An Analysis of Urban Smart Growth Indexes with an Emphasis on Compactness, Accessibility and Environment. Case Study: Piranshahr City, Iran

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A B S T R A C T

Smart growth has become a popular concept in territorial planning in the last twenty years. The main emphasis of smart growth is on mixed land use and the design of compact buildings, which produce high densities together with lower environmental effects. The current research aims at investigating urban smart growth indexes based on the three indexes of compactness, environment and access to districts and neighborhoods of Piranshahr City, Uremia. The main research method is descriptive-analytical and it is done through Analytic Network Process, GIS and Holderness and Shannon Entropy Models. Research findings reveal that Piranshahr has registered sprawl growth in the recent years. Furthermore, in terms of access index, public transportation does not cover the city, entirely. Also, in terms of green space index, there are many shortcomings and relative standards have not been observed.

1. INTRODUCTION

During the past century, the world's population has been rapidly congregating in urban areas. The urban population in the world was estimated at 2.4 billion in 1995 and a doubling is expected in about 2025 [1]. After the period 1961-1971, the population of Iranian cities has increased, because of both high natural growth and large scale immigration of villagers to cities, and the growth of urban form and construction did not happen based on needs but on land mongering. This led to an unorganized urban land market, especially within urban limits and the negative distribution of cities' sprawl and horizontal expansion [2].

Urban sprawl is one of the main challenges in spatial planning in the 21st century. Urban sprawl is defined as a specific form of urban development with low-density, dispersed, self-dependent and environmentally and socially impacting characteristics [3]. A whole range of consequences and negative implications related with this type of urban development are brought forward in literature. These include increased traffic and demand for mobility [4], land use fragmentation and loss of biodiversity, reduced landscape attractiveness and alterations of the hydrological cycle and flooding regimes [5], [6], [7].

The urban sprawl phenomenon has been studied intensively by the North American researchers. In the past, urban sprawl was regarded as a US phenomenon associated with the low-density outward expansion of the urban areas. Seeds for that growth were already shown during the interwar period. The environmental impacts of urban sprawl have raised concerns among planners and have stimulated other models of urban expansion such as "smart growth"

(Gabriel, Faria, Moglen, Litman, Turner) which attempted to reverse the low values of the eight dimensions stated above. Many public health advocates have recommended smart growth as a potential solution to the problem of urban sprawl [8].

Smart growth can be defined as a policy framework that promotes an urban development pattern characterized by high population density, walkable and bikeable neighbourhoods, preserved green spaces, mixed-use development (i.e. development projects that include both residential and commercial uses), available mass transit, and limited road construction [9]. Smart growth was originally conceptualized as an aesthetically pleasing alternative to urban sprawl that would offer residents a high quality of life and the convenience of local amenities.

Today, there are so rare the cases of cities not involved with problems of development and spatial and physical spread in Iran, and Piranshahr city is not an exception. It is an example of such cities whose traditional order and spatial organization have been shattered due to rapid growth and development as a result of natural population growth and increase in the rate of immigration acceptance because of its border markets in recent years. Therefore, from 965 people in 1956 its population has reached 72,722 people in 2011. In this period, population has increasingly and rapidly grown together with an irregular spread of the urban physical body, in such a way that its area has reached 844 hectares from 631 hectares. It has resulted in the fact that the city has grown in different directions and overlapped agricultural lands.

On the other hand, the increase in the migrations to the city has formed suburbia. All of those factors have resulted in irregular urban development and lack of order in the urban physical body.

Furthermore, environmentally speaking, any crisis can endanger the future of the city. For example, urban sewage and industrial water waste systems have not been controlled and it has resulted in pollution of the river waters. And, the lack of green spaces, urban open leisure areas and citizens' use of private cars instead of public transportation are some of the factors that caused huge problems in the city and those should be investigated and analyzed.

