

Evaluation of Ardabil City Carrying Capacity Using DPSIR Method and ELECTRE Model

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Abstract: In the modern view, argument about urban carrying capacity and spaces utilized due to urban development throughout the world has been considered. The increase in size and number of the cities, human activities such as land use change, high consumption of resources and emission of pollutants have left negative impacts on the function and structure of the urban ecosystems and have caused many problems for the circulation of materials and energy. The present study, by applied method and with the aim of studying carrying capacity of Ardebil City using the components of driving force, pressure, state, impact and response with multi-criteria decision model ELECTRE to prioritize the four-Regions districts of the Ardabil City by effective indicators in the form of 5 components discussed in the DPSIR method has been done. Collected information first, classified and categorized by DPSIR method, then by the means of utilizing Expert Choice weighted and ultimately by the implementation of ELECTRE model, the four- Regions districts of Ardabil City in terms of the presented indicators were prioritized. The results obtained from DPSIR method showed that, among the four- Regions districts of Ardabil City, driving force coefficient and then responding with 0/40 and 0/35 ratio have the greatest impact on the carrying capacity of the region. Also, the results of the prioritization of the ELECTRE model exhibit that regions 2 and 3 use the maximum capacity of the area according to the components used in DPSIR, and regions 1 and 4 are in the next priority.

Keywords: Carrying Capacity, DPSIR, Density and Urban Development, ELECTRE, Ardabil City.

1. PROBLEM STATEMENT

Today, the increase in size, number of the cities and human activities such as land use change, high consumption of resources and emission of pollutants have left negative impacts on the function and structure of the urban ecosystems and caused many problems for the circulation of materials and energy (Zhang *et al*, 2009 & Li *et al*, 2010). The population growth, various social and economic circumstances of the cities, provision of high-quality settlements in the cities (Shen *et al.*, 2011) fragmentation, isolation, and destruction of natural habitats due to urban development (Marzluff, 2001); on one hand have created a major challenge for the managers and planners, and on the other hand, cities inevitably have to endure pressures beyond the refining capacity of the environment and their regain potential (Song, 2011). The above-mentioned issues made the urban carrying capacity prominently to be considered. Planners usually know the carrying capacity as the capability of a natural or artificial system that can lead to population growth or physical development without environmental quality reduction or demand (Schneider *et al*, 1978).

From the perspective of urban planners, the environmental tolerance thresholds are the level of

human activities, population growth, patterns, development of land use and physical advance that sustain the urban environments stability without causing serious destructions and irreversible damages. It should be kept in mind that the natural environment has a limited ecological capability for human use. Therefore, the carrying capacity is the level of human activity, population growth, land uses and physical development that preserves urban environments without causing destruction and damage to the environment (Oh *et al*, 2002, 2005). Also, the natural ability and human made system that deliberate various needs of the land uses, considering the restriction and possibility of environment instability (Godschalk & Parker, 1975).

According to the development and expansion of human activities scope, the concept of carrying capacity can be expressed in terms of population carrying capacity, environment carrying capacity, resource carrying capacity and ecological carrying capacity (Xu *et al*, 2010). If urban carrying capacity exceeds beyond the environmental tolerance thresholds, it will exacerbate environmental damages and risks, which is summarized in four sections: trivial urban services, environmental destruction, resources scarcity and social conflicts (Wei *et al*, 2015).

In fact, the concept of carrying capacity is generated by Ecology knowledge, and is based on the principle

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that, there is always a limitation on the growth of bio-communities (Schroll *et al.*, 2012), which, can be an essential guide for urban planners and managers so as to be capable to manage, construct, and distribute the resources more excellently (Rengasamy, 2009). The pressures on environmental carrying capacity of the city can be attributed to human activities, population, land uses, physical development, that, besides the concentration on development rate, provide a framework for physical, social, economic, and environmental development in the planning process to attain a sustainable environment (Bernadette *et al.*, 2009).

