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Measuring Urban Sustainability over Time at National and Regional Scale for Addressing United Nations Sustainable Development Goal (SDG) 11: Iran and Tehran as Case Studies

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Abstract: It is evident that relations between political conditions and community development have become sophisticated in recent years. More people now live in urbanized areas, and this ongoing urbanization has various ramifications. Many countries are facing swift urban transformation which alters their regional development patterns. Urban sprawl, migration and rural depopulation, regional inequalities, increasing urban poverty, and social injustice are some of these emerging problems. Assessing regional development for identifying the aforementioned predicaments is really imperative and related to the United Nations Sustainable Development Goal (SDG) 11. However, there are limited studies that focus on the assessment of regional sustainable development at both national and regional scales, simultaneously. Thus, this study aims to fill the gap by developing a robust method that can assess and compare the level of sustainability in various regions and at varying scales. This helps to identify areas where urgent prevention or mitigation strategies and action plans are required. In this study, we strived to evaluate Iran's regions and Tehran's provinces based on sustainability indicators. To end this, the authors use factor analysis and F'ANP model in both assessments. The results of the study show that Tehran Province was the most developed province, and its F'ANP result was 2.006. Tehran is 10% more sustainable than the third region in the country which is Khorasan Razavi. Isfahan and Khorasan Razavi provinces were in the next in rank with scores of 1.984 and 1.8, respectively. At the bottom of the list, the northern Khorasan, Ilam, and Kohkiloye-Boyerahmad provinces were in the lowest ranked in terms of access to sustainability indices. It is patently obvious that Iran suffers from uneven development, and the majority of border provinces have moderate or bad situations. This uneven development also intensifies migration to Tehran, which already has one-sixth of Iran's population which has led todeteriorating social inequity and environmental injustice, nationally. The results of the regional assessment of Tehran also show that there is uneven development in Tehran Province. Tehran County is twice as good and sustainable as 68 percent of the counties in this region. The F'ANP result for Tehran County was 0.580, and it has been ranked first over a period due to the exceptional number of facilities in this region. Tehran County became 20% more sustainable during this decade. After Tehran, Firoozkoh and Damavand counties were in the next ranks with scores of 0.389 and 0.343, respectively. Qarchak, Ghods, and Baharestan counties were the weakest based on the sustainability indices, and their F'ANP results were below 0.2.

Keywords: sustainable development; regional inequality; Iran's regions; Tehran counties; uneven development

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1. Introduction

Community development and growing urbanization are able to alter spatial patterns in various regions. Development is a conscious effort and a plan to improve the various aspects of society will require coordination in all dimensions [1,2]. The commencement of

the development process coincided with the industrial revolution in the United Kingdom, where human relationships with the environment were transformed to reach maximum progress [3,4]. The spread of globalization has led to unbalanced development in almost all countries [5,6]. In most of these countries, facilities are concentrated in one or more cities, and thus, the imbalance formed in the region aggravates inequality [1,7]. It should be noted, however, that regional inequality is more pervasive in Global South countries than those of the north.

The lack of equilibrium in the spatial structure of the region shows itself in different conditions of life, economic disparities, and the level of development. Poverty, discrimination, corruption, and political, social, cultural, and economic inequality are some of the uneven development predicaments, which ultimately will reduce the residents' life expectancy [8]. In order to overcome this imbalance, as well as pay more attention to the environment, a sustainable development approach has been proposed [9]. The concept emerged with the Brundtland commission in 1987 and the UN conference in 1992, which presented the concept of intergenerational equity [8]. This approach advocates a kind of development that considers the basic needs of future and present generations, simultaneously [3,10]. The main idea of this approach is to balance economic development, social equality, and accountability to the environment [11]. Having said that, the major focus of sustainable development is not solely on environmental issues but also considers comprehensive subjects [12]. It should be noted that the sustainable development concept and reducing inequality and poverty are closely related to one another. Finally, the main purpose of sustainable development is to improve the quality of life in the long run, considering the conditions of other forms and equality between regions according to accessibility to facilities [13].

Ongoing globalization has disrupted the balance of regional development, especially in developing countries. The persistence of this type of development has led to many problems such as economic and social inequalities as well as excessive use of resources and damage to the natural environment [14]. The sustainable development concept emerged for ameliorating the aforementioned predicaments and became a popular strategy for all counties [15]. This type of development imposes various restrictions on using natural resources [16]. Most countries focused on sustainable development and have their principles for reinforcing this concept. According to sustainable development, appropriate social and economic development encourages equitable development [17]. This type of development clarifies future frameworks for various subjects such as education, justice, and environmental issues [15]. In general, sustainable development with three basic domains, sustainable social, economic, and environmental development, seeks to establish social justice and economic prosperity, with effective use of natural and environmental resources [17].

The implementation of sustainable development policy in national and regional programs is different. There are two main ideas about sustainable development policies. The strong and weak approaches are among the most important of these ideas. In the strong approach to sustainable development, it is assumed that economic and social development (human capital) is not an alternative to environmental integration (natural capital) [18]. On the other hand, in the weak approach, natural resources are replaceable with human resources. Therefore, although economic growth could lead to environmental degradation, it is still considered a sustainable strategy.

Uneven regional development could be a threat to national security. That is, principles of sustainable development focus on regional and natural scales at the same time. Focusing on sustainable development on the scale of the region is justified according to the importance of the mediator role between the national and local levels, and the consensus of most scholars is to apply sustainability principles at the regional scale [19]. For instance, Rahma and his co-workers mentioned that sustainable development strategies are more practical on the regional scale, since policies are more controllable on this scale rather than at national scale. Moreover, constructing a regional observatory is more feasible. Rahma also found that using national scale indicators could lead to impairing regional integration [20].

Reaching sustainable development aims and equitable planning have always been basic governments strategies; although, most developing countries are suffering from unsustainable conditions. Assessment of regional sustainability could clarify a region's potential in terms of facilities, infrastructure, and other aspects that assists policymakers in reinforcing the sustainability of regions [21]. That is, assessment of regional sustainability could facilitate social justice and lead to spatial equity [22]. There is an array of similar studies that focus on sustainability assessment, some of which are shown in Table 1. However, there is relatively limited research on sustainability transformation at national and regional scales. Thus, this study strives to illustrate the sustainability of Iran's provinces and assess the regional sustainable development transformations of Tehran Province in 2006, 2011, and 2016 which play a dominant part in the spatial pattern of Iran's development.

Table 1. Sustainable development assessments.

Authors	Location	Indicators	Method
Soares et al. (2001) [23]	4 subnational regions in Portugal	33 indicators in various dimensions	Cluster Analysis
Theodoropoulou et al. (2009) [24]	Methoni, Koroni, Pilos in Greece	Employment and literature rate, and different infrastructure indicators	Using questionnaire and Regression Method
Abdollahzadeh & Sharifzadeh (2012) [21]	Iran's provinces	14 social, 13 economic, and 14 infrastructure indicators	Comparative technique based on AHP
Dehcheshmeh & Alizadeh (2014) [25]	West Azarbaijan counties	40 indicators in economic, social, health, transportation, and infrastructure sections	FTOPSIS
Zebardast & Haghroosta (2014) [8]	Hamedan and Arak provinces (Iran)	Regional uneven development, 50 indicators	Factor and Cluster Analysis
Mabudi & Hakimi (2015) [26]	Sistan and Baloochestan counties	29 indicators in education, social, health, and infrastructure dimensions	VIKOR method
Hudrlikova et al. (2013) [11]	LAU region Prague (Czech Republic)	13 economic, 17 social, and 13 environmental	Cluster Analysis
Firoozi et al. (2017) [1]	Khoozestan province (Iran)	104 indicators	Vicor and Topsis models
Tret'yakova & Osipva (2018) [27]	Perm krai, Bashkortostan, Nizhny Novgorod oblast, Samara, Sverdlovsk, Tatarstan, Chelyabinsk	11 economic, 12 social, and 8 environmental indicators	Dynamic Standards
Mali et al. (2018) [28]	12 regions of Slovenia	32 economic, social, and environmental indicators	Thematic Model
Farinha et al. (2019) [29]	Algarve region in Portugal	Assessing different social, cultural, and environmental indicators	Surveys and Regression Methods
Shi et al. (2019) [14]	17 regions of Shandong province (China)	13 economic, 26 social, and 20 environmental	AHP and ANP
Garoui, Ezzeddin (2020) [30]	13 regions in Saudi Arabia	Green economic indicators	MICMAC analysis
Sueyoshi et al. (2020) [31]	China regions	National and human resources	DEA
Xu et al. (2020) [32]	China regions	17 United Nations Sustainable Development Goals include 119 indicators	Arithmetic means

Assessing regions based on the SDGs has become a popular pursuit in the field of sustainability. Particularly, the mission of SDG 11 is to make urban areas more inclusive, safe, resilient, and sustainable. However, there is a gap in measuring the sustainable development of urban areas over time which this study aims to fill.

