



Using fuzzy decision making models for measuring urban sustainability (case study: city of Rasht)

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Abstract

sustainable development is resulted from long-term evolution which has been changed and got up to date according to the people needs and given to the political, economic, social and environmental conditions, and has turned the preservation of sustainability in development into the main challenge in the urban management area. Method used in this research in order to rate regions and areas of city of Rasht in terms of sustainability, is descriptive- analytic and quantitative methods were used. In order to rate the sustainability of 3 regions and 8 areas of city of Rasht in terms of 38 described factors in social, economic, ecological-physical and managerial-institutional dimensions, current situation of the city was analyzed using questionnaire and in order to give weight to factors and to rate areas Fuzzy AHP method was used. Results acquired from the analysis show that among 8 areas of city of Rasht, region one area one with final confirmed weight of 0.271 is at the highest level and region one area 3 with final confirmed weight of 0.015 is at the lowest level which shows the major difference between various regions of area one with the other areas of regions.

Keywords: Rating; Sustainable Development; Sustainable City; Sustainability Dimensions; Fuzzy AHP

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1. Introduction

Brundtland's report revealed the necessity of rethinking about way of governance and living. Reaching sustainable development is related to integrity meaning that development in such a way that it can benefit wide part of society. In other words, it is necessary to consider the consequences of every decision that is made on society, environment and economy (Strange and Bayley, 2008; Breidlid, 2009).

Today, in developing countries, in order to strengthen economic and social infrastructures and to be free from attachment and removing available imbalances, more than ever, planning and identification of facilities and resources of their countries is required. Building a citizen-oriented urban society, healthy and efficient, which constitutes livable homes, regional and ecological security, high level of life quality, preservation of natural and historical-cultural resources, is of fundamental priorities for metropolitans' development strategies. Cities' environmental, social and economic issues and problems, emphasis on sustainable development necessity (Zallner et al., 2008). Access to facilities and correct zoning are subjects which urban managers should put as their priorities in order to achieve goals such as relaxation, beauty, and in general the matter of urban sustainability. Definitely on this pass, recognizing the situation, and the position of different districts are of most important factors in order to reach sustainable development. The incumbency of this research originates with zoning districts, place, space, social, cultural, and economic differences will be revealed. Too much focus of facilities and urban services in some districts of city, disturbs urban integration. Due to the fact that urban sustainable development has vast and complicated dimensions, depending on a single factor, and shaping it, doesn't count as examined and conscious measure. Therefore, current research aims to identify level of urban development by using sustainable development approach and its social, economic, ecological-physical and managerial-institutional factors. so, each urban region, based on the place and position that it has, will be paid attention to, in development process. Here, by zoning, hierarchy placement of urban districts and regions based on various sustainable development factors, is meant. This text seeks to, while analyzing current situation of city of Rasht and historical background of its formation based on urban sustainable development theory's dimensions and using prevalent multi-criteria decision making techniques, try to zone this city based on sustainability factors and variables. Thus, this research tries to, by using fuzzy AHP, regions and districts of city of Rasht are rated according to this sustainable factors.

1.1. Background of study

After 1980's, sustainable development was put as the main and fundamental concept in united nation's world conservation strategy and Brundtland. Brundtland's report (1983) describes sustainable development as "development that satisfies the needs of current generation without endangering capabilities of the future generation, satisfying their need" (WCED, 1987). This definition holds two main concepts:

- A) "need", especially, basic needs of the poor which need to be prioritized.
- B) "limitation", limitation is in the form of compatible technology, to conserve environmental resources for future generations (Purvis and Grainger, 2004).

Sustainable urban development has significant importance inside the concept of sustainable development (Xing et al., 2009). Urban sustainable development can be considered as the basis for renewal of urban