In addition, economically speaking, as a result of urban development and growth in agricultural lands, two problems occur: the demolition of farms and the increase in transportation expenses due to sprawl development. Socially speaking, there are such problems as neighbourhoods' lack of access to services, lack of security, citizens' laziness, lack of medical services all over the city, cultural ignorance, and the evacuation of the settlements in downtowns and the construction of new buildings in the city outskirts. Overall, it is necessary to investigate and analyze urban smart growth indexes for the city.

2. THEORY AND METHODOLOGY

2.1. Smart growth and the new urbanism

New urbanism and smart growth are the most important planning movements this century. Smart growth and new urbanism both have the goal of creating walkable neighbourhoods that would reduce the consumption of natural resources by reducing the need for automobile transport for basic living and social necessities [10].

One of the goals of smart growth and new urbanism is to encourage urbanization to be more compact instead of sprawled out. However, more research is needed in order to see if these sustainable growth plans are working because, if they are not, a more effective way of combating urban sprawl needs should be created. In the past few years, researchers have used models that they have created to show that these ideas can and have worked. However, critics claim that smart growth ideas are not working or are not plausible. Certain obstacles such as people not wanting to live in compact cities and developers going outside city limits in order to avoid development policies prevent smart growth from being implemented [11]. Maryland implemented the Smart Growth Initiative in April 1977 to help manage current growth. The Economic Growth, Resource Protection, and Planning Act came from this initiative and states that comprehensive plans prepared by local jurisdictions were the best way to find priorities for growth and conservation [12].

The New Urbanism reflects a vision not so much of the future but of a better past. For some, the New Urbanism reflects the small American town that might be seen in a New England village or a mid-western town. The style is neo-traditional: walkable, friendly streets with folks on their front porches, with neighbours able to walk on car-free or traffic-calmed quiet narrow streets to neighbourhood shops or schools. For others, the image is distinctly nostalgic of the European street scene: housing over shops, sidewalk cafes and restaurants, with attractive pedestrian spaces allowing the forgoing of autos for a walk to services, work, or recreation [10].

Different adherents of Smart Growth and New Urbanism advocate for different levels of density. Perhaps the New Urbanism has been inspired as much by the trips to American theme parks as visits to Europe. Many New Urbanism communities conjure images more like Disney or Las Vegas than Paris or Vienna. There is nothing wrong with the Disney Main Street design. Indeed, the Disney Imaginers are visionary in recognizing the nostalgic, or the romantic movie-inspired image of a friendly small town - a dream shared by many. The young and old are attracted to the New Urbanism communities, and developers are attracted to what could

An Analysis of Urban Smart Growth Indexes with an Emphasis on Compactness, Accessibility and Environment.
Case Study: Piranshahr City, Iran
Journal Settlements and Spatial Planning, vol. 6, no. 1 (2016) 15-22

result in better communities, urban revitalization, and higher profits from increased density. Like Smart Growth, the New Urbanism is a vague label with an unclear definition of appropriate density [13].

2.2. The principles of smart growth

Smart growth involves a set of principles to guide development and land-use decisions. These principles were developed by the Smart Growth Network, a partnership of government agencies, developers, environmentalists, historic preservation advocates, professional organizations and interests from the real estate industry. It was launched by the Environmental Protection Agency in 1996 [14].

a). Mix land uses. Each neighbourhood has a mixture of homes, retail, business, and recreational opportunities.

b). Build well-designed compact neighbourhoods. Residents can choose to live, work, shop and play in close proximity. People can easily access daily activities, transit is viable and local businesses are supported.

c). Provide a variety of transportation choices. Neighbourhoods are attractive and have safe infrastructure for walking, cycling and transit, in addition to driving.

d). Create diverse housing opportunities. People in different family types, life stages and income levels can afford a home in the neighbourhood of their choice.

e). Encourage growth in existing communities. Investments in infrastructure (such as roads and schools) are used efficiently, and developments do not take up new land.

f). Preserve open spaces, natural beauty, and environmentally sensitive areas. Development respects natural landscape features and has higher aesthetic, environmental, and financial value.

g). Protect and enhance agricultural lands. A secure and productive land base, such as BC's Agricultural Land Reserve, provides food security, employment, and habitat, and is maintained as an urban containment boundary.

h). Utilize smarter and cheaper infrastructure and green buildings. Green buildings and other systems can save both money and the environment in the long run.

i). Foster a unique neighbourhood identity. Each community is unique, vibrant, diverse, and inclusive.

j). Nurture engaged citizens. Places belong to those who live, work, and play there. Engaged citizens participate in community life and decision-making.

