Evaluation of the physical development pattern of Bonab city using Shannon's and Holden entropy models

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Abstract: In recent decades, cities in Iran, like many third world cities have significantly changed, so that urban growth trend are caused unbridled growth and cities with national and regional role in the wake of the economic and social developments which is due to the lack of appropriate policies and construction and without planning in the exploitation of urban lands in the most of cities. Urbanization has priority over the Urbanism and urban development is faced with serious problems. Bonab, like many cities in the country is not immune from these developments. Surveys of data shows that the city's population has increased more than 2.5 times during 30 years ago, the growing population is caused unchecked spread of city. So that, increasing the physical expansion of the city has made problems such as destruction of agricultural land around the city, environmental problems, lack of infrastructure and etc. Research method in this study was descriptive-analytical and has analyzed the physical-spatial expansion of the city using the Holden Model. The results of Holden model show that 36 percent of the city's physical growth in 1976 related to the population growth and 64 percent was related to the horizontal growth and Aspral of the city in 2006 which has led to the impure density reduction of population and increasing the impure poll-tax of urban land. Its cause has been issues such as economic, urban politics, communication networks, urban development plans, lack of monitoring and control of city manager and also the lack of a systematic plan for the physical development of the City.

Keywords: Patterns of urban growth, physical and spatial expansion, Shannon’s and Holdern entropy models, Bonab city

INTRODUCTION

City is like a living organism and has long been considered civilizations as one of the human achievements; the city deforms and expands during its life due to various factors, but the good city is a city that provides its people needs with regard to the time changes (Ebrahimzadeh Asemin et al, 2010), (Davoudpour et al, 2008). The advent of technological and economic complex developments that was formed followed industrial revolution was made greater changes in the size of cities, the ratio of their resident population and urbanization growth (Ebrahimzadeh et al, 2009) (Varesi et al, 2012). So that production and income increased in cities with the arrival of industrialization in the Third World from the early twentieth century and then increased demand for municipal services. This process increased the number and size of cities in this country and has led to the urbanization development (Pumain, 2003). Hence increasing population and the size of cities and towns in the world due to increasing urbanization has had many effects on the human and environment (Ebrahimzadeh et al, 2009). Considering that urbanization spread is not keeping pace with physical development of cities, it led to without planning construction, enormous changes in the spatial structure of cities and uncontrollable spread of cities and cities are faced with certain problems. Destruction of agricultural lands, expansion of cities in the steep elevations, integration of villages in the cities, environmental problems and natural hazards, increasing the costs, infrastructure and urban services, lack of the efficient use from land and etc are examples of these problems that we are witnessing today (Mir Katouli, 2011). Discordant development and uncontrolled expansion of cities is dynamic and continuous process and during it, the physical ranges of the city and its physical spaces increases in horizontal and vertical directions in terms of quantity and quality (Zangiabadi, 1992). Physical development and population growth was harmonious and balanced in cities of Iran a few decades ago. With
incidence of new developments, cities especially big cities quickly accepted the transformations and changes. The transformations were in the form of rapid increase of population and physical development of cities and it had been discordant and unbalanced, so that most of the urban infrastructure is dominated by residential buildings (Mashhadizadeh Dehaghi, 2006). In general, it should be noted that today whatever is being criticized as negative aspects of the city and urban development, mainly is not the nature of the city, but it is discordant process of the city. It is often due to the priority of physical development of cities on the infrastructure development and required services or priority of the scale on performance and quantity on the quality.

**Problem Statement**

Discordant distribution and development of urban is the knowledge of words has been entered the urban researchs literature as Aspral form in the last fifty years, and now it is the central subject of most urban seminars. The use of the term goes back to the mid-twentieth century. When, the uncontrolled use of private cars and development of the highway system and the expansion of urban areas boomed in the United States (Hess, 2001). In third world countries, urban Aspral is considered as known features of the cities of large areas. In these countries, Aspral in most large urban areas shows a vision of poverty, bad housing and illegal patterns of land use along with the lack of public facilities infrastructure and basic services. This model has evident difference with the U.S. pattern (Lango, 2001). When the pattern of growth and development in our country was organic and determining the urban growth, indigenous and local factors, urban areas was adequate to the urban traditional use and was established a balance between the environment and the city. However, when the basis for the development of cities became extrinsic nature due to social, political and economic developments, with motorized cities, revenues from oil was injected in the urban economy and our cities was affected by the global economic system and then development pattern of many cities in Iran became rapid and irregular procedure (Majedi, 1999). Ugly developments of the cities are the problems caused by inappropriate spatial structure and urban planning is facing today. Development of the cities is not only damaging surrounding areas, but it brings out the city's asymmetric shapes. Invasion on amount of ground, arable residents around the city and residents of the metropolitan area are the results of these problems (Shams et al, 2009). Optimal distribution of uses and service centers is one issue that planners often deal with it. Because of the accelerated growth of population and cities, problems have emerged such as the lack of appropriate spatial distribution of uses (Varesi, 2012).