In the field of carrying capacity associated to population and human activities on a city scale, several studies and researches have been conducted with different attitudes. Among these studies, there is a research entitled Urban Ecology Regulation, based on the environmental carrying capacity that has been done by KANG *et al.*, (2012). XU *et al.*, (2010), by evaluation and deliberation of the carrying capacity, demonstrated environmental carrying capacity of the city with three main patterns: population carrying capacity, ecological footprint and relative carrying capacity. Fuju *et al.*, (2011), also examined the environmental carrying capacity in the Yellow River Delta and in order to estimate the environmental carrying capacity, they used ecological footprint, so the range of environmental impacts of the area in terms of equilibrium and sustainable development achievement to be examined. Li *et al.*, (2010), in an article entitled Comprehensive Ecological Carrying Capacity Models, deliberated carrying capacity at three levels of human activities, human pressures, and ecological carrying capacity, and by utilizing the AHP method, a weight is dedicated to each one of the indicators to attain accurate evaluation and information.

Schroll *et al.*, (2012), in a research entitled carrying capacity with local spatial planning approach, examined the carrying capacity within 4 sections of food production, waste and forest in Indonesia. Liang and Lina (2012), studied the theoretical basics of comprehensive urban carrying capacity and recommended an eclectic set of useful indicators for estimating the carrying capacity in three diverse levels of social carrying capacity, economic carrying capacity, and resource carrying capacity. Xu & Xie (2012), also, paid more attention to the carrying capacity of urban ecosystems closely linked to the factors, for instance, health of urban ecosystems, city ecological safety and ecological hazards of the city that are on the research

pathway to the sustainable city. Wei *et al.*, (2015), applied Urban Carrying Capacity (UCC) as one of the concepts of sustainable urban development in a research entitled Sustainable Urban Development.

Dou *et al.*, (2015), furtherly considered the measurement and evaluation of the carrying capacity of water resources in Henan, China, due to the intensification of concerns about water resources and the necessity of paying attention to carrying capacity at the socioeconomic and stable environmental scale. Budihardjo *et al.*, (2013), in estimation of the carrying capacity using ecological footprints, concluded that, the progressions of the industrial sector, although led to the enhancement and economic growth of the region, exacerbated the negative impacts and environmental difficulties, and diminished the quality of the environment.

Over the areas of Iran, many researches in the field of urban carrying capacity have been done as well. Zebardast (2004), believes that, in order to assess the tolerance capacity of the environment to confront the needs and consequences of urban life with ability of the natural environment, it is possible to determine the urban environment condition due to accepting more population and its physical growth and development. The obtained results of the research of Abbaszadeh Tehrani (2008) entitled as the concepts combination of carrying capacity in urban management and planning process of Tehran City illustrated that, the ultimate range of carrying capacity of waste production index in any regions of Tehran is not optimal.

2. INTRODUCING THE CASE STUDY

Ardabil city, the capital of Ardabil province in the northwest of the country, is settled in a mathematical position of 15 minutes and 38 north latitudes and in 17 minutes and 48 longitudes. Its elevation is 1345 meters (Center of Iran Statistics 2011). The population of the Ardabil city, pursuant to the general census of population and housing in 2016 is 605,992 people. This city in terms of organizational structure according to the city size and city population for providing urban services, is divided into four districts, and in each region the municipality of that area with its subsets is responsible for providing urban services. The communications of Ardabil city with other areas of the city, whether in the province or outside of it, is done through the fundamental pathways. The main communicational route of the Ardabil City is the route of Tabriz-Bostanabad-Sarab-Ardabil-Astara with an east-west orientation. (Figure 1)