Moreover, there is no unified method for assessing the sustainability of regions, and as can be seen in Table 1, different studies exploited various methods. These studies mainly focused on either regional or national scales, and there is a limited number of studies

that concentrate on both scales at the same time. This study aims to explore changes in sustainability on regional and national scales and also evaluate upheavals of sustainable development in Tehran's counties over a decade with the contribution of F'ANP that enables using a LARGE number of indicators. This model helps to recognize the importance of each indicator and sorts regions based on their sustainability scores.

2. Materials and Methods

Evaluation of sustainable development has become a common practice globally; however, there is no unified method for implementing this assessment. There are several ways of assessing the sustainability of regions. Table 2 reveals some of these methods and their indicators and features.

Table 2. Different approaches for assessing sustainable development.

Method	Author(s)	Year	Indicators	Limitation
HDI [33]	UNDP	1990	Life expectancy, Literature rate, GDP	Cover limited aspects of sustainability
Environmental Sustainable Index [34]	Columbia and Yale university	2006	16 indicators in 6 dimensions such as health, environment, biodiversity, energy, water resources, quality of air, and resource management	Overconcentration on environmental indicators
Commitment to Development Index [35]	Center for Global Development	2006	Financial aids, transactions rate, investment, immigration, environment, and security	Cover limited aspects of sustainability
Index of Sustainable Economic Welfare [36]	Daly and Cobb	1989	Countries expenditures on different sections such as environmental pollution, national resources, and transportation accidents	No comprehensive assessment framework
Ecological footprints [37]	Wackernagel and Rees	1996	Energy consumption per capita, housing, transportation, and leisure expenses	Cover limited aspects of sustainability
Millennium Development Indicators [38]	United Nations	2005	Millennium targets	Cover limited aspects of sustainability
CSD indicators [39]	United Nations	2007	50 indicators in 14 different socioeconomic aspects	Does not focus on gender equity and accessibility to food
Sustainable Development Goals and Policy of the Agenda 2030 [40]	United Nations	2015	17 targets in environmental, social, and economic dimensions. It has 231 unique indicators.	

Sustainable Society Index (SSI) assessment is one of the newest methods for evaluating the sustainability of regions which was presented by Kerk and Manuel in 2006. This assessment evaluated 150 countries based on health, social services, national resources, climate change, transportation, and economic indicators annually [41]. The European Union approved this method as a quantitative approach for assessing the sustainable transformations of regions [42]. According to the SSI assessment, Iran was at the rank 136 in 2006. Figure 1 reveals the Iran situation in 2019.

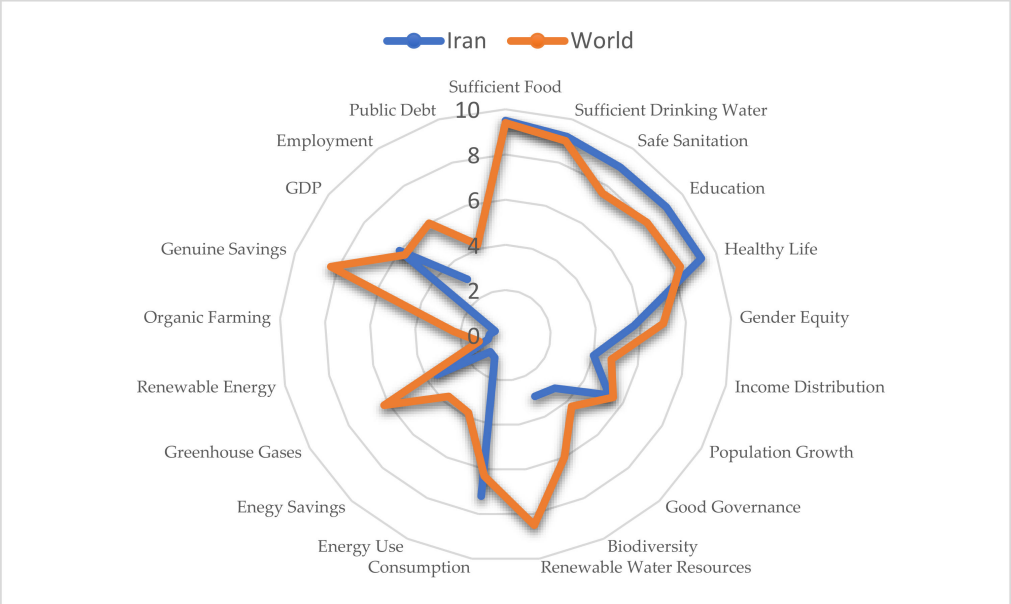

Figure 1. Sustainable Society Index of Iran 2019.

Since the SSI is one of the most acceptable methods for evaluating the sustainability of various regions, the authors try to use select indicators based on this assessment. Table 3 presents the SSI indicators and proposed indicators for this evaluation.

Table 3. Proposed and SSI indicators.

Dimension	SSI Indicators	Project Indicators
Basic needs	- Sufficient food - Accessibility to water resources	- The proportion of farmlands to the area of the province - Ratio of city water distribution network to ratio of the county area - The share of the towns with a sewage network in the province to the country - Percentage of population coverage of urban sewage collection services - Ratio of the number of urban sewage subscribers to the province's residential units to this portion in country
Health	- Healthy lifestyle - Accessibility to sanitation facilities	- Number of doctors per 1000 people - Number of paramedics per 1000 people - Number of dentists per 1000 people - Number of hospitals beds - Number of laboratories per capita - Number of rehabilitation per capita - Number of pharmacies per capita - The ratio of the number of clinics to the population - The number of health care centers in the population - The number of transportation accidents
Social development	- Education - Gender equity - Income distribution - Population growth - Appropriate governance	- Literacy rate - The ratio of the number of teachers to the number of students - The ratio of the number of elementary classes to the number of students - The ratio of the number of secondary classes to the number of students - The ratio of the number of high school classes to the number of students - The ratio of the number of kindergarten classes to the number of students - The ratio of the students to the teacher - The number of libraries per capita to this portion in the country - The population growth rate - Total Cost Index - Rate of economic cooperation - The number of orphans to orphan care centers

Table 3. *Cont.*

Dimension	SSI Indicators	Project Indicators
		- Ratio of social damage to centers - Number of children to kindergartens - The number of disadvantaged families to the number of families in province - The proportion of the disabled to the population - The number of families supported to all families in the province - The ratio of the number of nursing centers to the number of elderly - The number of families with female supervisors to all families of the province - Total marriage grants to their numbers - Number of pensioners to members of Social Security Insurance - The number of members of Social Security Insurance to the population
Natural resources	- Biodiversity - Water resources	- Ratio of the province's urban sewage network to the country - Ratio of sewage treatment of province - Ratio of the forest area in province to forest area in the country
Energy consumption and climate	- Energy consumption - Saving energy - Use of renewable energy	- Domestic consumption of the city's electricity - Gas consumption per capita - The province's share of the country's total solar hours - The province's share of the number of frosty days
Agriculture	- Natural agriculture - The amount of net reserve	- The proportion of garden lands to the area of the province - The proportion of forest lands to the area of the province - The proportion of agricultural lands to the area of the province
Economic	- Gross domestic product - Employment - Government debt	- The province's share of the total domestic and foreign tourists - Added value to the industry sector - Ratio of the size of the cinemas to their number - Rate of economic cooperation - Unemployment rate - The province shares of tourists to the country - The portion of roads in regions - The province's share of the country's hotels - The province's share of the passenger displacement - The value of 1 m of land - Number of building licenses - The province shares industrial workshops - The province's share of industrial practitioners in the country

The needed data in 2006, 2011, and 2016 were gathered from Census data which was produced by the Statistical Center of Iran [43]. In order to assess the SSI of Iran's regions, the authors used the F'ANP model. Figure 2 presents the framework of the F'ANP model. In this figure, bold phrases demonstrate the main phases of the F'ANP model, while others show steps below each phase.

Firstly, the Factor Analysis was exploited to reduce the number of indicators to some appropriate factors. The formula for producing factors among various indicators is:

$$Fj = \sum WjiXi = Wj1 \times 1 + Wj2 \times 2 + \ldots + WjpXp \quad (1)$$

In this equation, W is the factor coefficient, and P is the number of indicators. These factors were used in the F'ANP model for evaluating 31 provinces of Iran. In the F'ANP model, all the relations between the sustainability dimensions (economic–social–environmental), factors, and indicators were considered in order to present the rating. This model does not have the limitations of multiple-criteria decision analysis and does not need long calculations. F'ANP uses the potential of Factor Analysis and reduces the huge number of indicators to some limiting factors. Furthermore, by using ANP networks, it considers the relationship and dependencies between elements and clusters in order to find the relative significance of indicators of assessment [44].