**The importance of research**

Since the rapid growth of urban population has created problems such as suburbia, increasing the housing prices, lack of facilities and inadequate services, environmental pollution and congestion in the cities. These factors caused unbalanced physical development of cities (Madani Pour, 2005); Aspral or dispersion means dilate and straggle. But its concept in the research literature of urban is rapid and dispersed growth and discordant development of metropolitan areas and even small towns and suburbs in the nearby areas that in some cases, ils reached to rural areas or the border of ten cities. This requires the conversion of open spaces to built areas and developed lands. Urban distribution was first proposed by environmentalists and they would have paid more than any other group. The word Aspral is used in order to describing the reduction of rural land and surrounding thereby increasing the cover level of the city and suburbs in a specific time period (Babai, 2007). Urban dispersion is relatively new pattern in human settlements, come together the housing with low density and strip development is as commercial and it is disabled widespread use of the automobile (Ewing, 1997). Some researchers have known urban distribution due to low density, discontinuous development and expansion into areas outside and low-density suburb areas with the dominance of private cars in transportation (Wassmer, 2002). Several factors affect the distribution of cities, but the process of land speculation and gambling transactions are considered one of the main factors for the inharmonious physical development of cities; so that land speculation and hoard prevent the development of land; whereas other parts may rapidly covered by urban buildings (Shokoei, 2003). Bonab is a sample of these cities its fast growth during recent decades shatters the spatial organization and the city was formed in the limited space, organic and integrated a few decades ago, and was enclosed in hard physical space, today is very widespread and have the porous and discordant structure. This form of development is a model of patient city has lost their physical and spatial solidarity.

**Research Literature**

Several studies have been conducted about physical growth and development of cities, the most important ones are mentioned below: Emami (2001): In his MA thesis entitled “Effects of urban development on environmental resources Khorraramabad” has been analyzed environmental complications due to the physical growth and development of Khorraramabad such as water pollution, soil, noise and urban green space (Emami, 2001). Taghvaei and Saraei (2004) in an article entitled “The horizontal development of city and Earth
capacities: A case study of Yazd». After proving the horizontal growth of the city of Yazd and evaluate its dimensions, the use of potential of land or wasteland within city limits has been emphasized as a way to prevent the horizontal spread of city (Taghvaei et al, 2004). Mir Katouli et al (2011) in an article entitled “The study of the physical and spatial expansion of Babolsar city using Shannon and Holdern entropy models » shows that the population of Babolsar city has been 6 folds during 50 years which has led to growing problems of the city for citizens and these problems have been due to the lack of urban managers control and the lack of codified plan. Ebrahimzadeh et al (2009) in an article entitled “Analysis of physical-spatial development Marvdasht city using Shannon’s and Holden entropy models » introduced the research aims to organize the physical pattern of development the Marvdasht city. Based on the research results, he has recognized a pattern as a desirable pattern for future expansion. In general, it should be said, the unbridled expansion of Iranian cities in recent years is a reflection of historical background and affected by political, economic and social issues. So that balanced and reasonable urban system has changed from proper dispersion to inharmonious and unbalanced methods in this process.

**Research Method**

The research method in this paper relies on a combination of historical, descriptive and analytical methods. An analytical and descriptive method based on information provided at documents the various libraries is obtained the theoretical background, and in the next stage, the data and information was used in the master plan and detailed reports of Bonab for analysis changes in land use and population data from Census. In order to information processing, Holden model was used to analyze the inharmonious development pattern. This model specifies how much of the growth of the city is caused by population growth and how much has been due to the ugly growth of the city. Finally, statistical techniques were used for finding and spatial information for research.