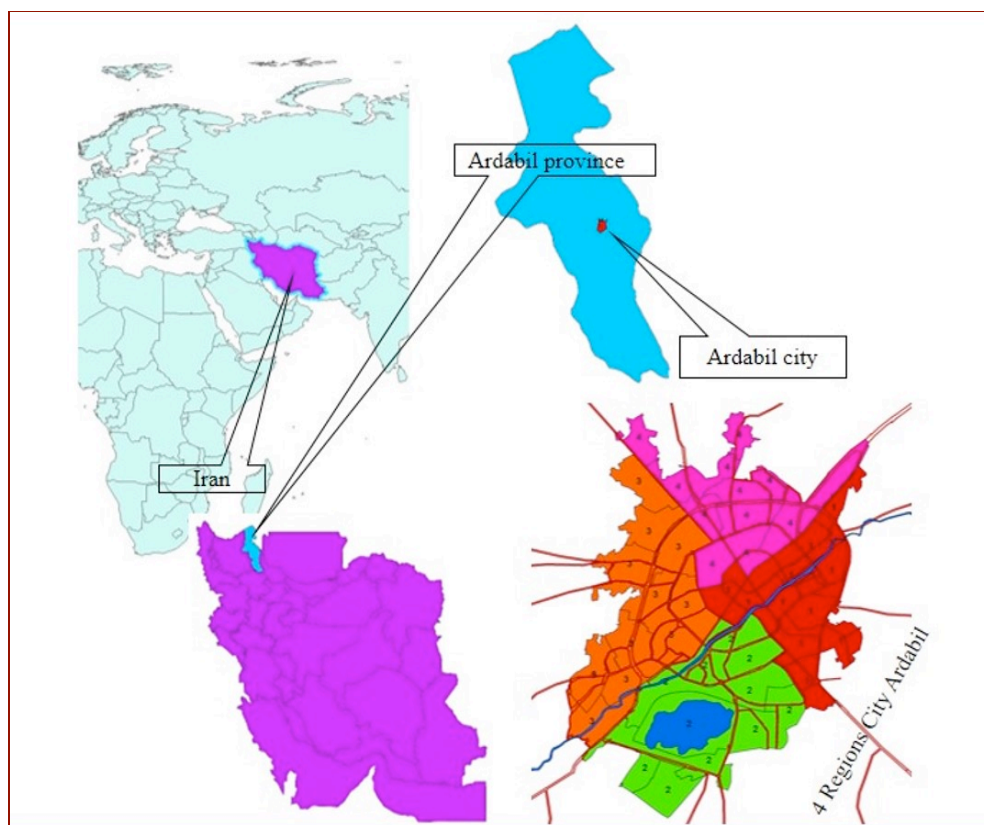


Figure 1: Location of Ardabil City in Ardabil province and the country of Iran.

3. MATERIAL AND METHODOLOGY OF RESEARCH

This research in terms of nature and methodology is analytical-descriptive, and in terms of target is applied studies. The study area territory of this research is Ardabil city. Initially, the data and information from the organizations correlated to the area subject were obtained (Municipality, Housing and Urban Development, waste management, Water, Electricity, Gas companies and etc). Then all indicators according to DPSIR framework were organized and grouped, and after list determination, indexes consistent with the research topic with paired comparison method in Expert choice environment were weighted. Ultimately, in the framework of the ELECTRE methodology, which is one of the outstanding techniques of multi-criteria analysis, the circumstance of urban carrying capacity components was prioritized in comparison form of the four- Regions districts of the Ardabil city.

4. THE STUDY OF DPSIR COMPONENTS ASSOCIATED WITH URBAN CARRYING CAPACITY IN ARDABIL CITY LEVELS

A comprehensive assessment should be presented in the form of a conceptual model so that the collected information to be capable to answer the discussed

questions. Among the existent methods and models connecting the subject of environment and carrying capacity, DPSIR can be considered as one of the most encyclopedic methods. This model is proposed by UNEP (United Nations Environment Program) and is utilized in the measurements of the European Environment Agency (EAA). In this model, besides the classification of economic, social and environmental information, the cause and effect relationships between them are identified and presented. The DPSIR model is the abbreviation of five words including "Driving forces", "Pressures", "State", "Impact", "Responses", which represents the cause and effect chain, respectively. Driving forces such as population growth, economic growth, urban facilities and equipment and the necessity of residents to them led to pressures associating with excessive consumption of resources, waste production, traffic congestion and population density. The mentioned driving forces besides of influencing the contemporary circumstance of the city, even can be accompanied by some positive functionality, but in the extreme situation cause environmental pollution, Urban landscape disorder and having negative impacts on human health and ecosystems. In order to reduce these effects, responses (control tools) are assumed that might affect and control the driving forces or other parts of the