economic, social, political, cultural and legal structures, that first aims to improve the process of urbanization and urbanism, restore urban environment, organize urban economy, and strengthen political, social and cultural aspects of urban life. Inefficiency of expansionists points of view which are based on uncontrolled population growth and too much use of resources, has resulted in that n new points of view, attention to justice between generations, level of use of resources, facilities and world resources and also environmental considerations must be paid more attention too. Thus, analyzing the level of urban sustainability is necessary in order to achieve sustainable development. Sustainability analysis is usually considered as part of the process of measuring different aspects of sustainable development (Pope, 2004). Sustainability assessment is used in two different contexts in the literature and experiences of development. First, it points to some advancements towards sustainability, secondly it points to the effort for sustainability assessment of proposed projects, plans, strategies or written regulations before they are performed. In current conditions, importance and necessity of sustainable development factors are due to the fact that they are the most important tools to see politics, plans, effects and results of development and being put on the path of advancement towards urban sustainable development. Sustainable development factor, must assess the sustainability of human development (Nourry, 2008). Also, factors can show the distance between goals of sustainable development and thus prevent environmental disasters (UN, 2007). As selecting factors without paying attention to current frameworks may result in not reflecting results and even results being effected by irrelevant items to sustainable development, selection of factors in this research is based on presented frameworks in sustainable development, which cover various social, economic, managerial-institutional and ecological- physical aspects.

2. Materials and methods

Dominant approach in this research is descriptive-analytic. Statistical population are 3 regions and 8 districts of city of Rasht as written in city's master plan. Data and required information for this research are gathered through basic questions and hypothesizes. Therefore, set of outcomes with an emphasis on identification of current situation of urban regions and districts from sustainable development view, based on foundation theory of research in city of Rasht, went under field and documental analysis. Thus, part of this research's data are available statistics and resources and the other part are gathered through questionnaire. This research interprets and describes sustainability condition of regions and districts of city of Rasht and analyzes relation between variables and structure in order to describe and explain effective factors on sustainability of related regions and districts. In order to measure sustainability score of urban regions and districts fuzzy AHP was used.

2.1. Design of fuzzy AHP model

Method of fuzzy AHP, is subset of multi-criteria models which are nowadays used to help decision makers in various fields. In this method, after selecting required factors for decision making and appointing options,

pair comparison of options is done based on factors and options are scored based on these comparisons. Most score is given to first chose and other scores are related to other choices.

Because sustainable development has a multi-dimensional meaning and has various economic, social and environmental dimensions (Boggia and Cortina, 2010), and sometimes it's considered to have cultural dimension urban sustainable development has four aspects, economic, social, environmental and institutional, and tries to solve urban problems. Therefore, and according to viewpoints of specialists and previous research, social, economic, ecological-physical and managerial-institutional dimensions are chosen in this research, which are based on following factors:

A) Social dimension: in social dimension of sustainable development, people's rights, democracy and beings of people is paid attention to, that are analyzed by characteristics such as social security, social solidarity, sense of belonging and social development and most important criterion are sense of place, identity, environmental safety.

B) Economic dimension: In economic dimension, components such as justice, economic consistency and welfare are analyzed, that sustainability of urban economy, and coordination between different levels of jobs, condition of urban housing, and condition of families' economy are assessed by criterion such as level of using governmental credit services, percentage of recreational and travel costs.

C) Ecological-physical dimension: in this dimension, characteristics such as quality of place, accessibility, space interaction and ecological quality are assessed through criterion such as public services, suitable access to favorable green space, followed by assessment of current condition of regions and districts from achieving sustainable development.

D) Managerial- Institutional dimension: In managerial- institutional dimension role of urban institutions and urban management in approval and management of rules, is very important. In this regard, dimensions and characteristics such as participation, being responsible, responsibly and rule of law which hold values such as transparency, conscious and voluntary presence in decision making, citizen rights, and mutual responsibilities, are measured in the form of criterion such as level of participation in social, religious activities and programs.

Table 1. selected components of sustainable development

Dimensions of sustainable development	Components	Confirming researchers
Social	Social security	(Navabakhsh and Arjomand siyahpush, 2009), (Ghaffari and Omid, 2009), (Salek, 2007), (Nourian, 2006), (Biglari, 2010), (Siamaki, 2010), (Jozsa and Brown, 2005)
	Social solidarity	(Navabakhsh and Arjomand siyahpush, 2009), (Ghaffari and Omid, 2009), (Rafeian et al., 2009), (Tavakolian and Ostadi sisy, 2009)
	Sense of social belonging	(Ghffari and Omid, 2009), (Azizi, 2006), (Nourian, 2006), (Biglari, 2010)
	Social development	(Rafieanet al., 2009), (Siamaki, 2010), (Ghaffari and Omid, 2009), (Navabakhsh and Arjomand siyahpush, 2009), (Jozsa and Brown, 2005)

Table 1. Cont.