**Research Area**

Bonab is one of the southern cities in East Azerbaijan province, and it is the city center of Bonab. The city is located the geographic coordinates of latitude 37° and 11 minuesto 37°, 32 minutes and east longitude 45°, 45 minutes to 46° and 10 minutes. It is adjacent to Ajabshir city from the north, the West with Urmia Lake, the East with Maragheh city, the southeast with malekanand from the southwest with the west Azerbaijan province. According to the latest divisions of the country, the city has a section (Bonab) and three villages (Banajuy-e shomali, Banajuy-e shargi, and Banajuy-e gharbi). (Space Consulting Engineers, Elijah Project, Hadi Project, Zavsht Village, 2008)

**Spread Pattern of Bonab**

In recent decades, the extent of Bonab has increased proportion to the population growth, but the physical aspects of the growth have almost been unbelievable. During the past few decades, development pattern of Bonab has been so that, in first phase, it has taken garden and plantation areas of the city. Then, space limitation within the city has transferred pressures to the surrounding villages. In this regard, the nearby towns have absorbed one after another then due to the increasing needs new residential units and installations, without planning has continued to expand fringes and land in surrounding villages. Town development and being pulled rural into the city which was done almost entirely without a plan, has provided formation of the village texture of within the city. Statistical analysis therefore implies that the population of Bonab during theyears 1970 to 2006 has approximately been 2.5 times. This means that 29,169 people in 1970...
has reached to 76,610 people in 2006. Thus it is also mentioned that Bonab city based on the census division in 1989 was separated from Maragheh and was converted an independent city. Table 1 shows changes in population and area of Bonab city within the period of 1970 to 2006.

Table 1. Changes in population, area, density, and impure poll-tax of Bonab during the years 1970-2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>population</th>
<th>Annual growth of population</th>
<th>Area (ha)</th>
<th>population</th>
<th>Annual growth of area</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>-</td>
<td>29169</td>
<td>-</td>
<td>102</td>
<td>29169</td>
<td>-</td>
<td>1976</td>
</tr>
<tr>
<td>1986</td>
<td>316</td>
<td>45885</td>
<td>11.97</td>
<td>316</td>
<td>45885</td>
<td>4.63</td>
<td>1986</td>
</tr>
<tr>
<td>1996</td>
<td>1132</td>
<td>63240</td>
<td>13.6</td>
<td>1132</td>
<td>63240</td>
<td>3.26</td>
<td>1996</td>
</tr>
<tr>
<td>2006</td>
<td>1460</td>
<td>76610</td>
<td>2.58</td>
<td>1460</td>
<td>76610</td>
<td>1.94</td>
<td>2006</td>
</tr>
</tbody>
</table>

Source: The city’s comprehensive plan and Census of Bonab 1970-2006

**Initial core**

Initial core of Bonab city is downtown like most of our cities which is around the central square and large Mosque is located in this range.

**The first stage of development**

Then a wider part formed radially in the formation process of Bonab around the initial core until 1950 that is after the central core of the city.

**The second stage of development**

Then another part of the city has occurred during the years 1950-1986, it has spread most linearly along the main communication roads of Bonaband has led to expansion of city towards the East. Bonab to Maragheh way have formed the development of residential and commercial units in this direction.

According to the map, the process of Bonab growth can be divided into four periods. Developmentstages of Bonab are expressed during different periods the following:

**Extending from 1986 to 2006**

Diffused construction has been conducted in the city especially in the North and East and southwest during the recent years in development process. Finally, it led to the emergence and expansion of the city to the north.

This model is used to analyze and determine the ugly growth of the city. General structure of model is as follow (Hekmatnia et al, 2006: 129)

$$H = - \sum_{i=1}^{n} P_i \times \ln(P_i)$$

In this relation:
H: the Shannon entropy
Pi: the ratio of built area (overall residential density) region i to the total built area
N: total area

The value of Shannon entropy is zero to Ln (n). Zero represents dense physical development (compact) of the city. While Ln (n) represents sporadic physical development of the city. When the value of entropy is more than Ln (n), ugly urban growth has occurred.

<table>
<thead>
<tr>
<th>Region</th>
<th>Area(H)</th>
<th>Pi</th>
<th>Ln(Pi)</th>
<th>Pi(Ln(Pi))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>567</td>
<td>0.5004</td>
<td>-0.6922</td>
<td>-0.3463</td>
</tr>
<tr>
<td>2</td>
<td>556</td>
<td>0.4995</td>
<td>-0.6940</td>
<td>-0.3466</td>
</tr>
<tr>
<td>Total</td>
<td>1133</td>
<td></td>
<td></td>
<td>-0.6929</td>
</tr>
</tbody>
</table>

Source: The author's studies

Factors affect the development and distribution of Bonab Communication networks

other factors affect the development of city is communication network passage, their impact are shown in three roads (Tabriz - Miandoab, Maragheh- Bonab and Bonab - malekan). The city has a strong tendency to connecting the Tabriz road has significantly grown in this area. Also, too many constructions are constructed in this road (Consulting engineering, environment role, 2006).