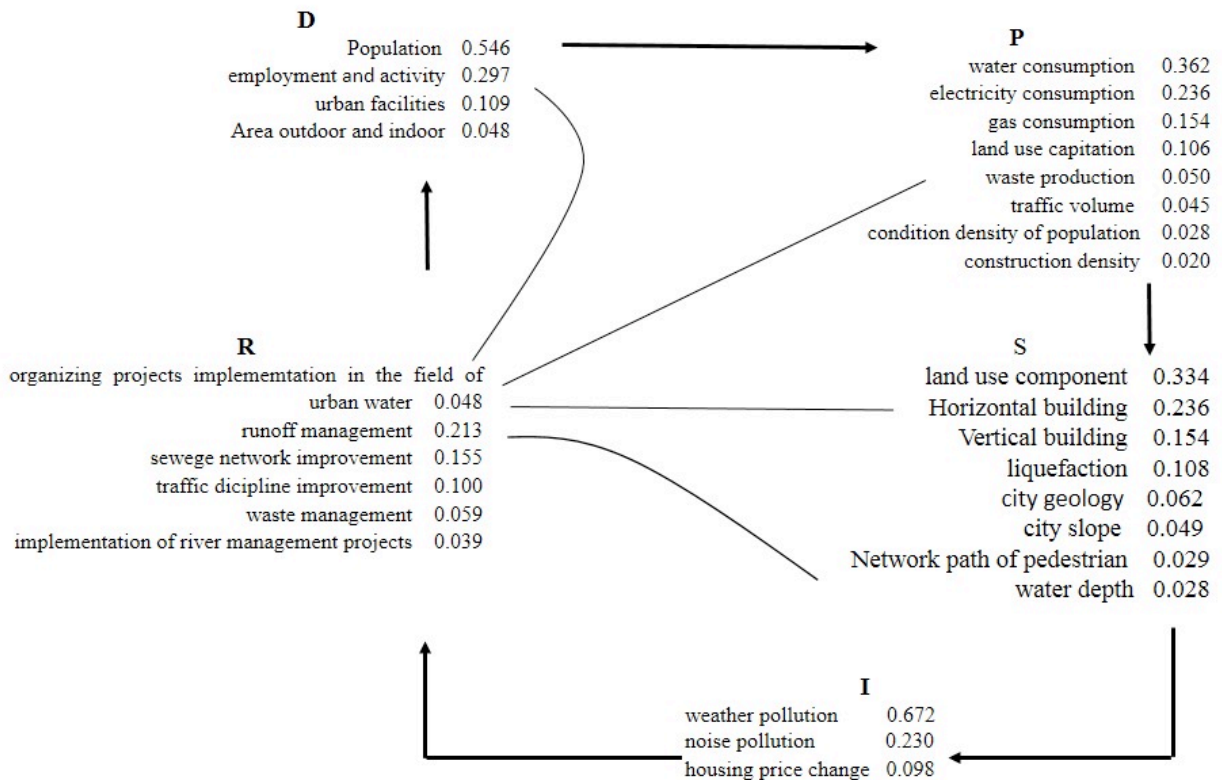


Figure 2: DPSIR components associated with urban carrying capacity in Ardabil city levels.

chain. The figure below illustrates the cause and effect relations and resulted weight of every components considering experts opinion in the relevant field.

As demonstrated in Figure 2. In driving forces, the population, and then employment factors with the weights of 0.546 and 0.297 have the greatest impact on utilizing of environment potential. In surveying of the pressures on the city of Ardabil, the highest weight is corresponded to resource consumption (water, Gas, electricity, etc.) with a total weight of 0.752. In the paired comparison methodology, the various types of contaminations with a total weight of 0.902 as well and population changes leading to higher housing prices and demand, have allocated the weight of 0.098. All of these factors have triggered that, the response associating with driving forces and impacts in Ardebil city in the field of urban water management (weighting 0.432), improving sewage network (0.155 weight), traffic discipline management (0.100) and waste management (Vern 0.059) to be more considered.