Dimensions of sustainable development	Components	Confirming researchers
Economic	Economic Justice	(Payesh green consulting engineers, 2006)
	Economic constancy	(Payesh green consulting engineers, 2006)
	Economic welfare	(Payesh green consulting engineers, 2006)
Ecological-Physical	Quality of place	(Payesh green consulting engineers, 2006)
	Accessibility and space interaction	(Payesh green consulting engineers, 2006), (Abdollahi, 2010)
	Ecological quality	(UN, 2001)
Managerial-Institutional	Participation	(Payesh green consulting engineers, 2006), (UN, 2001)
	Responsiveness and rule of law	(Abdollahi, 2010)
	Being responsible	(Abdollahi, 2010)

Table 1 represents sustainability factors in form of social, economic, ecological-physical and managerial-institutional dimensions of sustainable development by mentioning confirming resources, which are used in this research.

Steps of Fuzzy AHP algorithm are as follows:

Step 1: Making hierarchy figure

Step 2: Pairwise comparison of all factors using verbal words transformed into fuzzy triangular numbers, using fuzzy judgment matrix (Equation 1):

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \left\{ \begin{matrix} \tilde{a}_{121} \\ \tilde{a}_{122} \\ \vdots \\ \tilde{a}_{12P_{22}} \end{matrix} \right\} & \dots & \dots & \left\{ \begin{matrix} \tilde{a}_{1n1} \\ \tilde{a}_{1n2} \\ \vdots \\ \tilde{a}_{1nP_{1n}} \end{matrix} \right\} \\ \left\{ \begin{matrix} \tilde{a}_{211} \\ \tilde{a}_{212} \\ \vdots \\ \tilde{a}_{21P_{21}} \end{matrix} \right\} & (1,1,1) & \dots & \dots & \left\{ \begin{matrix} \tilde{a}_{2n1} \\ \tilde{a}_{2n2} \\ \vdots \\ \tilde{a}_{2nP_{2n}} \end{matrix} \right\} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \left\{ \begin{matrix} \tilde{a}_{n11} \\ \tilde{a}_{n12} \\ \vdots \\ \tilde{a}_{n1P_{n1}} \end{matrix} \right\} & \left\{ \begin{matrix} \tilde{a}_{n21} \\ \tilde{a}_{n22} \\ \vdots \\ \tilde{a}_{n2P_{n2}} \end{matrix} \right\} & \dots & \dots & (1,1,1) \end{bmatrix}$$

Equation 1. fuzzy judgment matrix (Chen and Hwang, 1992)

In this matrix P_{ij} is the number of people commented about first priority of i to j.

Step 3: Calculating calculative average of decision-makers' opinions using below matrix (Equation 2):

$$\bar{A} = \begin{bmatrix} (1, 1, 1) & \tilde{a}_{12} & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1, 1, 1) & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & (1, 1, 1) \end{bmatrix} \quad \tilde{a}_{ij} = \frac{\sum_{k=1}^{P_{ij}} a_{ijk}}{P_{ij}} \quad i, j = 1, 2, \dots, n$$

Equation 2. calculative average of decision-makers' opinions (Chen and Hwang, 1992)

Step 4: calculating sum of lines' elements using below equation (equation 3):

$$\tilde{s}_i = \sum_{j=1}^n \tilde{a}_{ij} \quad i = 1, 2, \dots, n$$

Equation 3. (Chen and Hwang, 1992)

Step 5: Normalize the sum of lines' elements using below equation (equation 4):

$$\tilde{M}_i = \tilde{s}_i \otimes \left[\sum_{i=1}^n \tilde{s}_i \right]^{-1} \quad i = 1, 2, \dots, n$$

Equation 4. (Chen and Hwang, 1992)

While we show as (li , mi , ui), above equation is calculated as below (equation: 5):

$$\tilde{M}_i = \left(\frac{l_i}{\sum_{i=1}^n u_i}, \frac{m_i}{\sum_{i=1}^n m_i}, \frac{u_i}{\sum_{i=1}^n l_i} \right)$$

Equation 5. (Chen and Hwang, 1992)

Step 6: determining degree of probability of being greater: degree of probability of being greater of each μ_i compared to other μ_j is calculated and we name it $d'(A_i)$. Degree of probability of being greater of a fuzzy triangular number $\mu_2 = (l_2, m_2, u_2)$ compared to fuzzy triangular number $\mu_1 = (l_1, m_1, u_1)$ is equal to (equation 6):

$$V(M_2 > M_1) = \text{Sub}_{y \geq x} \left[\min (\mu_{M_1}(x), \mu_{M_2}(y)) \right]$$