<table>
<thead>
<tr>
<th>Region</th>
<th>Area(H)</th>
<th>Pi</th>
<th>Ln(Pi)</th>
<th>Pi(Ln(Pi))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>419</td>
<td>0.2871</td>
<td>-1.2479</td>
<td>-0.3582</td>
</tr>
<tr>
<td>2</td>
<td>471</td>
<td>0.3228</td>
<td>-1.1307</td>
<td>-0.3643</td>
</tr>
<tr>
<td>3</td>
<td>255</td>
<td>0.1747</td>
<td>-1.7446</td>
<td>-0.3047</td>
</tr>
<tr>
<td>4</td>
<td>314</td>
<td>0.2151</td>
<td>-1.5361</td>
<td>-0.3305</td>
</tr>
<tr>
<td>Total</td>
<td>1459</td>
<td></td>
<td></td>
<td>-1.3583</td>
</tr>
</tbody>
</table>

Source: The author’s studies

Table 2 and 3 show amount of entropy has been 0.6929 in 1996, while closing entropy to the maximum amount indicate the dispersed growth of urban physical development. The amount in 2006 was equal to 1.3583 and it indicates physical development has been dispersed and non compact during ten years.

Holden’s Model

One of the main techniques to specify ugly urban growth is the use of Holden’s Model. In 1991, John Holden’s method was used to determine the ratio of horizontal and population growth. Using the method it can be determined the city growth due to population or due to ugly growth of the city. In this method, he used the formulation of impur poll tax of land; the equations of the model are as follows: The following equation is the basis of a theoretical for horizontal expansion of the city.

(1) \( A = P \cdot a \)

According to this equation, the total land area is occupied by an urban area (A) is depend on the impur poll tax (a) and population (P). Based on Holden’s logic, if during the period t, the population increased with growth equal p, and the land poll tax changes with a, therefore, total urban land increases (Taghvai and Saraei, 2004). With replacing in equation (1) we have:

\( a+a+p+P (=A+ (2)A \)

The extent change of converted range into city is obtained with replacing the equation 1 and 2 and dividing to A during the interval t.

(3) \( \frac{A}{A} = \frac{P}{P} + \frac{a}{a} + (p/p) \cdot (a/a) \)

Now, the Equation (3) is quite general and no assumption does not provide about the growth model or interval. Increase Percent of P and a, is low during one year. Therefore, the second term in equation (3) can be neglected. Hence, following the paradigm of Holden, equation (3) states that growth percent of city extent is the sum of the growth percentage of population and growth percentage of land use poll tax.
(4) Total percent of impure poll-tax growth + Percent of total population growth = Percent of total extent growth

According to Holden method, the share of population growth of total land use is obtained by the ratio of percent change of total population in a period to percent change of total land uses in the same period, which is expressed as follows:

(5) \( \frac{\text{Percentage of total extent growth}}{\text{Percentage of total population growth}} = \text{the share of population growth} \)

It is the same about consumption.

(6) \( \frac{\text{Percentage of land extent growth}}{\text{Percentage of total land use poll tax}} = \text{the share of land use poll tax} \)

Above two equations is presented based on paradigm of 5 Holden in the notes 1991. Based on population growth, a general model of growth is presented as follows:

(7) \( P(t) = P_0 (1+g_p)^t \)

Where \( p(t) \), \( p \) is population in time \( t \), \( P_o \) is initial population, \( g_p \) is the population growth rate during the interval.

(8) \( \ln \left( \frac{p_t}{p_0} \right)^\frac{1}{t} = \ln (1 + g_p) \)

Since \( \ln (1 + x) \) is almost equal \( x \) about small amounts, Equation (8) can be written as:

(9) \( \ln \left( \frac{p_t}{p_0} \right)^\frac{1}{t} = g_p \)

Such form of the growth rate can also be written for the land extent (A) and impure poll tax of land use (a).