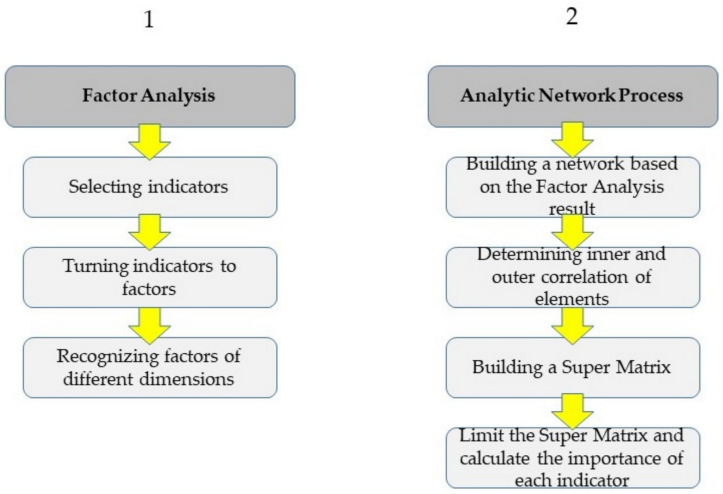

Figure 2. The framework of F'ANP model.

In the second phase, ANP was exploited to build a network model for phase one's upshots to evaluate the relative weights of the sustainable development indicators. Finally, the provinces were rated based on accessibility to sustainable development indicators and their transitions trend would be cleared.

In this study, Iran's provinces were evaluated based on the indicators in Table 3. Factor Analysis was used to reduce these 58 indicators to groups of factors. The FANP model was then exploited to rank Iran's provinces according to economic, education, health, environment, and social services dimensions which have the Kaiser–Meyer–Olkin (KMO) of 0.627, 0.77, 0.627, 0.610, 0.625, respectively. In factor analysis the KMO measure of sampling adequacy should be greater than 0.6, and Bartlett's test of Sphericity must be significant [44]. Figure 3 shows the factors and the F'ANP model for assessing the sustainability of Iran's provinces. Different colors are used to separate each dimension and its factors.

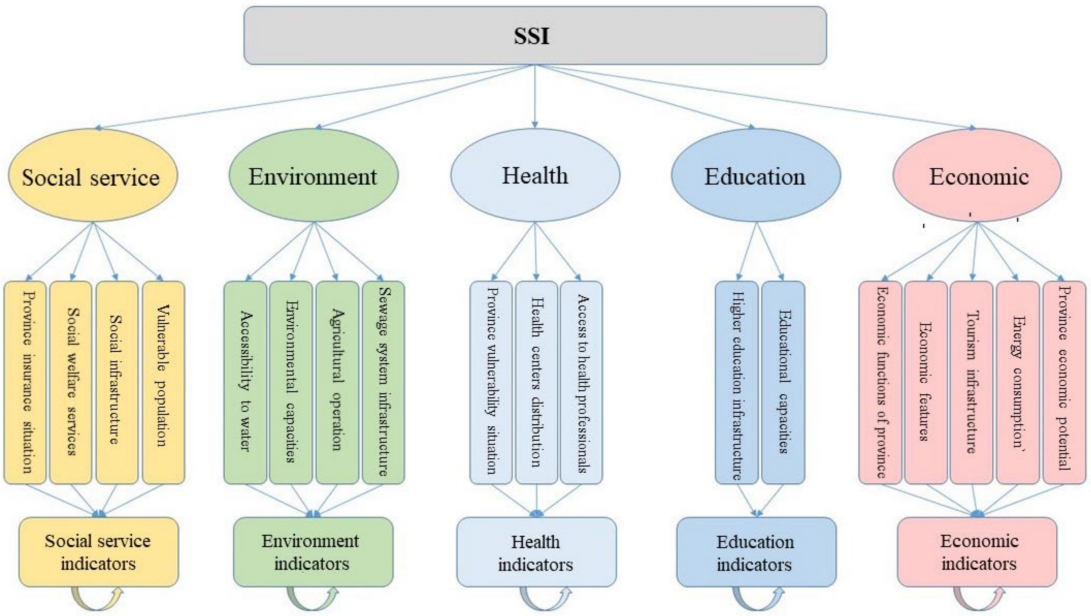

Figure 3. F'ANP model for assessing the sustainability of Iran's provinces.

The same methodology was exploited for assessing the sustainability of Tehran's counties. Figure 4 reveals the framework for assessing Tehran Province's sustainability transitions over a decade. Different colors in this figure demonstrate three dimensions and

their indicators. In this model, economic prosperity is acceptable in that it strengthens economic sustainability and efficiency by offering solutions to increase social equality as well as preserving natural resources. Evaluating sustainability transitions in the Tehran Province entails proposing an assessment framework, embracing various economic, social, and environmental indicators. Focusing on previous sustainability studies is also necessary in order to recognize the most frequently used indicator in sustainability assessments. With regards to accessibility of data and sustainable development indicators, the authors propose an assessment framework involving 60 economic, social, and environmental indicators. Table 4 presents the assessment indicators.

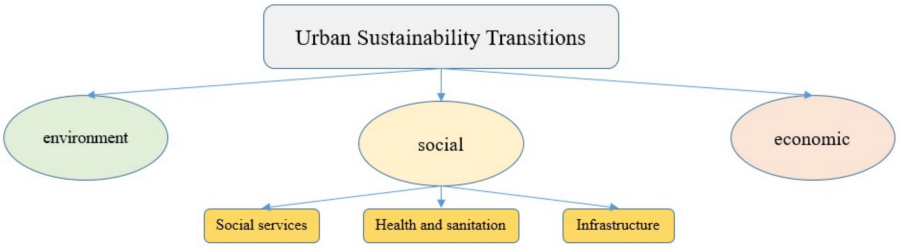

Figure 4. Theoretical framework.

Table 4. Assessment indicators.

Economic	
Indicators	**Reference**
Employed to active population ratio	[1,12,26,27,45]
The county's share of industrial workshops	[3,9,13,46]
The share of the county's transport companies to the province	[47]
The portion of roads in regions	[48]
Number of highways	[48]
Number of passengers	[1,23]
The flow of load displacement in and out of the county	[1,23]
Number of post administration in the county	[21,26,28,46,49,50]
Number of buildings with concrete and metal skeletons	
Number of job opportunities	[8,29,51,52]
Health	
Number of hospitals	[3,23]
Number of hospitals beds	[1,8,23,26,28,29,46,51,52]
Number of health centers per capita	[1,23]
Number of rural health centers per capita	[1,53]
Number of pharmacies per capita	[1,3]
Number of laboratories per capita	[1,3]
Number of rehabilitation centers per capita	[1,54]
Number of doctors per 1000 people	[1,3,13,14,26,28,46,50,52]
Number of nurses per 1000 people	[1,26]
Social Services	
Number of centers to serve the disabled	[21,51]
The ratio of the marriage loan to its number	[1]
The ratio of the number of nursing centers to the number of elderly	[55]
The proportion of the insured to the county population	[21,56]
Court per capita	[13,27,29,51,52]
The number of orphan care centers	[57]
The number of homeless household support centers	[57]
Number of centers to serve the disabled who need help	[21,51]
Number of Imam Khomeini centers to serve people	
Number of kindergartens	[1,58]
The ratio of the number of classes to the number of exceptional students	[1,58]

Table 4. *Cont.*

Economic	
Indicators	**Reference**
Education	
Number of public libraries	[1,23,26,28,50]
The number of the members of the library to the population of the county	[1,28]
The ratio of the number of education staff to the number of students	[58]
The ratio of the number of trainers to the trainees	[1,58]
The ratio of books to public libraries	[1,3,14,28]
The ratio of the number of classes to the number of students	[1,36]
The ratio of the number of elementary classes to the number of students	[1,15,59]
The ratio of the number of secondary classes to the number of students	[1,23]
The ratio of the number of high school classes to the number of students	[1,23]
The ratio of the theaters to the number of theater programs	[60]
Infrastructure	
Coverage of sewage networks	[1,14]
The ratio of sewage bifurcation in the county	[1,14]
The number of phones per capita	[18,21,28,49]
Number of fuel stations	[61]
Number of electricity customers	[18,21,28,49]
County's share of water network	[8,26,49,62]
The number of slaughterhouses in the county	[1]
The number of fire stations per 1000 people	[1,63]
The number of cities with gas facilities to all the cities of province	[14,21,28,50]
The number of rural areas with gas facilities to all the rural areas of province	[14,21,28,50]
County's share of sports facilities	[64]
The county's share of the number of workshops covered by social security insurance	[21,56]
The proportion of cinemas to the number of spectators	[3,65]
The proportion of forest areas to county area	[13,15,49,56,64,66]
The ratio of transportation waste to population of county	[12,15,26,27,52,62,67]
The ratio of CNG consumption to population of county	[68]
Gas consumption per capita	[12,14,18,61,63]
Water consumption per capita	[15,23,30,59,62,66]
Electricity consumption per capita	[18,21,28,49]
Number of greenhouses	[69]
Environment	
The proportion of forest lands to the area of the province	[13,15,49,56,62,66]
Range of land area to county area	[14,49]
County's share of the number of frosty days	[29,51]
County's share of sunny hours	[29,62]
County's share of public parks	[1,3,29]
Green space per capita	[1,3,15,28,29,46,59,62]
The proportion of agricultural lands to the area of the province	[70]
The proportion of farmlands to the area of the province	[13,15,28,29,49]
The proportion of garden lands to the area of the province	[13,15,28,29,49]
County's share of greenhouse area	[14,49]

One of the challenges of assessing regional development transitions was the change in the number of cities during the period. There were 13 counties in Tehran Province in 2006, while this number reached 14 and 16 in 2011 and 2016, respectively. Table 5 reveals changes in cities in Tehran Province over a decade.