Equation 6. (Chen and Hwang, 1992)

This equation can be explained similarly as below (Equation 7):

$$V(M_2 \geq M_1) = \text{hgt}(M_2 \cap M_1) = \mu_{M_2}(d)$$

$$\text{if } m_2 \geq m_1 \left\{ \begin{array}{l} 1 \\ \text{if } l_2 \geq u_1 \\ 0 \\ \text{otherwise} \end{array} \right. = \left\{ \begin{array}{l} 1 \\ 0 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \end{array} \right.$$

Equation 7. (Chen and Hwang, 1992)

In which d is the coordinate of highest level in overlapping region and intersection of two member functions and (Figure 1):

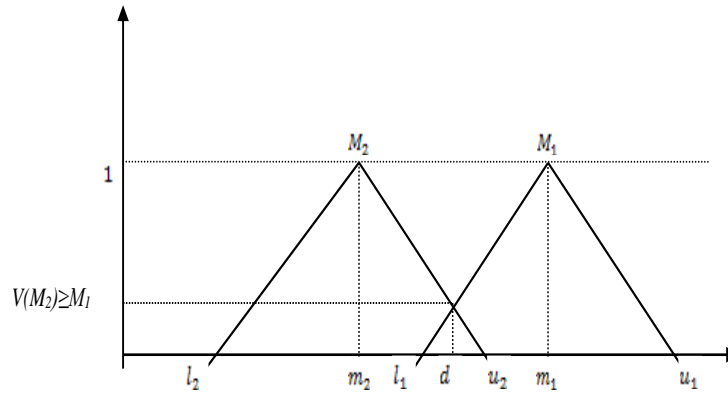


Figure1. priority of two triangular fuzzy numbers (Chen and Hwang, 1992)

Step 7: weights axis normalization using below equation (equation 8):

$$w = \left[\frac{d'(A_1)}{\sum_{i=1}^n d'(A_i)}, \frac{d'(A_2)}{\sum_{i=1}^n d'(A_i)}, \dots, \frac{d'(A_n)}{\sum_{i=1}^n d'(A_n)} \right]^T$$

Equation 8. (Chen and Hwang, 1992)

Step 8 : by combing options and criterion's weights in order to calculate final weight, we use below equation (equation 9):

$$\tilde{U}_i = \sum_{j=1}^n \tilde{w}_i \tilde{r}_{ij} \quad \forall i$$

Equation 9. (Chen and Hwang, 1992)

3. Results and Discussions

3.1. Results of solving AHP model

First step: Decision AHP tree of this project is as shown in (Figure 2):

Second, third and fourth step: in order to perform pairwise comparisons, verbal terms (table 2) are used.