(10) \( \ln \left( \frac{A_t}{A_0} \right)^\frac{1}{t} = g_A \)

(11) \( \ln \left( \frac{A_t}{A_0} \right)^\frac{1}{t} = g_a \)

According to the three equations for growth rate equation can be written in the form Holdern:

(12) \( g_A = g_p + g_p \)

Substituting the formula for growth rate and the relationship of initial values and the end of variables of a, P and A, during the interval we will have in equation 12:

(13) \( \ln \left( \frac{\text{city extent at end of period}}{\text{city extent at beginning of period}} \right) = \ln \left( \frac{\text{capitagross in the end of period}}{\text{capitagross in the beginning of period}} \right) + \ln \left( \frac{\text{Population base period}}{\text{Population begins}} \right) \)

In other words, the natural algorithm ratio of population of end of the period to the beginning of the period plus the natural algorithm ratio of impure poll tax of end to beginning of the period will be equal to the natural algorithm ratio of city extent at end to the beginning of the period. Variables in the equation above, is substituted about Bonab city as following (Hekmatnia et al, 2006).

(14) \( \ln \left( \frac{76610}{29169} \right) + \ln \left( \frac{190}{35} \right) = \ln \left( \frac{1460}{102} \right) \)

(15) \( \ln(2.63) + \ln(5.43) = \ln(14.31) \)

\( 0.97 + 1.69 = 2.66 \)

Then, using equations 5 and 6 the share of population growth percent and growth percentage of impure poll tax of urban land is obtained dividing both sides of equation to 2.
Thus, only 36 percent of the physical growth of Bonab was related to the population growth during 1986 to 2006 and 64 percent of the growth was related to the horizontal expansion and the city Aspral. The result has been impure population density and increasing the impure poll tax of urban land in order city spatial distribution.

**Urban policies**

with the preparation of land by the housing Foundation, devotees Foundation, road and other organs and building new hometowns the axes of the East, North and West North of the city, urban growth areas are provided in this section.

**Economic issues**

In many cases low prices in urban land in some respects is caused much construction will be done in that area. Meanwhile, due to the low price of land in parts of West and South, construction in these areas will be less. However, lower prices of land mean that land has lower values in these sections than other parts of the city (Gabli, 2006).

**CONCLUSION**

Twomodels of Shannon’s and Holden entropy were used to investigate the horizontal growth of Bonab. These results are discussed in the following models: The first approach (Model Shannon entropy): Grading of balanced distribution of population parameters using Shannon’s entropy coefficient. The values obtained for the coefficient of the two time periods 75 and 85 shows that the population distribution is unbalanced. The amount of imbalance has been in 1996. It was the number 0.6929 to the maximum (0.6931) that indicates dispersed growth (Aspral) physical development of the city. However, given that the amount of Bonab entropy in 2006 has been 1.3583, it shows physical development during the ten years has been dispersed and non-condensing.

**Holden models**

In the study of Harmonize the the city development with population during 1986 to 2006 using Holhen, We find that about 36 percent of the city population has been consistent with population growth and 64 percent of the physical development has been due to the ugly and dispersed growth of the city (Aspral). We studied how the proportions in the different decades and we found that disproportion of is related to the (1986 - 2006). In total the development of Bonab city had placed too high level from 1986 to 2006 and is not seen any discipline and harmony at this trend. So that the population has been more than 2.5 times and the city's development growth has been 7 times. In other words, despite the city’s population has increased greatly during this period but the physical expansion of the city take priority over population increase in the last decade and caused urban Aspral growth. It can be noted that the study area in its physical development has had rapid growth, it led to use changes, loss of services and an increase in migration. Increasing the population and development of the city is caused too much pressure on water resources and other infrastructure, destruction of agricultural land around the city and many other issues. Uncontrolled immigrations and growth of urbanization lowered flexible power of managers in urban planning and organization, so that several challenges are seen such as at high prices in urban environment, quality degradation of urban environmental, including traffic congestion in the city center, high prices at housing and the quality degradation of urban services of Bonab. In order to prevent uncontrolled physical expansion of the city it can be extended into the urban fabric, finally, providing amenities in rural areas to prevent rural-urban migration.

**Guidelines and Recommendations**

The following recommendations will be provided on reducing the horizontal distribution and also problems reduction due to it in Bonab city:

1. Reduce the size breakdown: This is a good policy to avoid excessive horizontal distribution of a city.
2. More control of urban areas: One of the main reasons the horizontal dispersion is the lack of attention and planning for how the development of the city by relevant organizations and planners or the lack of relevant projects.

3. Lead the city towards the non-agricultural land.

4. Creating the residential estates in low-density areas as the fundamental solution to the problem of urban and limit physical development of the city.

5. For a balanced development of the city and it is necessary to Urbanism take priority over Urbanization.

6. Physical development of Bonab is caused uncontrolled growth of residential use than other uses. Considering the spatial-place distribution the use in the city, the service may be more expensive and problem, thus, it is necessary to develop other uses with residential use.

7. Use the wasteland and empty in the town.

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