Table 1. Design principles of smart growth [15].

Principle	Description
Mixed Land Uses (SGP1)	Supporting the integration of mixed land uses in communities as a critical component of achieving better place to live
Compact Building (SGP2)	Providing a means for communities to incorporate more compact building design as an alternative to conventional, land-consumptive development
Variety of Housing Choices (SGP3)	Providing a range of housing types, sizes, and prices
Walkable Neighbourhoods (SGP4)	Creating walkable communities to live, work, learn, worship, and play
Community with Strong Sense of Space (SGP5)	Fostering communities with a strong sense of place to craft a vision and set standards for development that respect community values of architectural beauty and distinctiveness, as well as expand choices in housing and transportation
Preserve Open Space and Critical Environmental Areas (SGP6)	Open space preservation supports smart growth goals by bolstering local economies, preserving critical environmental areas, improving our community's quality of life, and guiding new growth into existing communities
Infill Development of Existing Communities (SGP7)	Directing development towards existing communities already served by infrastructure, seeking to utilize resources that existing neighbourhoods offer, and conserving open space and irreplaceable natural resources on the urban fringe
Variety of Transportation Choices (SGP8)	Providing a wider range of transportation options in an effort to improve beleaguered current systems
Cost Effective Development (SGP9)	Embracing the private sector to help make development decisions to be Predictable, fair, and cost effective
Community-stakeholder partnership (SGP10)	Encouraging community and stakeholder to jointly making development decisions

2.3. Benefits of smart growth

While many Americans have benefited from decades of post-World War II suburbanization, many have not. It is also a development pattern that has led to some negative consequences for the community as a whole. Our nation is now experiencing heightened concern over the social, environmental, and fiscal quality of our communities arising from development practices that aggravate the decline of many urban communities and older suburbs, congest streets and highways, demand higher levels of energy consumption, accelerate the loss of natural resources and deteriorate the natural environment, and limit opportunities for the retention and creation of affordable housing. Often these problems are simply and collectively labelled, *"sprawl"*. In response, the Smart Growth movement emerged. Infill development and redevelopment, increased density of development, and the adaptive re-use of existing buildings result in efficient utilization of land resources, more compact urban areas, and more efficient delivery of quality public services. Efficient use of public and private infrastructure starts with creating neighbourhoods that maximize the use of existing infrastructure. Special consideration should be given to the location and timing of infrastructure extensions in rural areas so as not to encourage growth that will promote inefficient and unsustainable development patterns; create the need for additional inefficient and costly infrastructure; result in the loss of viable agriculture, forest land, and important natural habitat; create conflicts between agricultural and urban land uses; or ultimately harm the character of the rural community. Smart Growth principles have an economic benefit to the communities and regions that employ them [16].

Mixed-use developments include quality housing, varied by type and price, integrated with shopping, schools, community facilities, and jobs. Human-scale design in harmony with the existing urban form and quality construction contribute to successful compact, mixed-use development and also promote privacy, safety, visual appeal, and compatibility among uses and users. In rural areas, a mix of housing types and price ranges should be encouraged to meet the needs of the entire community. Mixed-use development is not limited to vertical mixed-use structures; locating parks, neighbourhood retail and services, schools, and housing all within walking distance is another way to create a mixed-use community.

Integrating land use and transportation planning to accommodate more than just the automobile and to provide increased transportation choices, including mass transit, bicycling, and walking is a hallmark of Smart Growth. Such development is pedestrian-friendly at a human scale. Rural residents, who range in age and abilities, also have needs for access to public transportation. All forms of transportation must be reliable, efficient, and user-friendly, creating opportunities for access of all segments of the population to housing, employment, education, recreation, and human and community services.