Table 5. Tehran Province cities from 2006 to 2016.

2006	2011	2016
Eslamshahr	Eslamshahr	Eslamshahr
Pakdasht	Baharestan	Baharestan
Tehran	Pakdasht	Pakdasht
Damavand	Pishva	Pardis
Robat Karim	Tehran	Pishva
Rey	Damavand	Tehran
Savojbolagh	Robat Karim	Damavand
Shemiranat	Rey	Robat Karim
Shahriar	Shemiranat	Rey
Firuzkuh	Shahriar	Shemiranat
Karaj	Firuzkuh	Shahriar
Nazar abad	Ghods	Firuzkuh
Varamin	Malard	Ghods
	Varamin	Qarchak
		Malard
		Varamin

The same areas should be considered during the period in assessing the weight of indicators. Having said that, the authors used a data polling method that focused on the history of regions. Table 6 shows the counties that are considered for assessing indicators. It should be noted that after recognizing the importance of each indicator, these measures contribute to demonstrating ratings for the cities in 2006, 2011, and 2016.

Table 6. Counties that are considered for finding the importance of indicators.

Counties
Eslamshahr
Pakdasht
Tehran
Damavand
Robat Karim
Rey
Shemiranat
Shahriar
Firuzkuh
Varamin

Similar to the process of assessing Iran's provinces based on 58 sustainable indicators, the authors assessed the regional sustainable transformation of Tehran province by using Factor Analysis and the F'ANP model. The details of this method were presented for the economic dimension, and the same approach was repeated for other dimensions. Table 7 demonstrates tests of the KMOmeasure of sampling adequacy and Bartlett's test of Sphericity for the economic dimension. Factor Analysis was exploited for 10 economic indicators, and it produced three different factors, namely the employment situation, transportation features, and communication properties.

Table 7. Economic indicators KMO and Bartlett tests.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.790
Bartlett's Test of Sphericity	Approx. Chi-Square	262.596
	df	45
	Sig.	0.000

Regarding the factor analysis result, the Analytic Network Process was shaped. Figure 5 demonstrates the network of economic dimension. Different colors in this figure show various factors and their indicators.

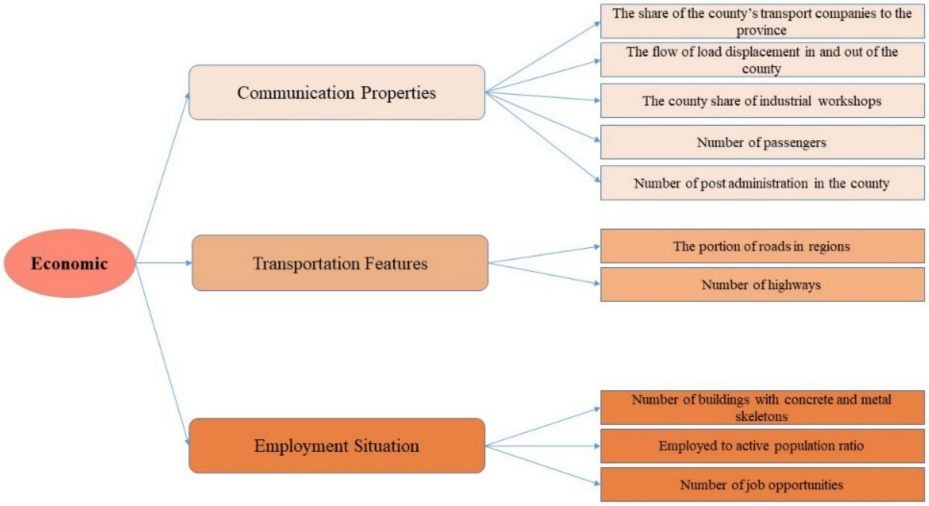

Figure 5. The network of economic dimension.

The Super Matrix was then shaped with the contribution of Analytic Network Process. Figure 6 reveals how the Super Matrix was produced.

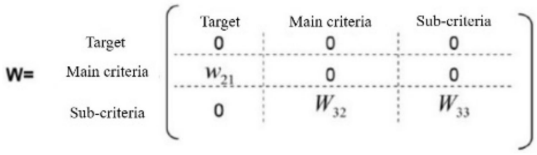

Figure 6. Super Matrix.

The economic Super Matrix would be shaped with the help of the F′ANP model and its limit Super Matrix could be produced by MATLAB software (Figure 7). Table 8 also shows the economic Super Matrix.

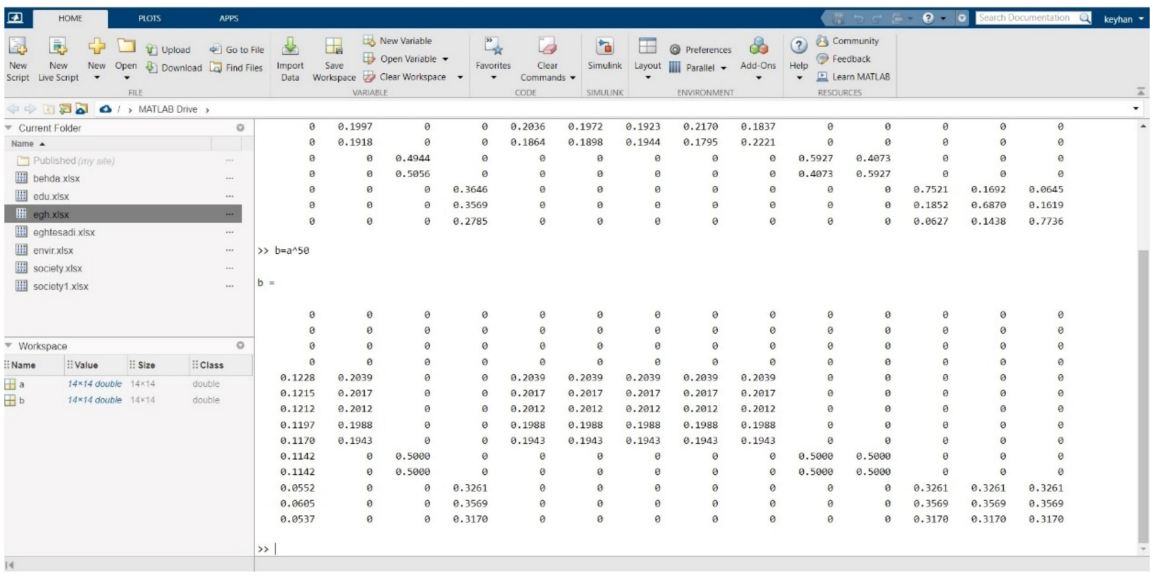

Figure 7. Using MATLAB software for producing the Limit Super Matrix.

Table 8. Economic Super Matrix.

	Goal	F1	F2	F3	Haml	Barbu	Sanat	Jabja	Post	Azadbzr	Kolrah	Flz	Shagh	Work
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haml	0.1228	0.2039	0	0	0.2039	0.2039	0.2039	0.2039	0.2039	0	0	0	0	0
Barbu	0.1215	0.2017	0	0	0.2017	0.2017	0.2017	0.2017	0.2017	0	0	0	0	0
Sanat	0.1212	0.2012	0	0	0.2012	0.2012	0.2012	0.2012	0.2012	0	0	0	0	0
Jabja	0.1197	0.1988	0	0	0.1988	0.1988	0.1988	0.1988	0.1988	0	0	0	0	0
Post	0.117	0.1943	0	0	0.1943	0.1943	0.1943	0.1943	0.1943	0	0	0	0	0
Azadbzr	0.1142	0	0.5	0	0	0	0	0	0	0.5	0.5	0	0	0
Kolrah	0.1142	0	0.5	0	0	0	0	0	0	0.5	0.5	0	0	0
Flz	0.0552	0	0	0.3261	0	0	0	0	0	0	0	0.3261	0.3261	0.3261
Shagh	0.605	0	0	0.3569	0	0	0	0	0	0	0	0.3569	0.3569	0.3569
Work	0.0537	0	0	0.317	0	0	0	0	0	0	0	0.317	0.317	0.317

3. Results

After implementing the F'ANP model, the importance of each of the 58 indicators was evaluated. Subsequently, with the contribution of these indicators, Iran's provinces would be rated in economic, social, and environmental dimensions. Table 9 demonstrates the rating of Iran's provinces based on these dimensions.