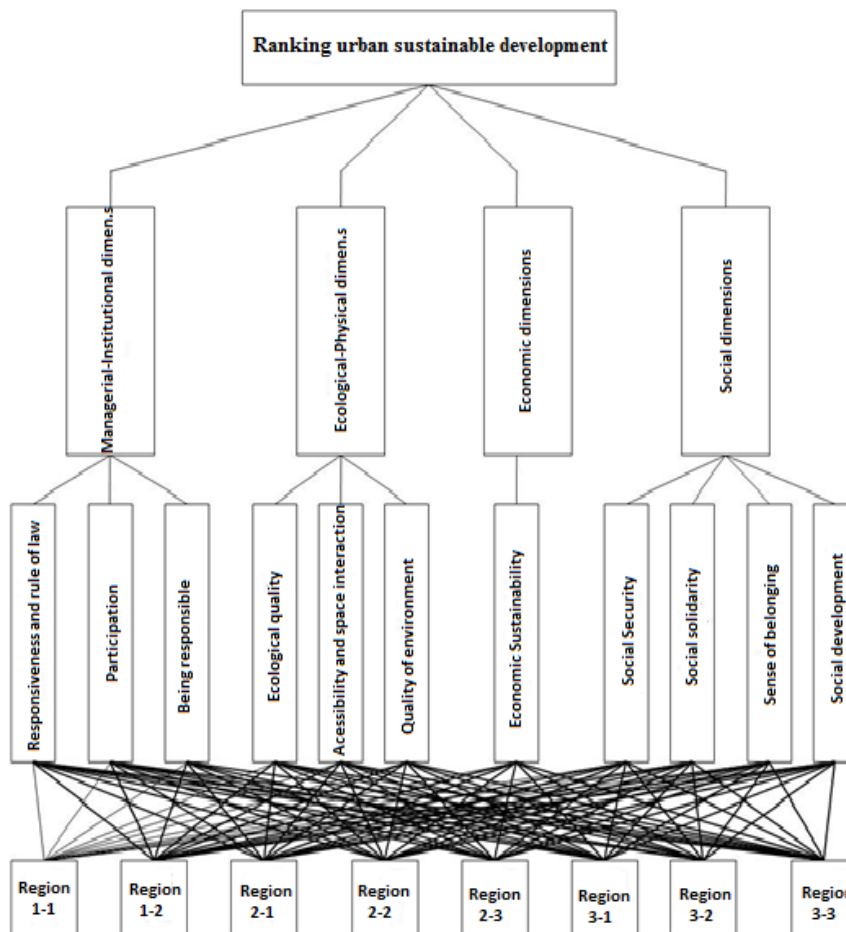


Figure 2. AHP figure of Ranking urban regions and districts' sustainability

Table 2. fuzzy spectrum and respective verbal terms

	Verbal terms	Fuzzy number
1	Equal preference	(1, 1, 1)
2	Low to medium preference	(1, 1.5, 1.5)
3	Medium preference	(1, 2, 2)
4	Medium to high preference	(3, 3.5, 4)
5	High preference	(3, 4, 4.5)

Table 2. Cont.

	Verbal terms	Fuzzy number
6	High to very high preference	(3, 4.5, 5)
7	Very high preference	(5, 5.5, 6)
8	very high to completely high preference	(5, 6, 7)
9	Completely high preference	(5, 7, 9)

Table 3 and 4 show calculative average of experts' opinions. In last columns of these tables, sums of lines' elements are shown.

Table 3. Average of pairwise comparisons in respect with urban sustainability ranking

Urban sustainability ranking	Social Dimensions	Economic Dimensions	Ecological-physical dimensions	Managerial-institutional dimensions	Sum	Normalized
Social dimensions	(1,1,1)	(0.667, 0.667, 1)	(1, 2, 2)	(3, 3.5, 4)	(5.667, 7.167, 8)	(0.239, 0.343, 0.475)
Economic dimensions	(1, 1.5, 1.5)	(1, 1, 1)	(1,2,2)	(3, 3.5, 4)	(6, 8, 8.5)	(0.254, 0.383, 0.505)
Ecological-physical dimensions	(0.5, 0.5, 1)	(0.5, 0.5, 1)	(1, 1, 1)	(1, 1.5, 1.5)	(3, 3.5, 4.5)	(0.127, 0.167, 0.267)
Managerial-institutional dimensions	(0.25, 0.286, 0.333)	(0.25, 0.286, 0.333)	(0.667, 0.667, 1)	(1, 1, 1)	(2.167, 2.239, 2.666)	(0.092, 0.107, 0.158)
sum					(16.834, 20.906, 23.666)	
CR^m =0.01 CR^g =0.084						
Compatible						

Table 4. calculation of degree of preference of sub- criterion in respect to urban sustainability ranking

Urban sustainability ranking	Social dimensions	Economic dimensions	Ecological-physical dimensions	Managerial-institutional dimensions	Final degree of greatness	Normalized weights
Social dimensions	-	0.848	1	1	0.848	0.444
Economic dimensions	1	-	1	1	1	0.524

Table 4. Cont.

Urban sustainability ranking	Social dimensions	Economic dimensions	Ecological-physical dimensions	Managerial-institutional dimensions	Final degree of greatness	Normalized weights
Ecological-physical dimensions	0.137	0.06	-	1	0.06	0.032
Managerial-institutional dimensions	0	0	0.344	-	0	0
Sum					1.908	1

Based on the results of above table, prioritization of level two criterion in respect to urban sustainability ranking is as follows:

- 1- Economic dimensions
- 2- Social dimensions
- 3- Ecological-physical dimensions
- 4- Managerial-institutional dimensions

3.2. Calculation of final weights of criterion, sub-criterion, options:

In tables 5 to 7, result about final calculation of criterion and sub-criterion and also ranking of analyzed options (from sustainability factors) are shown:

Table 5. Matrix of final weights of criterion in respect to urban sustainability ranking

criteria	Final absolute weight of criterion
Social dimensions	0.444
Economic dimensions	0.524
Ecological-physical dimensions	0.032
Managerial-institutional dimensions	0

Table 6. Sub-criterion final weight's matrix in respect to urban sustainability ranking

Criteria	criterion's final absolute weight
Social security	0.194
Social solidarity	0.059
social sense of belonging	0.083
Social development	0.108
Economic sustainability	0.524
Quality of environment	0.01
Accessibility and spatial interaction	0.005

Table 6. Cont.

