Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

An investigation of urban systems using entropy and elasticity measures: case study of North Region of Iran

Nader Zali[1]*, Ali Soltani[2] and Ahmad Panahi[3]

[1]*Department of Urban Planning, Faculty of Art and Architecture, University of Guilan, Rasht, Iran*
[2]*Department of Urban Planning, Faculty of Art and Architecture, Shiraz University, Shiraz, Iran*
[3]*Lecture of Art and Architecture Faculty, University of Guilan, Rasht, Iran*
nzali@Guilan.ac.ir*, soltani@shirazu.ac.ir, ahmadpanahi1@yahoo.com

Abstract

Achieving a balanced distribution of population and activities over space is one of the critical goals of spatial planning profession. This paper reviews the status of this issue for the North Region of Iran including provinces of *Mazandaran*, *Giulan* and *Golestan*. The study applied two well-known methods including entropy and elasticity for measuring the extent of regional balance of population distribution throughout the study area. The results showed that the disorder of urban system has been increased dramatically along with fast population increase. Three capital cities of the region have experienced focal concentration whereas small cities have encountered with stagnation in population growth. Those cities with 50 thousand people and over have showed higher tendency to absorb further population. These trends have resulted in intensifying irregularity of urban system and emerging of new megacities.

Keywords: Urban System; North Region of Iran, Elasticity, Entropy.

Introduction

Urban development is the process of emergence and evolvement of urban settlements. In this way, urban growth can be regarded as the increased importance of cities as focal nodes of population within a particular society and economy (Bhatta *et al*., 2010). However, cities are not isolated systems; but they are connected to each other. A network of cities can be defined as a structure where the nodes are the cities, linked through

physical or virtual channels in which flows of different kinds are exchanged (Bertolini & Dijst, 2003). The 'urban system' concept was introduced by Berian Berry for the first time in 1964. Later on, Pred in 1977 used the corresponding concept 'system of cities', which he defined as "a national or regional set of cities which are interdependent" (Limtanakool *et al*., 2007). In a broader term, an urban system is defined as a human settlement above a threshold population size that satisfies the functional requirements of that population (Bessey, 2002). In this study, by urban system we mean a composition of towns with different sizes and functions, which contact and depend on each other and are spatially distributed in a relatively integrated homogenous region.

Urban systems are of high attention and importance due to the role they play in population settlement. In the second half of the 20th Century, population growth and increasing concentration of particular cities especially in the Third World countries were the most important challenges for planning profession. Experts call this phenomenon as anomaly leading to the imbalance and inequality in the distribution of opportunities and the inefficiency of the development process. The imbalanced distribution of cities happens in where urban development is expected as an essential component of national development policies and contributes to economic growth and social justice.

In Iran the urban population had noticeable changes owing to increased population and reached from 37.9% in 1967 to 68.46% in 2007. On the other hand, in addition to cities' population, increased number of towns functions as another effective factor in changes of city configuration and space system. Therefore, an imbalance has occurred in urban network in several parts of the country. Regarding the official statistics, there were 272 cities in the country in 1967, which indicated a 36.7% growth compared to 199 cities in 1957. As a consequence of dominant issues in population flows, this number reached 373, 496, and 612, in 1977, 1987, and 1997, respectively. The gradual growth ultimately yielded 1016 cities in recent census in 2007 (Seyed Fatemi & Zali, 2011) (Table 1)

The North Region of Iran (NRI) as a homogeneous economic, social and cultural conditions prevailing in the country has experienced a rapid population growth during past four decades (1966-2006). This milestone changes in population has been associated with social

Table 1. Population and country city numbers in general headcount between 1967 to 2007 years (ISC)

Year	Urbanization rate	City growth rate	City numbers	Urban Population (Thousand)	Sum population
1967	37.96	36.7	272	9790	25778000
1977	47.04	37.1	373	15855	33708000
1987	54.3	33	496	26848	49445000
1997	61.31	23.4	612	36817	60055000
2007	68.46	66	1016	48245	70472000

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

and environmental consequences such as rapid village-to-urban emigration, emergence of informal settlements, poor distribution of facilities and infrastructure, intensification of environmental degradation and pollution and spatial-social disorders. This paper attempts to investigate the imbalance existed in NRI using a comparative and quantitative method.