Table 9. The rating of Iran's provinces based on environment, economic and social dimensions.

Environment	Fanp Results	Economic	Fanp Results	Social	Fanp Results
Gilan	0.615	Tehran	0.896	Yazd	2.006
Kordestan	0.539	Alborz	0.863	Tehran	1.984
Kermanshah	0.539	Qom	0.777	Semnan	1.800
East Azarbaijan	0.524	Yazd	0.713	Isfahan	1.795
West Azarbaijan	0.498	Markazi	0.637	Mazandaran	1.753
Isfahan	0.473	Isfahan	0.618	Fars	1.747
Khorasan Razavi	0.444	Qazvin	0.600	Alborz	1.729
Hamedan	0.423	West Azarbaijan	0.592	Qazvin	1.687
Lorestan	0.408	Khorasan Razavi	0.569	Markazi	1.659
Khoozestan	0.405	Golestan	0.563	Qom	1.658
Chaharmahal and Bakhtiari	0.392	Semnan	0.552	Hamedan	1.643
Mazandaran	0.384	Hormozgan	0.547	Golestan	1.640
Qazvin	0.374	Khoozestan	0.546	Zanjan	1.633
Ardabil	0.353	Booshehr	0.530	Booshehr	1.616
Markazi	0.337	Fars	0.518	Hormozgan	1.608
Ilam	0.305	Sistan and Baluchestan	0.496	Khorasan Razavi	1.596
Fars	0.299	Mazandaran	0.460	East Azarbaijan	1.560
Tehran	0.294	Zanjan	0.457	Khoozestan	1.551
Kohgiluyeh and Boyer-Ahmad	0.255	Hamedan	0.427	West Azarbaijan	1.550
Kerman	0.253	Kermanshah	0.419	Kerman	1.527
Alborz	0.229	Gilan	0.409	Chaharmahal and Bakhtiari	1.526
Zanjan	0.228	East Azarbaijan	0.407	Gilan	1.486
North Khorasan	0.212	Kerman	0.389	Sistan and Baluchestan	1.473
Sistan and Baluchestan	0.207	South Khorasan	0.365	South Khorasan	1.438
Hormozgan	0.202	Kordestan	0.335	Kermanshah	1.397
Golestan	0.195	Chaharmahal and Bakhtiari	0.320	Kordestan	1.331
Semnan	0.189	Ardabil	0.312	Ardabil	1.314
South Khorasan	0.183	North Khorasan	0.296	North Khorasan	1.264
Qom	0.162	Lorestan	0.287	Ilam	1.227

Table 9. *Cont.*

Environment	Fanp Results	Economic	Fanp Results	Social	Fanp Results
Yazd	0.160	Ilam	0.175	Lorestan	1.101
Booshehr	0.124	Kohgiluyeh and Boyer-Ahmad	0.154	Kohgiluyeh and Boyer-Ahmad	0.899

After assessing all three dimensions, the sustainability of regions was measured. Table 10 shows Iran's provinces rated based on the sustainablity framework.

Table 10. Iran's provinces rating based on the sustainable framework.

Sustainability	Results
Tehran	2.006
Isfahan	1.984
Khorasan Razavi	1.800
Mazandaran	1.795
East Azarbaijan	1.753
Yazd	1.747
Fars	1.729
Gilan	1.687
West Azarbaijan	1.659
Qazvin	1.658
Hamedan	1.643
Markazi	1.640
Khoozestan	1.633
Alborz	1.616
Semnan	1.608
Kermanshah	1.596
Chaharmahal and Bakhtiari	1.560
Kordestan	1.551
Zanjan	1.550
Kerman	1.527
Golestan	1.526
Qom	1.486
Ardabil	1.473
Booshehr	1.438
Hormozgan	1.397
Sistan and Baluchestan	1.331
South Khorasan	1.314
Lorestan	1.264
North Khorasan	1.227
Ilam	1.101
Kohgiluyeh and Boyer-Ahmad	0.899

The results show that Tehran Province is the development pole of the country. The difference between this province with other regions demonstrates that there is huge centralization of socioeconomic facilities in Tehran. This study shows that there is no social justice or spatial equilibrium in Iran, and as it is clear from Figure 8, all the border provinces with the exception of Khorasan Razavi and West Azarbaijan are suffering from unsustainable situations. Moreover, those provinces with higher industrial and tourism potentials absorb more facilities in their regions. Regarding the distribution of unsustainable provinces, it is evident that most of these regions are concentrated in the east of the country, and it appears the trend of regional inequality will be exacerbated in the future.

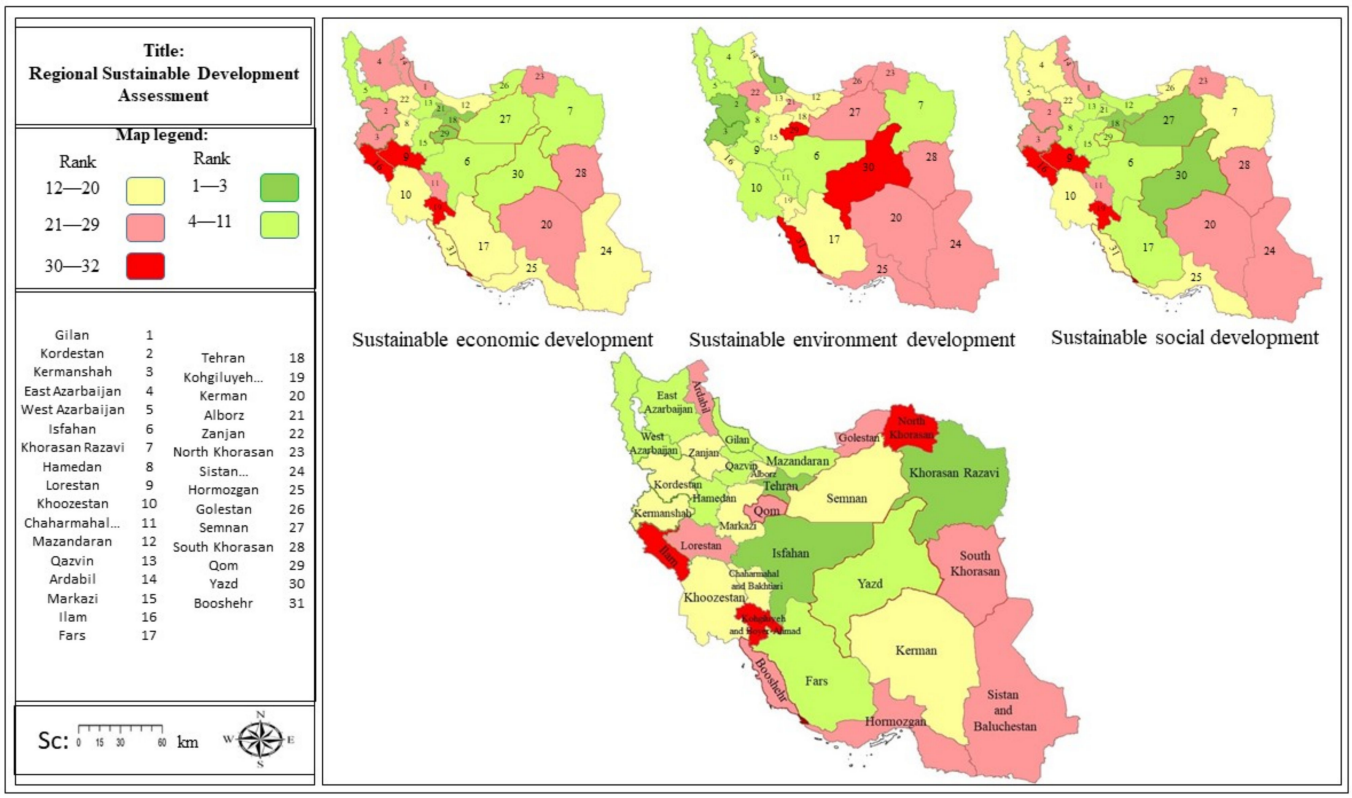

Figure 8. Regional Sustainable Development Assessment.

Tehran is the capital of Iran, and it is the concentration of many pivotal facilities. This focus has altered the development pattern in Iran which results in more unsustainable development. The regional inequality encourages migration to this province, and over two million Tehran residents live in informal settlements. Although the upshots of the F'ANP model present Tehran as the most sustainable province, the authors want to evaluate the sustainability transitions in this significant area. Having said that, this study aims to assess regional sustainable development upheavals of Tehran province from 2006 to 2016 to clarify development patterns within this region.