Smart Growth includes evaluating the appropriate geographies to improve air quality, water quality and quantity, habitat functionality, economic prosperity, and transportation choices; and for local jurisdictions within these geographies to establish and coordinate policies that address these elements in a manner that is appropriate for their regions and governance structures. Smart Growth does not work without cooperation and partnerships among governments, property owners, developers, financial institutions, and the public.

The principles of Smart Growth can form the basis for dialogue between these parties and challenge all to ensure that we create in America communities of lasting value. Smart Growth provides timely tools not only for long-range planning but also addressing current issues related to communities with high foreclosure rates, limited infrastructure, and fiscal challenges [17].

2.4. Methodology

Our research was done through descriptive-analytical method, involving collecting data, library and document research, sites, calendars, articles, theses and dissertations. We analyzed urban smart growth indexes, and employed Arc GIS, Analytic Network Process (ANP) and Holderness and Shannon Entropy Models.

2.5. Study area

Piranshahr which is considered the political centre of Piranshahr county is located in south of West Azerbaijan province and 12 km to Iran and Iraq (Iraq Kurdistan).
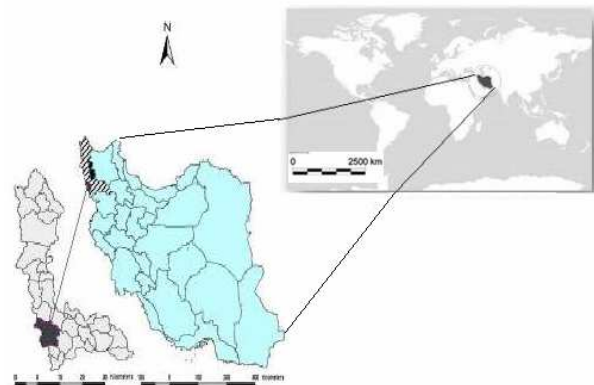

Fig. 1. Location of Piranshahr City in Iran.

An Analysis of Urban Smart Growth Indexes with an Emphasis on Compactness, Accessibility and Environment.
Case Study: Piranshahr City, Iran
Journal Settlements and Spatial Planning, vol. 6, no. 1 (2016) 15-22

This city is encompassed from north to Oshnaviye and Naghadeh and from south to Sardasht and from west to Mahabad (Consultant Engineers Armanshahr, 2009:2). Based on the 2006 and 2011 censuses, Piranshahr's population was of 59,721 (2006) and of 70,722 people in 2011 [18].

3. RESULTS AND DISCUSSION

3.1. Evaluation of urban form

The Holderness model. One of the principal methods for determining urban sprawling growth is the use of Holderness Method. In 1991, John Holderness applied a method for determining urban sprawl growth and population growth. Using this method, it could be specified what extent of urban growth is the result of population growth and to what extent it is the result of unorganized urban growth. He employed the equation of land gross per capita [19].

$$Ln\left(\frac{\text{population at the end of period}}{\text{population at the beginning of period}}\right) + Ln\left(\frac{\text{land gross per capita at the end of period}}{\text{land gross per capita at the beginning of period}}\right)$$
$$= Ln\left(\frac{\text{urban area at the end of period}}{\text{urban area at the beginnig of period}}\right)$$

$$Ln\left(\frac{72722}{61250}\right) + Ln\left(\frac{85}{97}\right) = Ln\left(\frac{844.45}{631.62}\right)$$

$$Ln(1.0155) + Ln(0.9711) = Ln(1.0450)$$

$$(0.0153) + (0.029) = (0.044)$$

$$\left(\frac{0.0153}{0.044}\right) + \left(\frac{0.0293}{0.044}\right) = \left(\frac{0.044}{0.044}\right)$$

$$\%34 + \%66 = 1$$

Therefore, about 34% of the physical growth in Piranshahr City from 1990 to 2012 is due to population growth and 66% is due to urban growth which is related to urban sprawl and horizontal growth, which results in a decrease in population's gross density and an increase in urban land gross per capita.