Materials and methods

Generally, two major approaches have been applied to study of urban systems and the hierarchy of its elements. Cities can be ranked in terms of population size, economic profiles, or activities. Furthermore, they can be ranked from an interaction perspective by using flow data. This approach focuses on the extent to which nodes interact with each other in the system of flow (Limtanakool *et al*., 2007).

The research methodology of this study is documentary and is based on time-series data collected from Iranian Statistical Center (ISC) publications. However, the focus of analysis is on those cities which had population of over 10 thousand in 2006. Two well-known measures used for this study included: entropy index and elasticity index.

Spatial Entropy

According to the second law of thermo-dynamics, any isolated system unexpectedly underlines states with the highest entropy. On the other hand, non-isolated or open systems can evolve to states with lower entropy than the system itself. The entropy differences between source and sink permits the production of work. For non-isolated or open systems, sources at low entropy level may be applied to decline the systems' entropy, discharging irreversibility into the environment (Balocco & Grazzini, 2006).

The concept of "Spatial Entropy" has been developed first by Batty (1974) and used to test various hypotheses concerning the distributions of population and its density, in the New York, London and Los Angeles regions. In urban and regional studies, there are mainly two types of researches using the entropy concept. The first type uses as a "descriptive statistics" and the second one as the "MaxEnt" method (Esmer, 2005). This method has been also applied for determining the sprawled urban pattern (Kumar *et al*., 2007; Lata *et al*., 2001; Li & Yeh, 2004; Sudhira *et al*., 2004; Yeh & Li, 2001) ; Zali, 2010; Narisra, et al., 2007; Guangjin, et al., 2002.

The theory index shows a degree of stability and uniformity in a system and it changes from zero (maximum concentration) to one (maximum degree of separation) (Eq. 1 and 2).

$$H = \sum_{i=1}^{n} P_i \log \frac{1}{P_i} = \sum -P_i \log P_i \quad \text{(Eq. 1)}$$

$$R = 1 - \frac{H}{H_{\max}} = \frac{H}{\log K} \quad \text{(Eq. 2)},$$

where H represents absolute entropy; P_i shows proportion of frequency of population class; R denotes to relative entropy; and $H_{\max}$ shows maximum entropy (completely homogenous distribution). If population is completely concentrated in one region, then $R = 0$, whereas if population is distributed homogenously then $R = 1$.

Elasticity: Elasticity is a simple index showing the rate of change of one factor to another, and is useful in comparing regions. In this study, elasticity index was applied as the proportion of urban population change to entire population change of the region. The elasticity index was calculated for each city and for each time interval using the following equation (Eq. 3):

$$E_{(t,t+10)} = \frac{r_v(t,t+10)}{r(t,t+10)} \quad \text{(Eq. 3)},$$

where *E (t, t+10)* shows the elasticity between time period of *t* and *t+10*; r_v represents annual urban population rate and r shows annual entire population rate of the region.

Case study area

Iran is one of the largest countries in the heart of the *Middle East* and does link the region to the *Central Asia* and *Caucasus* countries through *Caspian Sea*. The three major cities in the northern provinces of *Sari*, *Rasht* and *Ghorgan* in this issue are of a great importance (Fig.1).

Fig.1. Case study area, NRI (source: iranologie.com, 2011)

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Table 2. The population change and rate of city growth of NRI between 1966 and 2006 (source: ISC, 1966-2006)

City classes (thousand)	population of cities					rate of growth			
	1966	1976	1986	1996	2006	1966-1976	1976-1986	1986-1996	1996-2006
5-10	36542	69259	105621	134061	140981	6.60	4.31	2.41	0.50
10-15	40577	76153	115221	137949	155868	6.50	4.23	1.82	1.23
15-25	44072	73988	113718	141397	175932	5.32	4.39	2.20	2.21
25-50	203362	321822	527889	705414	823902	4.70	5.07	2.94	1.56
50-100	72425	92761	142312	181809	220777	2.51	4.37	2.48	1.96
100-250	211399	316601	517013	670521	807206	4.12	5.03	2.63	1.87
250 +	239285	347743	571347	802340	1079471	3.81	5.09	3.45	3.01

Analysis

Data needed to discover the disorders and elasticity in the urban network through the study area were collected from the publications of ICB and analyzed with MS Excel 2010. Since a large number of current small cities were parts of bigger cities or counties in former census data, thus their time-series data were not available independently. Accordingly, 57 cities (with population over 5000 in 2006 census) were selected and entered into the analysis. Firstly, the disorder of the urban system was investigated and then secondly, elasticity of the urban classes were analyzed (Table 2).