After implementing the F'ANP model for Tehran's counties, the importance of sustainable development indicators was cleared. Table 11 shows the importance of economic indicators in this assessment. Upheavals of sustainability in this region are shown in Table 12, and Figure 9 demonstrates the economic sustainability of Tehran's counties during a decade.

Table 11. The importance of economic indicators.

Indicators	Importance of Indicators
The share of the county's transport companies to the province	0.1228
The flow of load displacement in and out of the county	0.1215
The county's share of industrial workshops	0.1212
Number of passengers and holiday-makers	0.1197
Number of post administration in the county	0.1170
Number of highways	0.1142
The portion of roads in regions	0.1142
Number of building with concrete and metal skeleton	0.0552
Employed to active population ratio	0.0605
Number of job opportunities	0.0537

Table 12. The rating of Tehran Province counties according to economic development.

Legend	2006		2011		2016	
	County	FANP Result	County	FANP Result	County	FANP Result
0 Unsustainable	Tehran	0.724	Tehran	0.811	Tehran	0.886
0.1	Karaj	0.353	Rey	0.401	Rey	0.386
0.2 Underdeveloped	Rey	0.347	Damavand	0.305	Firuzkuh	0.359
0.3 Middle-range	Damavand	0.293	Pakdasht	0.215	Damavand	0.308
0.4 Relatively developed	Pakdasht	0.208	Shahriar	0.209	Varamin	0.254
0.5	Shahriar	0.206	Robat Karim	0.188	Eslamshahr	0.227
0.6 The most sustainable	Robat Karim	0.183	Firuzkuh	0.184	Pakdasht	0.224
	Savojbolagh	0.18	Shemiranat	0.176	Shahriar	0.216
	Varamin	0.176	Varamin	0.175	Malard	0.208
	Shemiranat	0.148	Baharestan	0.114	Pardis	0.197
	Firuzkuh	0.147	Eslamshahr	0.113	Baharestan	0.196
	Eslamshahr	0.141	Pishva	0.092	Robat Karim	0.189
	Nazar Abad	0.036	Malard	0.091	Pishva	0.151
			Ghods	0.058	Qarchak	0.138
					Shemiranat	0.137
					Ghods	0.087

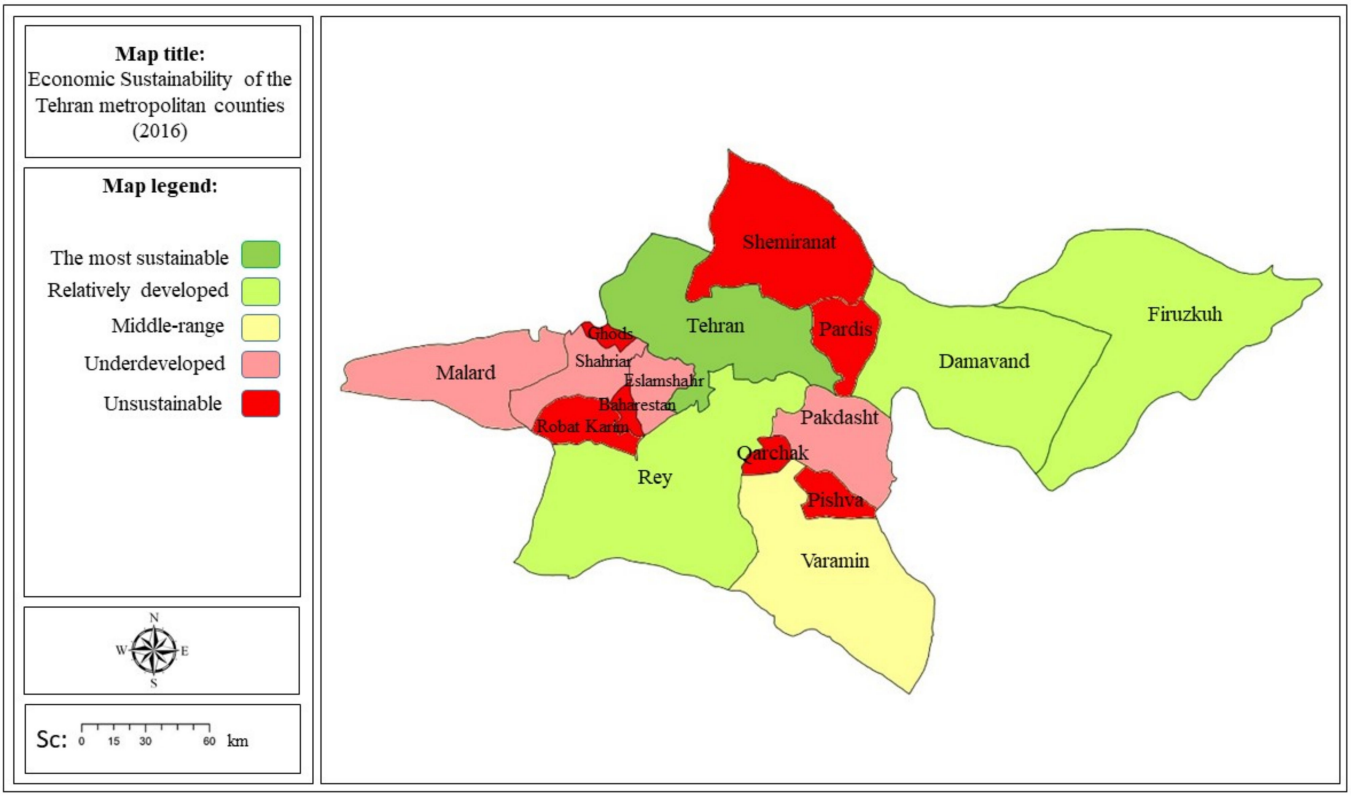

Figure 9. Economic sustainability of the Tehran Province (2016).

The weighted indicators were used to rate the counties of the Tehran provinces in 2006, 2011, and 2016. This process was then continued for social and environmental dimensions to clarify the transformations of sustainable development in Tehran province. The social dimension includes four sections, namely health, education, social, and infrastructure

services. Factor analysis was used for evaluating the importance of indicators in these sections. All these sections have acceptable significant rates, and their KMO are 0.631, 0.606, 0.659, and 0.624 for education, health, infrastructure, and social service, respectively. The factors for these sections are shown in Table 13.

Table 13. Education, health, infrastructure, and social service factors.

Education	Health	Infrastructure	Social Service
F1—Accessibility to education infrastructure F2—Accessibility to education services F3—Accessibility to basic education centers F4—Cultural features F5—Educational capacities	F1—Health infrastructure F2—Accessibility of health care centers F3—Access to medical experts	F1—Social service properties F2—Access to electric and gas infrastructures F3—Energy consumption and waste production F4—Access to environmental infrastructure F5—Infrastructure properties	F1—Support services F2—The properties of the welfare organization F3—Access to social services F4—The infrastructure of support agencies

In the following stage, the ANP model was shaped with the help of these factors, and the super matrix of social dimension was also shaped. Similar to the economic dimension, MATLAB was exploited to recognize the significance of each social indicator. After identifying the importance of each indicator, the rating for the social dimension was measured by gathering the F'ANP points from the education, health, infrastructure, and social service sections. Table 14 illustrates the rating of Tehran Province counties according to social development. Also, Figure 10 shows the social stability of Tehran's counties in 2016.

Table 14. The rating of Tehran Province counties according to social development.