5. ELECTRE MODEL

The ELECTRE method is a set of decision making methods in which quantitative and qualitative indicators are used in it and are ranked by bidirectional

comparisons between alternatives. Multi-index issues are expressed as contractual form with a set of alternatives, indicators, and values of excellence. In multi-criteria decision-making issue, in the case of existing n-criteria and m-alternative, due to choosing the outstanding alternative, this method will be utilized which contains the following steps:

5.1. Step 1 – Decision Matrix Formation

Considering the number of criterions and alternatives and evaluated values of alternatives for varied criterions the decision matrix is formed as follows:

$$X = \begin{matrix} & X_{11} & \dots & X_{1n} \\ \cdot & \dots & \dots & \dots \\ \cdot & \dots & \dots & \dots \\ X_{m1} & \dots & \dots & X_{mn} \end{matrix}$$

Where xij is the function of the i-th (i = 1, 2, ..., m) in connection with the criterion (j = 1,2, ... n) j.

5.2. Step 2 – Descaling of the Decision Matrix

At this step, it is strived to transform the criterions with diverse dimensions into dimensionless criterions and define the matrix R as follows.

$$R = \begin{matrix} & I_{11} & \dots & I_{1n} \\ \cdot & \dots & \dots & \dots \\ \cdot & \dots & \dots & \dots \\ \cdot & \dots & \dots & \dots \\ I_{m1} & \dots & \dots & I_{mn} \end{matrix}$$

There are multiple methods for descaling, but in the approximated mastery method 1, generally, the following equation is used.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}$$

5.3. Step 3 – Determination of the Criteria Weight Matrix

At this step, according to the significance coefficients of different criteria in decision making, the vector for significance coefficient of criteria is defined as follows. The elements of vector w contains the significance coefficient of the criteria.

$$W = w_1 \quad w_2 \quad \dots \quad w_n$$

5.4. Step 4 – Determination of the Weighted Normalized Decision Matrix

The weighted decision matrix is obtained by multiplying the descaled decision matrix in weight vector of the criteria:

$$V_{ij} = w_j r_{ij} \quad j=1, \dots, n; i=1, \dots, m$$

5.5. Step 5 – Formation of Agreement and Disagreement Criteria

For each paired-alternatives of k, e (k, e = 1, 2, ..., m, k ≠ e), set of criteria J = {1, 2, ..., m} are divided into two subsets of agreement and disagreement. The agreement collection (S_{ke}) is a set of criteria in which the alternative k is preferred to alternative e in it, and its complement collection is the disagreement set (I_{ke}). The set of agreement criteria for the positive and negative criteria are explained as follows:

$$S_{ke} = \{j | v_{kj} \geq v_{ej}\}$$

$$S_{ke} = \{j | v_{kj} \leq v_{ej}\}$$

The set of disagreement criteria for the positive and negative criteria are described as follows:

$$I_{ke} = \{j | v_{kj} < v_{ej}\} = J - S_{ke}$$

$$I_{ke} = \{j | v_{kj} > v_{ej}\} = J - S_{ke}$$

5.6. Step 6 – Agreement Matrix Formation

The agreement matrix is a square matrix that is followed by the number of alternatives. Each one of the elements of this matrix, is called agreement index between two alternatives. The value of this indicator is derived from the total weight of the criteria exists in the agreement set. In other words, due to calculating the Index of concordance (C_{ke}), the alternative k and alternative e must to be compared and its value is acquired from the total weight of the criteria that alternative k is preferable to alternative e. In mathematical terms, the agreement index is calculated from the following equation (Roy, 1990):

$$c_{ke} = \frac{\sum_{j \in S_{ke}} w_j}{\sum_{j=1}^m w_j}$$

In the set of normalized weights, $\sum_{j \in 1} w_j$ is equal to 1, therefore:

$$c_{ke} = \sum_{j \in S_{ke}} w_j$$

The agreement index demonstrates that alternative k is superior to alternative e and its value varies from 0 to 1. By calculating the agreement index for all the paired-alternatives, it is possible to describe the matrix of agreement as follows. Generally, this matrix is not symmetric.