The data analysis showed that the degree of entropy or disorder of urban system in the north region intensified. The degree of entropy changed dramatically from 0.989 to 0.837 between 1966 and 2006. This trend represents a considerable decrease in spatial order, of distribution of cities throughout the region in recent years (Fig.2).

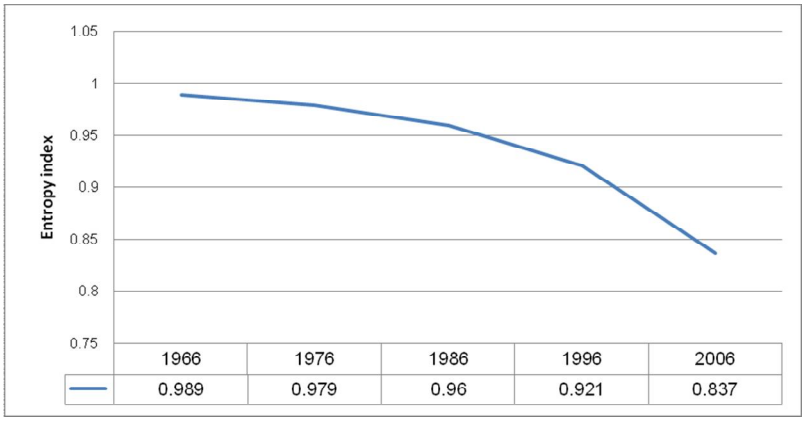
While NRI has a better situation in terms of other regions of the country, however it is still far from a balanced spatial order. It seems that the lack of clear policy to regulate urban development plans has been the main cause of disparity in urban network throughout the NRI. Because of the tourist-based economy of the region, the distribution of population and public services follows the demand market thus remaining in inequality and discrimination among settlements located within the region.

The elasticity analysis showed that cities with population of 50 thousand and over have had a higher elasticity to absorb the population (especially for the period of 1996-2006). On the other hand, cities of population lower than 15 thousand have been unsuccessful to accommodate enough residents. In fact, the figure is in accordance with what has been happened for all medium-size cities throughout the country (Fig.3).

Some major findings of the analysis include: The entropy rate of cities during the study period follows stability and the rate has decreased from 0.989 to 0.837 between 1996 and 2006. The stagnation of elasticity for cities of under 25 thousand people is quite evident over the past 40 years, and the stagnation (recession) has increased gradually. Cities with population over 100 thousand people, have experienced a better population elasticity, compared to other cities of the region. This figure has always been close to 1. The cities with population of 50 to 100 thousand have had the highest elasticity while the cities of under 10 thousand experienced the lowest figure,

The analysis of urban population of the region confirms that cities populated between 50 and 100 thousand as well as cities with 100 thousand populations and over have encountered with dramatic population growth. On the other hand, cities with population lower than 15 thousand have experienced a low elasticity. Two other important points can be observed from the trend of urban system change: The elasticity of small cities (with population between 15 and 25 thousand people) has increased in recent decade after dramatically decline experienced during three past decades. The elasticity of medium cities (with population between 25 and 50 thousand people) has decreased during recent decade after experiencing smooth trend for three decades.

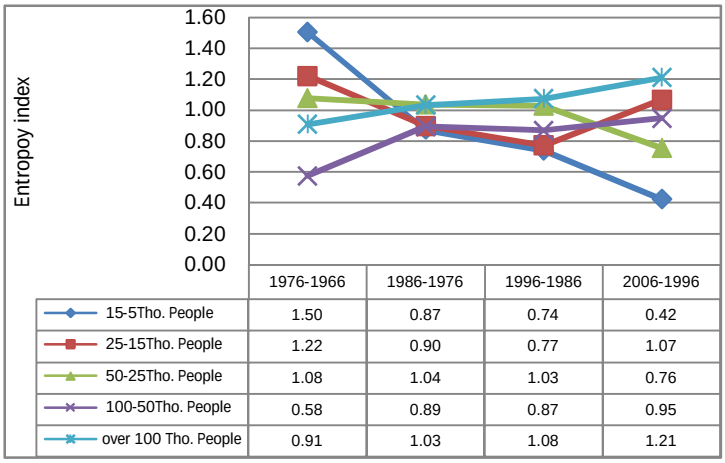
Fig. 2. Trend of disorder change for NRI within last 40 years(1966-2006) (source: authors, 2011)



Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Discovering the reasons of these two changes needs further investigation which is not within the scope of this study.