Criteria	criterion's final absolute weight
Ecological quality	0.016
Being Responsible	0
Participation	0
Responsiveness and rule of law	0

Table 7. matrix of final weights of options in respect to urban sustainability ranking

Prioritization based on absolute weight	Final absolute weight of options	Options
1	0.271	Region 1 District 1
2	0.242	Region 2 District 2
3	0.178	Region 1 District 2
4	0.146	Region 2 District 2
5	0.09	Region 3 District 2
8	0.015	Region 1 District 3
6	0.041	Region 2 District 3
7	0.018	Region 3 District 3

4. conclusions

Today, achieving sustainable growth and development, is one of the major issues of countries especially developing ones. Developing countries, due to their flaws, running away from political, economic, cultural poverty... and in order to achieve a balanced and all-aspect development, which will result in improvement of everyone's lives, requires correct recognition and suitable and optimum planning in national and regional levels. Increasing gap between poor and rich in national, regional and local levels and environmental crisis in the recent half-century, are all evidences of lack of complete success of development goals and strategies. Till today, planning has been done by governments and in a focused manner in developing countries, and mainly devoted resources haven't had much relation with potentials and requirements and therefore, the gap and dichotomy between regions is constantly increasing. Determining the goal and spatial strategies of cities' sustainable development, have been determined based on districts' developmental strength and weakness points. Thus, by identifying place of urban housings from a suitable framework view of sustainable development dimensions and factors, planning can be done with a wider view.

In this research, in order to rank sustainability of regions and districts of city of Rasht, after studying theoretical framework and research literature and also field and documental studies of respective areas, a framework of urban sustainable development factors in five main dimensions, social, economic, ecological-physical, and managerial-institutional, was prepared and by each of these dimensions and in the form of base criteria and factors, and also key and detailed factors, analysis of current condition of regions and districts of city of Rasht was done. Because each of dimensions and factors have a different importance in achieving sustainable development according to their weight, fuzzy AHP method was used so that each of dimensions and factors are analyzed based on their importance effect and role that they have in urban sustainable development. In general analysis, research's findings show that most influence in creating rank difference sustainability-wise in regions and areas of city of Rasht are related to factors of economic dimension of sustainable development. Factors related to social dimension are in second rank, ecological-physical and managerial-institutional dimensions of suitable development are in further ranks of effectiveness in creating sustainability rank difference between regions and districts of city of Rasht. Also, findings show that districts of 1st region of city of Rasht, from sustainable development factors viewpoint, are in a more ideal condition compared to other districts of other regions and also, districts of region three are in the lowest level of sustainability compared to districts of other two regions.

5. Suggestions and guidelines

In this section, a number of suggestions for sustainable development in Rasht are provided based on the research findings.

5.1. Sociocultural strategies

- Promoting culture through giving proper instruction on environmental conservation and utilization and use of urban spaces
- Arranging empowerment, entrepreneurship, education and trust programs and boosting citizens' participation in urban programs
- Formation of a coordinated council consisting of academic institutions, the officials at Natural Resources Organization and tourism departments, lawyers and members of regional councils in order to establish the rules and regulations for the conservation of natural resources and tourism zones
- Improving the readability of neighborhoods through expanding public spaces and symbols
- Holding national, religious and local ceremonies and programs
- Immunization of neighborhoods through increased military, security and educational services

5.2. Economic strategies

- Increasing the role of the private sector in the economic structure of the city
- Attracting domestic and foreign investment in all sectors of the economy and infrastructures

- Increasing the share of public and social services in creating job opportunities

5.3. Physical-environmental strategies

- Creating mixed diverse user experiences
- Improving basic facilities and services
- Establishing clean and environment-friendly industries
- Efficiently use the existing residential units
- Improvement and renovation of worn urban fabrics

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