = -\Sigma P_i \times ln\ (p_i) \tag{1}$$

where H is the Shannon's entropy amount and P_i is the ratio of built area (the residential density). Shannon entropy value is from zero to the value of $Ln(n)$. Zero value represents physical compressed (zipped) development of city. The value of $Ln(n)$ represents the scattered development of city. When Entropy value is more than amount of $Ln(n)$ uneven development of urban (sprawl) happens. For the application of this model in determining the value of uneven growth of the city, Sari was divided into 4 regional and 11 area. We plan to determine the physical development using Shannon entropy. Nevertheless Area of Sari By the last City studies, is 4208.6 hectares that is determined in 11 areas. According to Table 2 and Table 3 we have H= - (-3.157) = 3.157 for year 2000 and H= - (-2.230) = 2.230 for year 2010.

Table 2
Calculation of the Shannon entropy for the year 1379(2000) in Sari

Zones	Urban area	Area	Pi	Ln(pi)	Pi × Ln(pi)
	1	421	0.156	-1.854	-0.289
	2	175	0.065	-2.732	-0.177
	3	207.7	0.077	-2.561	-0.197
1	4	231	0.085	-2.455	-0.208
	5	902.9	0.335	-1.091	-0.365
	6	159.3	0.059	-2.826	-0.166
	1	148.3	0.055	-2.900	-0.159
	2	131.9	0.049	-3.014	-0.147
	3	137.3	0.051	-2.975	-0.151
2	4	161.0	0.059	-2.816	-0.166
	5	280.8	0.104	-2.259	-0.234
	6	264.4	0.091	-2.390	-0.217
	1	113.4	0.041	-3.116	-0.127
3	2	231.3	0.085	-2.453	-0.208
	3	199.7	0.074	-2.600	-0.192
4	1	134.4	0.049	-2.996	-0.146
Total area	16	2690.5	1	-41.038	-3.157

Table 3
Calculation of the Shannon entropy for 1389 (2010) in Sari

Zones	Urban area	area	Pi	Ln(pi)	Pi × Ln(pi)
	1	339.1	0.080	-2.518	-0.201
	2	350.2	0.832	-0.183	-0.152
1	3	546.9	0.129	-2.040	-0.263
	4	277.1	0.065	-2.270	-0.147
	1	363.3	0.086	-2.449	-0.210
	2	638.6	0.151	-1.885	-0.284
2	3	258.6	0.061	-2.789	-0.170
	4	363.6	0.086	-2.449	-0.0210
	1	416.1	0.098	-2.313	-0.226
3	2	520.5	0.123	-2.090	-0.257
4	1	134.6	0.031	-3.442	-0.106
Total area	11	4208.6	1	24.428	2.230

Since the value of entropy amount is close to the maximum value, it indicates a physical scattered growth of the city. That shows during ten years physical development spectrum is scattered and uneven.

7. Survey of the Size of City Spread with Heldern Model

Heldern is one of the basic methods for determining uneven urban growth. With this method, it is possible to determine the amount of city growth based on population growth and the amount of uneven urban growth. This model first was applied to calculate the ratio population to any other source by Heldern in 1991. According to Beck et al. (2003), the method first calculates per capita GDP as follows,

$$a = A / P, \tag{2}$$

where per capita GDP (a) is equal to the product of the area (A) divided by Population (P). Next, we calculate Heldern as follows,

$$Ln (P / w) + ln (e / r) = ln (y / s), \tag{3}$$

where P is population of end Period, W is population of start period, E is impure capitation of end period, R is impure capitation of start period, Y is city extent at end period and, S is the city extent at start period. Table 4 demonstrates the summary of some basic statistics associated with Heldern method.