Fig.3. The elasticity of city classes of NRI between 1966 and 2006



	1976-1966	1986-1976	1996-1986	2006-1996
15-5Tho. People	1.50	0.87	0.74	0.42
25-15Tho. People	1.22	0.90	0.77	1.07
50-25Tho. People	1.08	1.04	1.03	0.76
100-50Tho. People	0.58	0.89	0.87	0.95
over 100 Tho. People	0.91	1.03	1.08	1.21

Conclusion and discussion

The results of this study discuss that while the urban system of NRI has enjoyed relative stability comparing to other regions of the country, however, its spatial distribution of population is still away from equilibrium. The necessity of achieving a balanced urban network has often been discussed in development planning activities in the country during half a century, but few practical outcomes have been achieved yet.

There are several policy implications of this study thus some strategic policies can be recommended as follows: a) decentralization from two major cities, *Rasht* and *Sari* and empowering medium cities of the region simultaneously; b) promoting the polycentric nature of the urban system of the region through the support of sub-regional urban systems; c) managing of the village-to-urban migration flows in hope of preventing in-migration into major cities; d) fostering infrastructures of small cities to support their economic growth; and e) encouraging native skilled to not leaving their hometowns.

This study can be improved in several ways: In addition to population, some other aspects of regions such as physical interaction and flows should be considered. Furthermore, since cities are not isolated systems; the interaction of NRI with other regions of the country needs further investigation.

References

1. Bessey KM (2002) Structure and dynamics in an urban landscape: toward a multiscale view. *Ecosystems*. 5, 360-375.
2. Balocco C and Grazzini G (2006) Sustainability and informations in the urban system analysis. Energy Policy. 34 (17), 2905-2914.
3. Bertolini L and Dijst M (2003) Mobility environments and network cities. *J. Urban Design*. 8(1), 27-43.
4. Bhatta B, Saraswati S and Bandyopadhyay D (2010) Quantifying the degree-of-freedom, degree-of-sprawl, and degree-of-goodness of urban growth from remote sensing data. *Appl. Geography*. 30, 96-111.
5. Esmer O (2005) Information theory, entropy and urban spatial structure. Ph.D. Thesis, Department of city and regional planning, Middle East Technical University, Turkey.
6. Guangjin T, Jiyuan L and Zengxiang Z (2002) Urban functional structure characteristics and transformation in China. *Cities*. 19 (4), 243-248.
7. ISC (1966-2006) Population data of 1966, 1976, 1986, 1996, 2006. Center of Statistics, Iranian Statistic Center.
8. Kumar JAV, Pathan SK and Bhanderi RJ (2007) Spatio-temporal analysis for monitoring urban growth-a case study of Indore city. *J. Indian Soc. Remote Sensing*. 35(1), 11-20.
9. Lata KM, Rao CHS, Prasad VK, Badarianth KVS and Rahgavasamy V (2001) Measuring urban sprawl: a case study of Hyderabad. *GIS Devpt*. 5(12), 26-29.
10. Li X and Yeh AGO (2004) Analyzing spatial restructuring of land use patterns in a fast growing region remote sensing and GIS. *Landscape & Urban Planning*. 69, 335-354.
11. Limtanakool N, Dijst M and Schwanen T (2007) A theoretical framework and methodology for characterizing National urban systems on the basis of flows of people: empirical evidence for France and Germany. *Urban Studies.* 44(11), 2123-2145.
12. Narisra L, Dijst M and Schwanen T (2007) A theoretical framework and methodology for characterising national urban systems on the basis of flows of people: empirical evidence for France and Germany. *Urban Studies*. 44, (11), 2123-2145.
13. Seyed Fatemi S and Zali N (2011) A study of the necessity for constructing new towns in Iran urban system. *Indian J. Sci. Technol*. 4 (8), 990-994.
14. Sudhira HS, Ramachandra TV and Jagdish KS (2004) Urban sprawl: metrics, dynamics and modelling using GIS. *Intl. J. Appl. Earth Observation & Geoinfo*. 5, 29-39.
15. Yeh AGO and Li X (2001) Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. *Photogrammetric Engg. & Remote Sensing*. 67(1), 83-90.
16. Zali N (2010) Using spatial planning approach to analysis of homogeneous and official regions, vase study east Azerbaijan of Iran. *J. Urban-regional Studies & Res. Univ. of Isfahan*. 1, (4), 77-94.