$$C = \begin{matrix} & c_{12} & \dots & c_{1m} \\ c_{12} & - & \dots & c_{2m} \\ \cdot & \cdot & - & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ c_{m1} & \dots & c_{m(m-1)} & - \end{matrix}$$

5.7. Step 7 – Define the Opposite Matrix

The disagreement matrix is a square matrix which is followed by the number of alternatives. Each one of the elements of this matrix is called discordance index between two alternatives. The value of this index is obtained from the following equation (Roy, 1990):

$$d_{ke} = \frac{\max_{j \in I_{ke}} |v_{kj} - v_{ej}|}{\max_{j \in J} |v_{kj} - v_{ej}|}$$

The value of disagreement indicator alters from 0 to 1. By computing the disagreement index for all the paired-alternatives, the disagreement matrix can be defined as follows. In general, this matrix is not symmetric.

Table 1: Acceptance Mastery Matrix

Region 4	Region 3	Region 2	Region 1	
1	1	1	-	Region 1
1	1	-	0	Region 2
1	-	0	0	Region 3
-	0	0	0	Region 4

$$D = \begin{matrix} & d_{12} & \dots & d_{1m} \\ d_{12} & - & \dots & d_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \vdots & - \\ d_{m1} & \dots & d_{m(m-1)} & - \end{matrix}$$

The available information in agreement matrix is mainly different with the information exist in the disagreement matrix, and indeed this data is complement of each other. The difference between the weights is obtained by the matrix of agreement, while the difference between the determined values is obtained by the disagreement matrix.

5.8. Stage 8 – Formation of an Acceptance Matrix

In the sixth step, the calculating method of the agreement index (C_{ke}) was expressed. At this stage, a determined value for the agreement index is specified, which is called agreement threshold and is exposed by C^- . The agreement threshold is obtained from the averaging of Index of concordance (elements of the agreement matrix). In mathematical terms, the value of agreement threshold is calculated from the following equation (Roy, 1990).

$$C^- = \sum_{\substack{k=1 \\ k \neq e}}^m \sum_{\substack{e=1 \\ e \neq k}}^m \frac{cke}{m(m-1)}$$

The agreement mastery matrix (F) is formed pursuant to the agreement threshold value. In the case that C_{ke} is greater than C^- , the alternative k superiority against the alternative e is acceptable; otherwise, the

alternative k is not superior to alternative e; therefore, the elements of agreement mastery matrix is determined by the following equation (Roy, 1990). (Table 1)

$$f_{ke} = \begin{cases} 1 & c_{ke} \geq c \\ 0 & c_{ke} < c \end{cases}$$

5.9. Step 9 – Formation of Disagreement Mastery Matrix

The disagreement mastery matrix (G) is formed as agreement matrix. For this purpose initially, the disagreement threshold (d^-) must to be computed from the averaging of disagreement indexes (elements of disagreement matrix). In mathematical terms, the value of disagreement threshold is calculated from the following equation (Roy, 1990).

$$d^- = \sum_{\substack{k=1 \\ k \neq e}}^m \sum_{\substack{e=1 \\ e \neq k}}^m \frac{d_{ke}}{m(m-1)}$$

As stated in step seven, the lower value of disagreement indicator is optimal (d_{ke}). Because, the opposition rate (disagreement) denotes the superiority of the alternative k to the alternative e. If d_{ke} is greater than (d^-) the disagreement value is high and cannot be neglected. Therefore, the elements of disagreement mastery matrix (G) is computed as follows (Roy, 1990). (Table 2)

$$g_{ke} = \begin{cases} 1 & c_{ke} \geq d^- \\ 0 & c_{ke} < d^- \end{cases}$$

Every member of the matrix G also demonstrates the mastery relationship between the alternative.