Table 4
The summary of basic statistics associated with Heldern method

Period	Population (n)	Gross per capita (in m)	Urban area (in hectares)
Start time (year 1335) (1956)	27037	127	260
End of the period (1385) (2006)	261293	96	4208

Using Eq. (2) and Eq. (3) yields,

Ln (261293/27037) + ln (160/96) = ln (4208000/260000)

Ln (9.6642) + ln (1.6666) = ln (16.184)

2.268 + 0.510 = 2.784

Then with assignee of each equation side to 2.784 shares related to population growth percent and per capita of urban areas percent are obtained:

2.268/2.784 + 0.510/2.784 = 2.784/2.784

0.82 + 0.18 = 1

Finally we can say that 82% of city growth during (2000-2010) is related to population growth and remaining 18% is related to horizontal growth and city sprawl that the result has been decreasing impure population and increasing capitation of impure urban areas at horizontal spread of Sari city line.

8. Conclusion

The city of Sari during its life in both natural and pre-meditated forms, has faced different patterns of expansion and sometimes has encountered many challenges that now has concerned citizens and city

management too. Therefore, for the purpose of prevention, the increase in difficulties of physical expanding (sprawl) in future, choice of future extend patterns is very important.

The city of Sari, like other cities has received many changes over time. In this paper, the city development was overviewed with Heldern and Shannon entropy models and the results of the models have shown that at study decades about 82 percent of growth area of city was associated with population growth. In addition, the remaining 18 percent had uneven urban growth, horizontal and sprawl. Moreover, evaluation of effective factors have indicated that having flat topography, appropriate land incline around the city, particularly in north of the city, inappropriate and non-essential implementations such as military use, prison and vacant, etc. in the city have created some challenges.

Another issues such as having much migration, earth assignment policy and housing after the revolution, increasing rate of personal cars or improving transportation, integrating rural and villages in the city, the ambiguity in the urban law and provisions and frequently changes of urban managers influence the city, significantly. It can be said that artificial and natural factors limiting physical development of the city of Sari like zone barrier, rural residential zones, agricultural zones, forest land, and altitude, linear constraints including Tajan river and power lines and railways and obstacles area (oil company storage) have led to much horizontal and linear development in the size of the city.

8.1. Suggestions

Based on the results of this survey, the following suggestions for the growth of the city are presented:

- At city development and spread, different factors especially environmental factors and geomorphological phenomena at different dimensions should be considered.
- In use of new lands to city development and earth divestiture to people in addition to attention to local customs and habits and details of cultural and social we should try to decrease distribution construction and instruments and increase density at surface unit in order to present more services for citizens.
- Construction of multi-story housing pattern to prevent the growth of rapid horizontal expansion is another important factor for city development.
- Filling empty spaces inside the city (using from unused lands),
- Transferring incompatible and other authorized uses (industry uses) out of city,
- Improvement of fabric design and renovation of the old city and its content,
- Increase residential areas density by accelerating the implementation of the modernization of old parts of city and prevent to increase in intensive any uncontrolled construction outside the existing city and organize prompt the user to prevent horizontal growth of the city's nuisance,

- Transfer the military centers, prisons and other essential facilities within the urban fabric, such as vegetable centers, slaughterhouses to other appropriate places outside the city limits;

- Development of appropriate regulations to prevent the loss of land allocated to various uses;
- Greater government control over the actions of the city's physical development and implementation of policies such as supporting of land preparation.

References

Abbaszadegan M, & RostamYazdi B. (2008). Use of smart growth development organization distributed in cities. *Journal of Technology and Education*, 3(1).

Ahadnezhad Roshti, M., & Hosine, S A. (2011). Evaluate and predict changes and horizontal distribution of cities using multi temporal satellite images and GIS (Case Study: Tabriz in the period from 2010 to 2014), *Journal of Urban Studies and Planning*. 2(4).

Azizi, M. M. (2005). *Congestion in urban (principles and criteria for optimum density)*. Institute of Tehran University Publications and Printing. Tehran. (In Persian).

Beck, R. H., Kolankiewicz, L. J., & Camarota, S. A. (2003). *Outsmarting smart growth: Population growth, immigration, and the problem of sprawl*. Center for Immigration Studies.