The Shannon's Entropy Model. This model is used for analyzing and determining the extent of urban sprawl growth phenomenon. The general structure of this model is as follows:

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

where:
H - value of Shannon's entropy;
P_i - ratio of constructed zones area (total housing density) to the total sum of zones area;
n - total sum of the zones.

The value of the Shannon's Entropy is between 0 and Ln(n) 0 means a very compact (dense) urban physical development, whereas Ln (n) shows urban sprawl physical growth. When the value of the entropy is more than Ln(n), urban sprawl growth takes place.

Table 2 indicates that the value of entropy is 1.3452 in 2012, while the maximum value is Ln (4) = 1.3862.

Table 2. Calculating Shannon's Entropy for 2012 in Piranshahr City.

Areas	Constructed area	P_i	Ln(n)	$P_i \times Ln(P_i)$
1	3,098,485	0.3637	-0.9845	-0.3678
2	1,951,727	0.2353	-1.3368	-0.3404
3	1,735,277	0.2092	-1.5633	-0.3272
4	1,507,012	0.1817	-1.7053	-0.3098
$\sum$	8,292,501	$\sum P_i = 1$	-5.5899	-1.3452

The closeness of entropy value to the maximum value suggests urban sprawl physical development. The entropy value is of 1.3452 in 2012, indicating that physical growth has been in sprawl and incompact form.

3.2. Evaluation of access

To achieve smart growth, the main aim is to make more options of transportation available for citizens. Increasingly, cities are looking for different options of transportation. Specially, they are searching for wider transportation tools so that they could change public transportation systems. Therefore, in order to achieve urban sustainable development, cities need newer modes of transportation planning including better coordination of transportation use, more access to quality transportation, multiple transportation options, flexibility and inner relationships of transportation network and the warranty of the relationships among passengers, bicycle riders and public transportation.

With respect to the investigation done in 22 global metropolitans, Gehl (2002) states that in order to reach special lines, the normal radius of movement for most of the bicycle riders is between 400 to 700 meters. Also, he explains that the normal radius of movement on foot for most of the people is 400 to 500 meters [20].

In the current research, to investigate the radius of citizens' access to bus stops, taxi lines and minivan lines, 500-meter distance is considered as acceptable distance.

3.2.1. Buses

Piranshahr has 47 bus stops and 5 bus lines. According to the observations of the study, the performance of the system is not proper and the low use rate of the system shows lack of inclination toward the system against other transportation vehicles such as private cars, taxis and private hired cabs.

19

Among the main reasons of this lack of propensity could be the high waiting time due to lack of buses in the lines. Therefore, according to the findings and calculations, 27.26% of urban areas are located within 5-minute (500-meter) distance from bus stops in the city. Also, 72.64% of urban areas are located within over than 5-minute (500-meter) distance from bus stops in the city. The calculations reveal improper distribution of bus stops in the city. The highest coverage belongs to neighbourhood 8 with 82.15% and the lowest one to district 14 with no access.
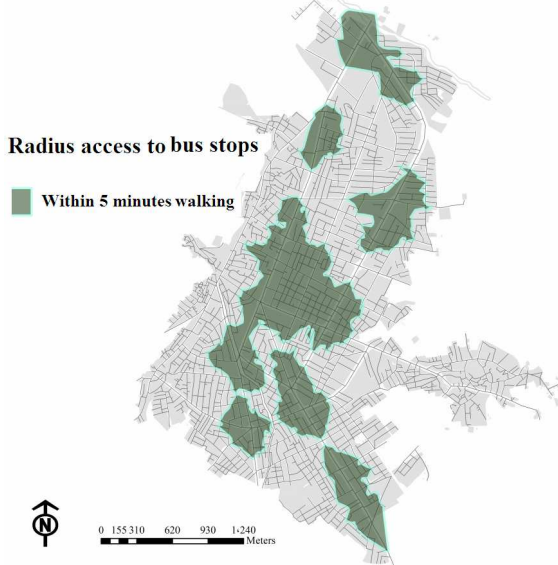

Fig. 2. Radius access to bus stops.