Table 2: Disagreement Mastery Matrix

Region 4	Region 3	Region 2	Region 1	
0	0	0	-	Region 1
0	1	-	0	Region 2
0	-	0	0	Region 3
-	1	0	1	Region 4

Table 3: Final Mastery Matrix

Region 4	Region 3	Region 2	Region 1	
1	1	1	-	Region 1
0.91	0.846	-	1	Region 2
1	-	1	1	Region 3
-	0.18	1	0.54	Region 4

Table 4: Alternative Priority

Difference	Defeat Number	Dominant Number	Alternative
0	0	0	Regions 1
1	0	1	Regions 2
1	1	0	Regions 3
0	0	0	Regions 4

Region2= Region3> Region1= Region4.

5.10. Step 10 – Formation of the Final Mastery Matrix

The final mastery matrix (H) is obtained from the multiplication of every elements of the agreement mastery matrix (F) in its corresponding elements in the disagreement mastery matrix (G) (Roy, 1990).(Table 3)

$$h_{ke}=f_{ke}.g_{ke}$$

5.11. Step 11 – Choose the Best Alternative

The final mastery matrix (H) describes the minor preferences of the alternative. For instance, if the value of h_{ke} is equal to one, means that the superiority of

alternative k to alternative e in both cases will be acceptable (in other words, its superiority is higher than agreement threshold and its opposition and / or weakness is also lower than disagreement threshold), and but alternative K has still the opportunity to be dominated by other alternative. An alternative should be selected that, its mastery value to be more than defeat, and in this regard, alternative can be ranked. (Table 4)

Therefore, according to prioritized ELECTRE model, it is observed that, the regions 2 and 3 apply more environmental capacity than the districts 1 and 4. (Figure 3)

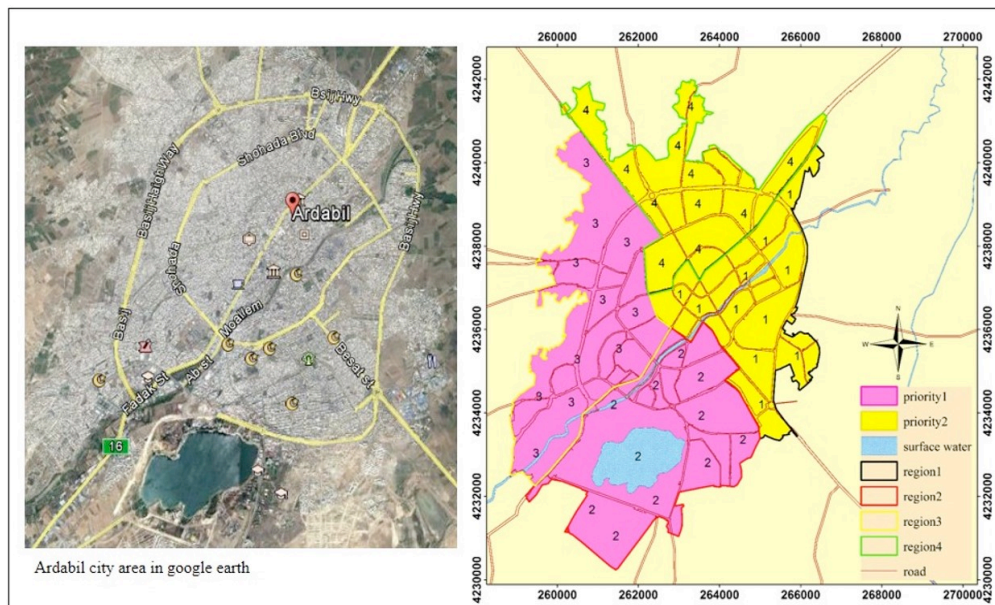


Figure 3: Priority of Ardabil City four regins based on the urban carrying capacity components with DPSIR and ELECTRE models.