Legend	2006		2011		2016	
0 Unsustainable 0.1 0.2 Underdeveloped 0.3 Middle-range Relatively developed 0.4 0.5 0.6 The most sustainable	**County**	**FANP Result**	**County**	**FANP Result**	**County**	**FANP Result**
	Shemiranat	0.448	Tehran	0.48	Tehran	0.499
	Tehran	0.396	Shemiranat	0.377	Shemiranat	0.384
	Damavand	0.31	Damavand	0.375	Rey	0.358
	Damavand	0.227	Firuzkuh	0.335	Firuzkuh	0.325
	Karaj	0.188	Rey	0.273	Damavand	0.31
	Shahriar	0.187	Pishva	0.234	Pishva	0.265
	Savojbolagh	0.183	Pakdasht	0.229	Pardis	0.249
	Varamin	0.178	Varamin	0.209	Ghods	0.241
	Rey	0.173	Robat Karim	0.204	Varamin	0.212
	Firuzkuh	0.165	Eslamshahr	0.176	Pakdasht	0.211
	Pakdasht	0.147	Shahriar	0.173	Shahriar	0.191
	Nazar Abad	0.14	Malard	0.135	Robat Karim	0.178
	Robat Karim	0.136	Ghods	0.093	Eslamshahr	0.175
			Baharestan	0.085	Qarchak	0.161
					Malard	0.158
					Baharestan	0.104

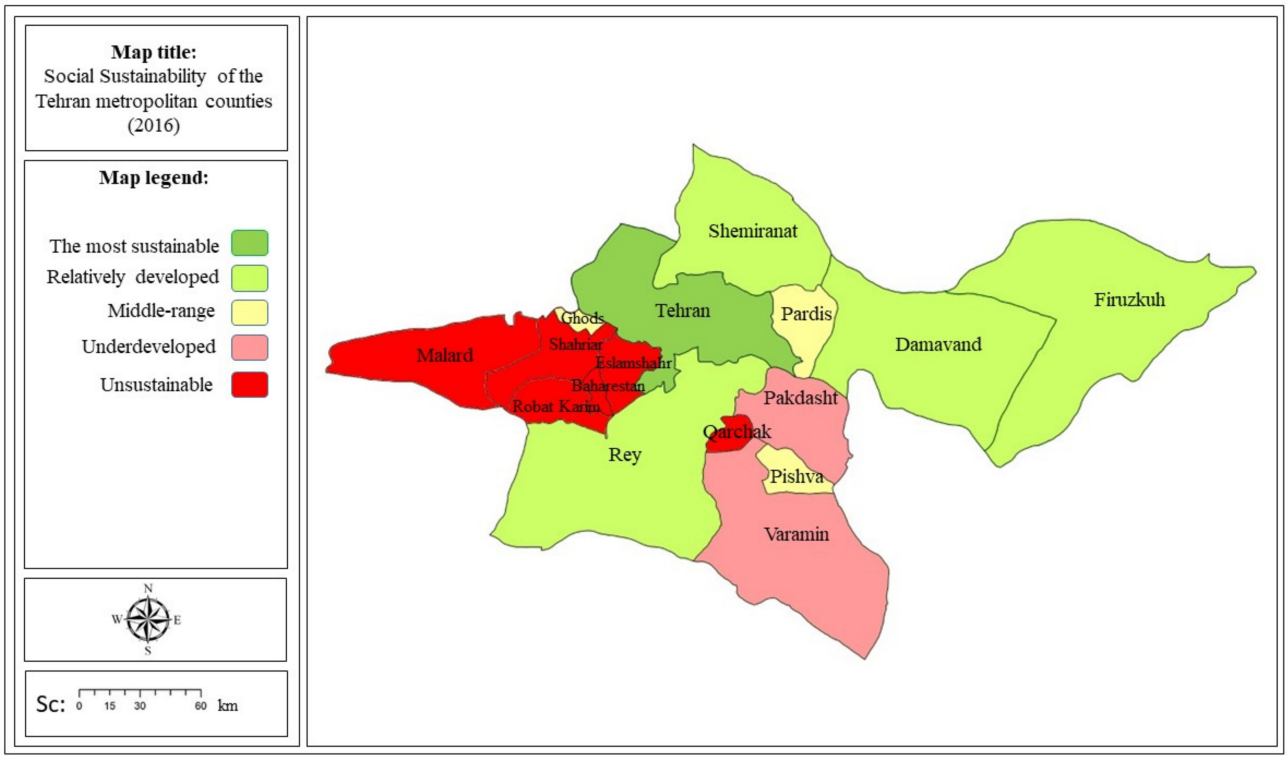

Figure 10. Social sustainability of the Tehran Province (2016).

Factor analysis was used to produce environmental factors as in previous dimensions. Sustainable environmental development has an acceptable significant rate, and its KMO is 0.621. Agricultural production capacities, access to good gardening capacities, access to urban green spaces, and environmental infrastructure status are four factors of this dimension. Similar to economic and social domains, the ANP model was shaped by the contribution of these four factors, and the super matrix of the environmental dimension was shaped. The importance of each environmental indicator was identified by MATLAB which is shown in Table 15. In Table 16 and Figure 11 the environmental sustainability of Tehran counties is shown.

Table 15. The importance of environmental indicators.

Environment	
The proportion of forest lands to the area of the province	0.0509
Range of land area to county area	0.1738
County's share of the number of frosty days	0.1550
County's share of sunny hours	0.1171
County's share of public parks	0.0481
Green space per capita	0.0462
The proportion of agricultural lands to the area of the province	0.1593
The proportion of farmlands to the area of the province	0.0662
The proportion of garden lands to the area of the province	0.1171
County's share of greenhouse area	0.0662

Table 16. The rating of Tehran province counties according to environment development.

Legend	2006		2011		2016	
	County	FANP Result	County	FANP Result	County	FANP Result
0 Unsustainable	Shahriar	0.583	Firuzkuh	0.495	Firuzkuh	0.483
0.1	Eslamshahr	0.329	Damavand	0.463	Damavand	0.475
0.2 Underdeveloped	Rey	0.394	Varamin	0.437	Robat Karim	0.405
0.3 Middle-range	Varamin	0.385	Pishva	0.43	Shemiranat	0.368
Relatively developed	Damavand	0.377	Malard	0.403	Tehran	0.357
0.4	Pakdasht	0.338	Shahriar	0.393	Malard	0.345
0.5	Tehran	0.326	Pakdasht	0.335	Varamin	0.345
0.6 The most sustainable	Firuzkuh	0.316	Tehran	0.312	Pishva	0.34
	Robat Karim	0.291	Rey Karim	0.297	Rey	0.335
	Nazar Abad	0.283	Shemiranat	0.276	Qarchak	0.281
	Shemiranat	0.2	Ghods	0.271	Pardis	0.279
	Savojbolagh	0.189	Eslamshahr	0.271	Pakdasht	0.261
	Karaj	0.102	Robat Karim	0.269	Eslamshahr	0.221
			Baharestan	0.234	Shahriar	0.208
					Baharestan	0.204
					Ghods	0.2

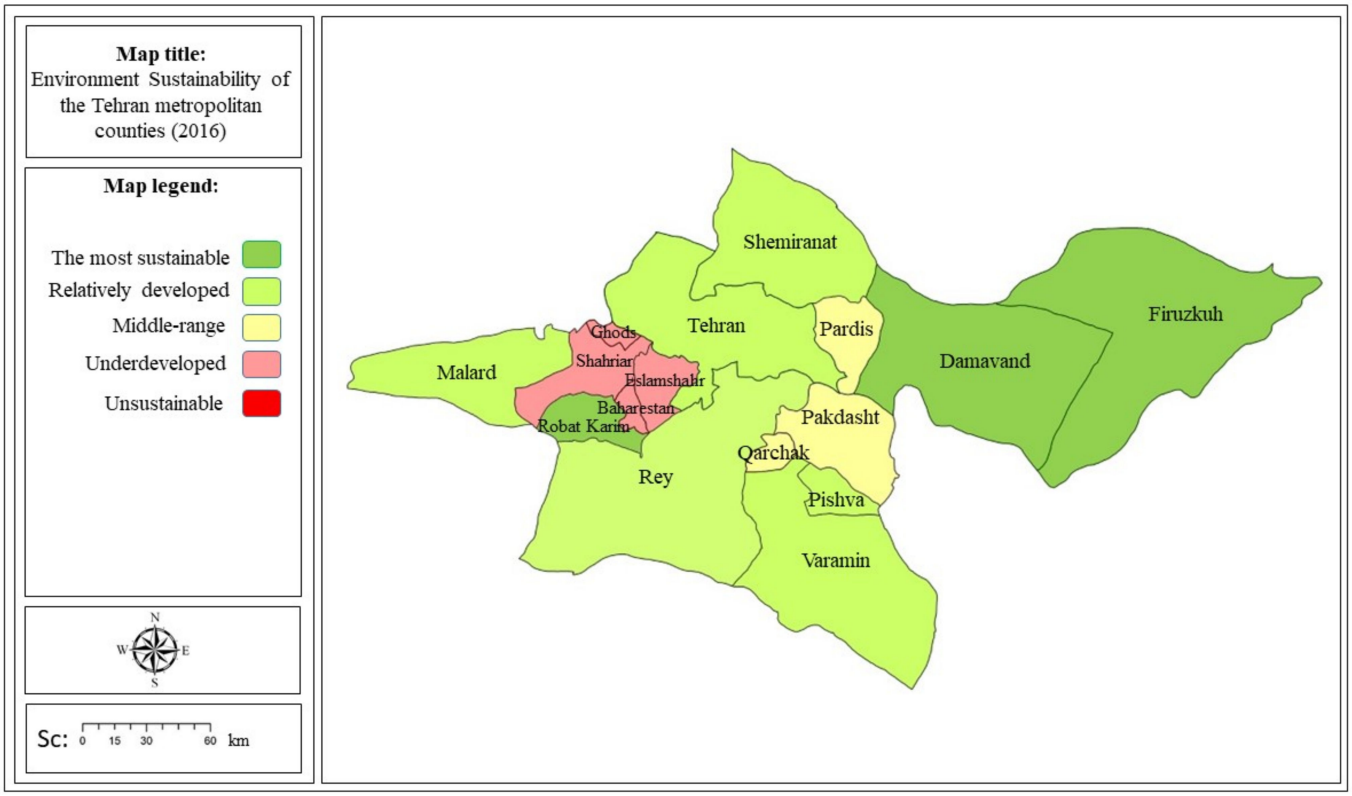

Figure 11. Environment sustainability of the Tehran province (2016).