3.2.2. Taxis

Piranshahr has 6 taxi lines, 283 regular taxis and 68 line taxis. According to Piranshahr Municipality's Traffic and Transportation Department, most of the travels are done by private cars and taxis in the city.
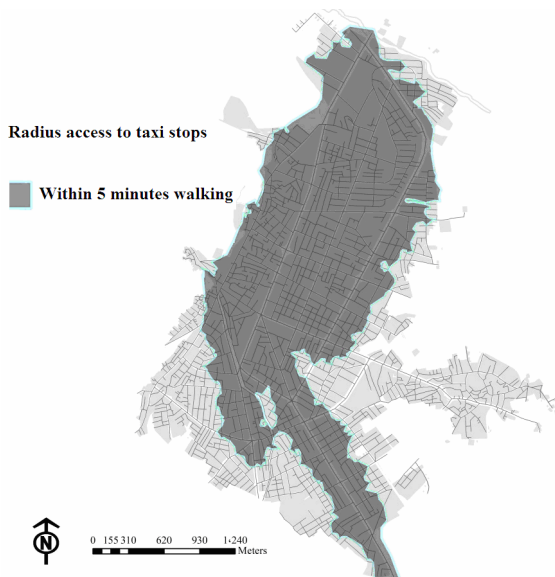

Fig. 3. Radius access to taxis stops.

Therefore, according to the findings and calculations, 56.73% of urban areas are located within 5-minute (500-meter) distance from taxi lines in the city. Also, 43.27% of urban areas are located in over than 700-meter distance from taxi lines in the city. The highest coverage belongs to neighbourhoods 3 and 2 and the lowest one to neighbourhood 14 with no access.

3.3. Evaluation of green space

In Piranshahr, an area of 12.77 hectares is given green use in the form of parks, green spaces, refuges of streets and green parts of squares and it is 1.9 square meters per capita. Its occupation rate against all areas is of 2.41% and its percentage against all urban area is of 1.7%. The lack of sports green space land (about 22.7 hectares) is notable. In the following parts, the specifications of those two types of green use are shown in the city.

Equipped green spaces (parks) cover an area of 12.77 hectares and represent 2.41% of all urban area. This type of land use is 1.9 square meters per capita.
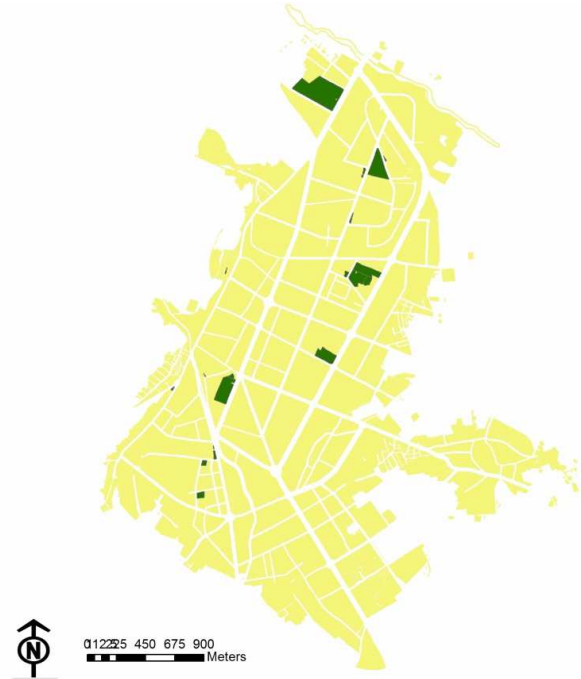

Fig. 4. Distribution of green space in Piranshahr.

3.4. Sewerage network

One of the important indexes of safe life is the urban sewerage system. In addition to wastewaters produced by residents, the wastewaters of industrial and agricultural centres are polluting underground and surface waters, especially rivers, lakes and seas. Piranshahr's wastewater collection network includes notable share of the city in such a way that the length of the network is of about 90 to 100 kilometres with diagonal of 200 to 800 millimetres and 14,000 main offshoots. About 74% of population is covered by

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Case Study: Piranshahr City, Iran
Journal Settlements and Spatial Planning, vol. 6, no. 1 (2016) 15-22

wastewater collection network (traditional through transition to urban outskirts and modern through transition to infiltration system); the rest of the population dispose of their wastewaters in traditional wells [21].