CONCLUSION

Broaden use of population from the natural resources corresponding with particular targets, in order to make more profit and benefit without considering environmental capacity of the city and sources leads to extension of the human impacts and activities on the environment that individually destructs the environment and dwindles the quality of environment that directly influences life quality. As urban carrying capacity considers the level of human activities, population growth, land uses and physical development of the city without any destruction and damaging, therefore, is determined as one of the critical discussions of stable development. For this purpose, in investigation and recognition of the factors and elements affecting the urban carrying capacity considering the role and position of the Ardabil city as the capital of the province which dedicated the highest population, the existing status of the effective elements in urban carrying capacity was studied. The obtained results exhibited that, among the criterions of DPSIR, D and R with average weights of 0.41 and 0.35, have the greatest impact on the determination of Ardabil city carrying capacity, and the indicators P, S, I are as next priorities, which are effective in urban carrying capacity. Therefore, it can be declared that, the city of Ardabil in the field of driving force has the necessary infrastructures to attract the population, but if the consumption of the resources and capacity of the city increase without planning and considering the ecological potential of the environment, adverse influences on the city will be demonstrated. (Figure 4)

Also, the consequences of urban carrying capacity analysis and its integration with DPSIR and ELECTRE methods for Ardabil city illustrated that, the initial determination of indexes list with the nature of each criterions in the form of DPSIR besides of being an appropriate pattern for determination of the urban carrying capacity, provides the possibility of combining with multi-criteria decision-making models (in this research with ELECTRE) so, the decision-making process to be provided in an obvious way about the urban population, utilizing of resources and urban land uses for four- Regions districts of Ardabil city. Meanwhile, this model exposed for four- Regions districts of the Ardabil city that, the regions 2 and 3 of Ardabil city due to DPSIR components, use more environmental capacity in comparison with the regions 1 and 4. Generally, it can be said that, considering the city of Ardebil in terms of bio-environment as a city that continues toward the ecological footprint increasing, the need to pay more attention to the urban carrying capacity is more felt. Because population growth and consumption, besides of having negative environmental impacts in the city of Ardabil, will ruin the nature as well. Commonly, according to vey and his colleagues opinion in 2015, it can be concluded that, if the urban carrying capacity exceeds the limit, will results in the poor urban services for the citizens and destruction of desirable lands, loss in resources for public use and, ultimately, results in social anomalies. Therefore, strengthening of driving forces with government responses accompaniment in the city of Ardabil in particular in regions 2 and 3 is more perceived, because urban managers and planners can

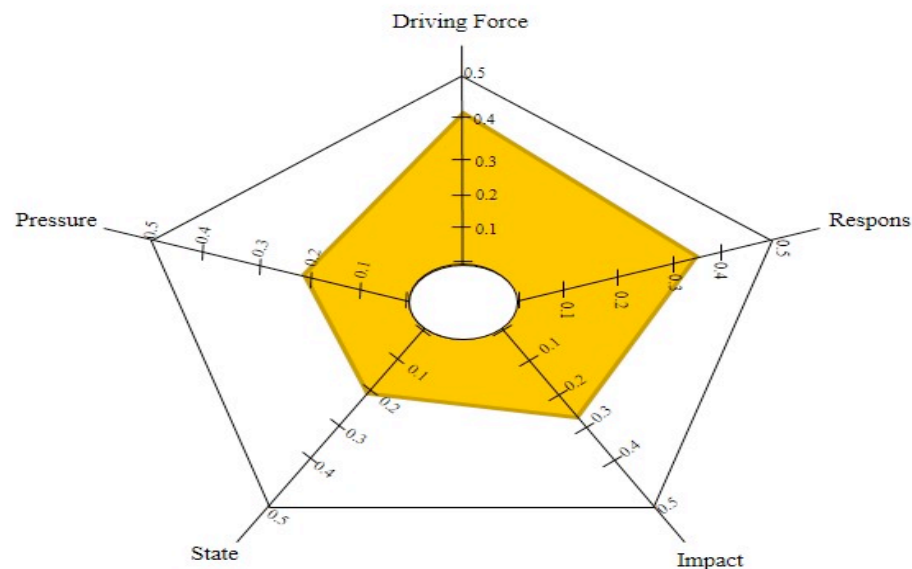


Figure 4: Priority and Importance indicators in carrying capacity with DPSIR methods.

outstandingly manage, build, and distribute resources with the proper understanding of the a concept of urban carrying capacity.

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