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

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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, Guilan 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” (Limitanakool 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>
<thead>
<tr>
<th>Year</th>
<th>Urbanization rate</th>
<th>City growth rate</th>
<th>City numbers</th>
<th>Urban Population (Thousand)</th>
<th>Sum population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>37.96</td>
<td>36.7</td>
<td>272</td>
<td>9790</td>
<td>25778000</td>
</tr>
<tr>
<td>1977</td>
<td>47.04</td>
<td>37.1</td>
<td>373</td>
<td>15858</td>
<td>33708000</td>
</tr>
<tr>
<td>1987</td>
<td>54.3</td>
<td>33</td>
<td>496</td>
<td>26848</td>
<td>49445000</td>
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<tr>
<td>1997</td>
<td>61.31</td>
<td>23.4</td>
<td>612</td>
<td>36817</td>
<td>60055000</td>
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<tr>
<td>2007</td>
<td>68.46</td>
<td>66</td>
<td>1016</td>
<td>48245</td>
<td>70472000</td>
</tr>
</tbody>
</table>
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).

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

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

where \(H\) represents absolute entropy; \(P_i\) shows proportion of frequency of population class; \(R\) shows to relative entropy; and \(H_{\text{max}}\) 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):

\[
E_{(t, t+10)} = \frac{r_i(t, t+10)}{r(t, t+10)} \quad \text{(Eq. 3)}
\]

where \(E_{(t, t+10)}\) shows the elasticity between time period of \(t\) and \(t+10\); \(r_i\) 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)
### 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.

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

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<tbody>
<tr>
<td>5-10</td>
<td>36542</td>
<td>69259</td>
<td>105621</td>
<td>134061</td>
<td>140981</td>
<td>6.60</td>
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<tr>
<td>10-15</td>
<td>40577</td>
<td>76153</td>
<td>115221</td>
<td>137949</td>
<td>155868</td>
<td>6.50</td>
<td>4.23</td>
<td>1.82</td>
<td>1.23</td>
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<tr>
<td>15-25</td>
<td>44072</td>
<td>73988</td>
<td>113718</td>
<td>141397</td>
<td>175932</td>
<td>5.32</td>
<td>4.39</td>
<td>2.20</td>
<td>2.21</td>
</tr>
<tr>
<td>25-50</td>
<td>203362</td>
<td>321822</td>
<td>527889</td>
<td>705414</td>
<td>823902</td>
<td>4.70</td>
<td>5.07</td>
<td>2.94</td>
<td>1.56</td>
</tr>
<tr>
<td>50-100</td>
<td>72425</td>
<td>92761</td>
<td>142312</td>
<td>181809</td>
<td>220777</td>
<td>2.51</td>
<td>4.37</td>
<td>2.48</td>
<td>1.96</td>
</tr>
<tr>
<td>100-250</td>
<td>211399</td>
<td>316601</td>
<td>517013</td>
<td>670521</td>
<td>807206</td>
<td>4.12</td>
<td>5.03</td>
<td>2.63</td>
<td>1.87</td>
</tr>
<tr>
<td>250+</td>
<td>239285</td>
<td>347743</td>
<td>571347</td>
<td>802340</td>
<td>1079471</td>
<td>3.81</td>
<td>5.09</td>
<td>3.45</td>
<td>3.01</td>
</tr>
</tbody>
</table>
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

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>15-50tho. People</td>
<td>1.50</td>
<td>0.87</td>
<td>0.74</td>
<td>0.42</td>
</tr>
<tr>
<td>25-100tho. People</td>
<td>1.22</td>
<td>0.90</td>
<td>0.77</td>
<td>1.07</td>
</tr>
<tr>
<td>50-250tho. People</td>
<td>1.08</td>
<td>1.04</td>
<td>1.03</td>
<td>0.76</td>
</tr>
<tr>
<td>100-500tho. People</td>
<td>0.58</td>
<td>0.89</td>
<td>0.87</td>
<td>0.95</td>
</tr>
<tr>
<td>over 100 Tho. People</td>
<td>0.91</td>
<td>1.03</td>
<td>1.08</td>
<td>1.21</td>
</tr>
</tbody>
</table>

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 immigration 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