Detailed Plan Sari. (2000). *Consulting engineers and Spatial Planning*, Housing and Urban Development Office of Mazandaran.

Ebrahimzadeh Asmyn, H., Ebrahimzadeh, H., & Habib, M. A. (2010). Analytical physical expansion and growth factors sprawl Tabas earthquake after using Heldern entropy models. *Journal of Geography and Development*, 19, Autumn, Mashhad.

Habibi, S. M. (1999). *Flux to the city*, Tehran University publications. 2nd ed., Tehran.

Hekmatnia, H., & Mousavi, M. N. (2006). Use of models in geography with an emphasis on urban and regional planning, modern science publications. 1st ed., Yazd.

Hernando, A., Hernando, R., & Plastino, A. (2014). Space–time correlations in urban sprawl. *Journal of The Royal Society Interface*, *11*(91), 20130930.

HosseinzadehDalir, K., & Hushyar, H. (2006). Views, elements of the physical development of cities. *Journal of Geography and Regional Development*, 6. Ferdowsi University of Mashhad.

Mashhadizadeh dehaghani, N. (2003). Analysis of the characteristics of urban planning from Iran University of Science and Technology. Sixth edition. Tehran.

Majedi, H. (1999). Geological main problem of urban development, *Village Magazine, Urban and Architectural Studies and Research Center of Iran*, 33, Tehran.

Master Plan Sari. (1972). *Amkv Consulting Engineers*, Department of Housing and Urban Development.

Master Plan Sari. (1992). *Consulting engineers and Spatial Planning*. Housing and Urban Development Office of Mazandaran.

Poormohammadi, M. R., & Qorbani, R. (2003). Dimensions and strategies compression paradigm of urban spaces, Journal of Modarress, 7(2).

Poormohammadi, M. R., & Jamekasra, M. (2011). Analytical model of uneven development Tabriz, Geographical Research Quarterly, 25(100), Springs. Esfahan University.

Rahnama M R, AbbasZadeh Gh R. (2006). Comparative study to assess the degree of dispersion the compact metropolis of Sydney and Mashhad. *Journal of Geography and Regional Development*, 3(6).

Rahnama, M. R., & AbbasZadeh, Gh. R. (2008). *Principles and models of assessment in physical forms*. First Printing, Publishing Jahaddaneshgahi. Mashhad,

Revision of the comprehensive plan Sari designs. (2013). *Mazandaran Consulting Engineers Project*. Department of Roads and Urban Mazandaran.

Sari Detailed Plan. (1985). *Project and Kavosh Consulting Engineers*. Department of Housing and Urban Mazandaran.

Sayf o Dini, F. (2006). *Specialized vocabulary of urban and regional planning*. Ayzh publications. First printing. Winter. Tehran.

Sayf o Dini, F., Ziari, K. A., Pourahmad, A., & Poor Nick, H. (2013). Explaining the distribution and density of urban form in Amol approach to sustainable urban form. *Journal of Human Geography*, 80.

Shakuyi, H. (2000). *New views in urban geography*, 4th ed., Tehran.

Shie, I. (1998). *Introduction to the fundamentals of Urban Planning*, University of Science and Technology, 8th ed., Tehran.

Samat, N. (2006). Applications of geographic information systems in urban land use planning in Malaysia.

Taghvaee, M., & Saraee, M. H. (2006). Expansion of existing capacities in Horizontal Ground (Case Study: Yazd). *Journal of Geographical Research*, 55, Spring, Institute of Geography Tehran University.

Yosefifar, Sh. (2006). Patterns of physical development in the history of the middle ages. *Journal of the Humanities*, 52. Shahid Beheshti University.

Zakerian, M., Mousavi, M. N., & BagheriKashkooli, A. (2010). Analytic distribution and the distribution of population in urban areas Meibod sustainable development. *Journal of Urban Studies and Planning*, Islamic Azad University Marvdasht.