There is no wastewater infiltration network in public centres, hospitals, industries, large public and private organizations located in the city and wastewaters of the city's waste removal centre and butcher house enter into river and pollute its waters. Urban wastewaters are dangerous due to the high amounts of Nitrate and severe bacterial pollution. The drainage of urban wastewater into wells and its removal in rivers threaten supply resources of urban waters and, in turn, it endangers the health of citizens. Among urban districts, district 2 or downtown has the highest density and highest coverage of wastewater collection network, and district 3 has the lowest coverage of the network.

4. CONCLUSIONS

Smart growth is a flexible, while wide, expression including vast volume of new meanings and concepts struggling for the improvement of urban environments. Unlike urban sprawl development, it tries to adopt a sustainable approach against different dimensions of urban life. For doing so, regarding urban physical growth, it leads development toward inner city capabilities and natural resources protection. Therefore, the current research attempts at investigating and analyzing the urban smart growth indexes among Piranshahr's districts in terms of neighbourhoods, using different methods and models.

Findings reveal that Piranshahr's neighbourhoods have different discrepancies with each other regarding indexes investigated. The Shannon's Entropy Model indicates that the city has sprawl development. The Holdereness model shows that, regarding the city physical growth or its area development, about 66% belongs to population growth and 34% to urban sprawl development. Regarding environmental indexes, green spaces sub index, district 1 has the highest green spaces per capita with area of 89,471.11 square meters and population of 27,279 and district 4 has no urban green spaces with population of 7,758.

In the case of sub index of access to sewerage network, district 2 with average population has the highest coverage of urban sewer network and district 3 with the population of 19,797 enjoys the lowest coverage of the network. In addition, in the sub index of wastes among the districts, districts 1 and 2 have the highest rate of waste production and in the sub index of old textures, districts 1, 2 and 3 consisting of neighbourhoods 1, 7 and 11 with the population of 21729 have the highest extent of old textures.

For the sub index of access to bus stops, the highest coverage belongs to neighbourhood 8 (located in district 2) with 82.15% while neighbourhood 14 (located in district 3) has no access to the stops. Furthermore, for the sub index of access to taxi lines, neighbourhoods 2 and 3 are on the first place (located in district 1) with 100% of citizens covered whereas the lowest coverage belongs to neighbourhood 14 (located in district 4). And, in the case of sub index of access to minivan lines, neighbourhoods 2 and 3 (located in district 1) enjoy the highest access with 100% of the citizens receiving the service while the lowest coverage belongs to neighbourhood 15 (located in district 4) with 35% of citizens covered. Ultimately, regarding three indexes of compactness, accessibility and environment, Piranshahr is not in an acceptable condition. However, in order to approach to smart growth indexes, the following items are recommended:

- creating more green spaces and parks in the neighbourhoods for such purposes as coordination and unity with other spaces and buildings as well as citizens' use and enjoyment, in addition to environmental effects such as air pollution control and noise pollution control;

- creating compactness in the neighbourhoods, including a balanced combination of different activities such as living, shopping, working and spending leisure times area;

- developing needed mixed land uses including educational-cultural uses;

- reconstructing inner city old textures in order to avoid leaving those old parts of the city alone as well as forbidding new constructions in the city outskirts;

- allocating more urban spots to bus stops and taxi lines in order to deliver better services to citizens;

- correcting urban transportation system and creating facilities and infrastructures for walking in the passages having attractions for the citizens;

- promoting public culture in order to reduce fuel consumption and use public transportation vehicles;

- regulating efficient, clear and scientific strategies in order to avoid irregular urban forms;

- correcting and reviewing available patterns of urban limit protection and regulating necessary laws in this regard;

- creating vast variety of settlements in size and ownership.

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