4. Discussion and Conclusions

Evaluation of sustainability at differing geographical scales became imperative in view of the development circumstances in Iran, generally. While many earlier studies have focused on comparative research of sustainable development in various regions, there is a gap in evaluating the sustainability of urban areas on different scales and over

time. This study aims to fill this gap in achieving SDG11. In this research, 31 provinces of Iran were assessed based on 58 sustainable development indicators, and 16 counties in Tehran Province were evaluated over a decade based on a proposed framework, containing 60 different economic, social, and environmental indicators. It is worth mentioning that, due to data limitations, some of the selected indicators for each assessment are different from one another. Although 41% of Iran's assessment indicators and 28% of Tehran's assessment are identical, there are some differences in their indicators based on availability of data for those indicators. Having said that, the authors endeavored to choose the most similar indicators for both assessments.

The results of this study illustrate that there are various socioeconomic inequalities and also environmental injustice challenges that undermine the level of sustainability achieved in Iran. Table 17 demonstrates the ranking of Tehran Province counties based on the sustainable development indicators. Results from the F'ANP model illustrate the level of sustainability in the regions. Tehran's regions would be the most sustainable if their results were greater than 0.4. Being between 0.3 and 0.4 shows that the region is relatively developed. Middle range regions have scores between 0.23 and 0.3. The results of underdeveloped regions are between 0.2 and 0.23, and the scores of unsustainable regions are below 0.2. Tehran County has been ranked first over a period due to the dominant focus of facilities in this region. After Tehran, Firuzkuh and Damavand counties were in the next ranks and Qarchak, Ghods, and Baharestan counties were the weakest based on the sustainable development indicators. Moreover, Table 18 reveals the sustainable development transition of these counties from 2006 to 2016. Also, Figure 12 shows the urban sustainability of Tehran's counties in 2016. In general, it can be noted that Tehran County had better conditions than its counterparts due to its existing capacities and being the capital of Iran. Furthermore, most of the youngest counties were among the worst in terms of the sustainablity indicators.

This study developed a robust methodology that can be applied in various regions and at different scales for future directions of this research.

Table 17. The sustainable development transitions of Tehran Province.

Legend	2006		2011		2016	
	County	**FANP Result**	**County**	**FANP Result**	**County**	**FANP Result**
0 Unsustainable	Tehran	0.482	Tehran	0.534	Tehran	0.58
0.1	Shahriar	0.339	Firuzkuh	0.381	Firuzkuh	0.389
	Damavand	0.327	Damavand	0.338	Damavand	0.364
	Rey	0.305	Rey	0.324	Rey	0.36
0.2	Shemiranat	0.265	Shemiranat	0.276	Shemiranat	0.297
Underdeveloped	Varamin	0.246	Varamin	0.274	Varamin	0.27
	Pakdasht	0.231	Robat Karim	0.26	Robat Karim	0.257
0.3 Middle-range	Eslamshahr	0.219	Pishva	0.258	Pishva	0.252
Relatively developed	Karaj	0.214	Pardis	0.252	Pardis	0.242
0.4	Firuzkuh	0.209	Malard	0.22	Malard	0.237
	Robat Karim	0.203	Pakdasht	0.21	Pakdasht	0.232
0.5	Savojbolagh	0.184	Eslamshahr	0.186	Eslamshahr	0.207
	Nazar Abad	0.153	Shahriar	0.144	Shahriar	0.205
0.6 The most sustainable			Ghods	0.141	Qarchak	0.193
					Ghods	0.176
					Baharestan	0.168

Table 18. Sustainability transition of counties of Tehran Province.

Sustainability Transition	
County	**Trend**
Tehran	⇧
Firuzkuh	⇧
Damavand	⇧
Rey	⇧
Shemiranat	⇧
Varamin	⇨
Robat Karim	⇧
Pishva	⇨
Pardis	⇨
Malard	⇨
Pakdasht	⇩
Eslamshahr	⇩
Shahriar	⇩
Qarchak	⇩
Ghods	⇨
Baharestan	⇨
Legend	
⇧	Progression in sustainability
⇨	Stay untouched
⇩	Regression in sustainability

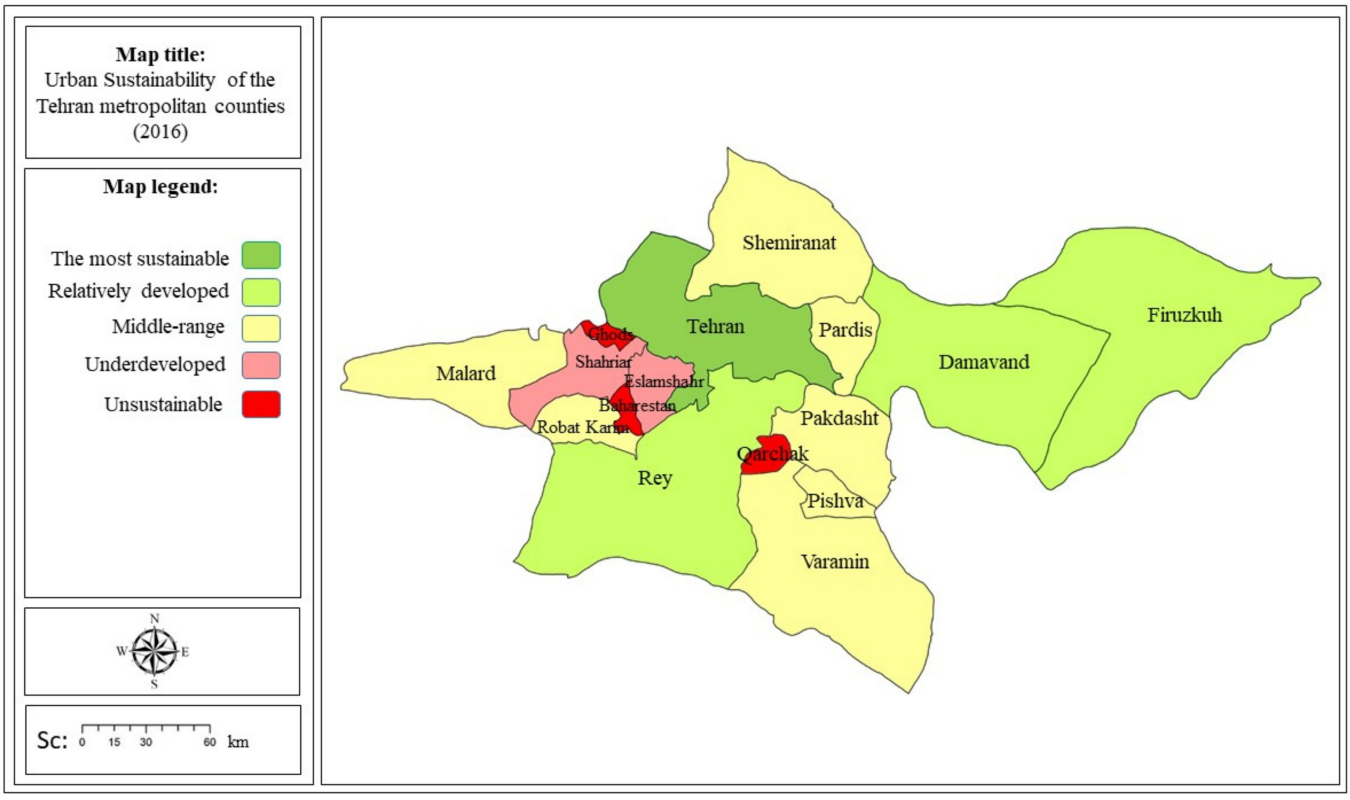

Figure 12. Urban sustainability of the Tehran Province (2016).

Guidelines and Policies to Promote Sustainability in Tehran Province

Regarding the perspective of sustainable development and achieving SDG11, the ultimate goal is reaching spatial equilibrium, equitable planning, and considering ecological capability in this region. These aims follow regional integration that leads to the improvement of sustainability. To reach sustainable development in Tehran Province, the authors anticipate prevention or mitigation strategies and action plans to prioritize areas where the sustainability level is decreasing or where this level remained low over time. That is, eight different strategies are presented in regional development, spatial equilibrium, economic prosperity, and conservation of natural resources categories. Figure 13 illustrates the strategic planning of regional sustainable development in Tehran Province. Different colors in this Figure demonstrate how various projects are related to their categories.

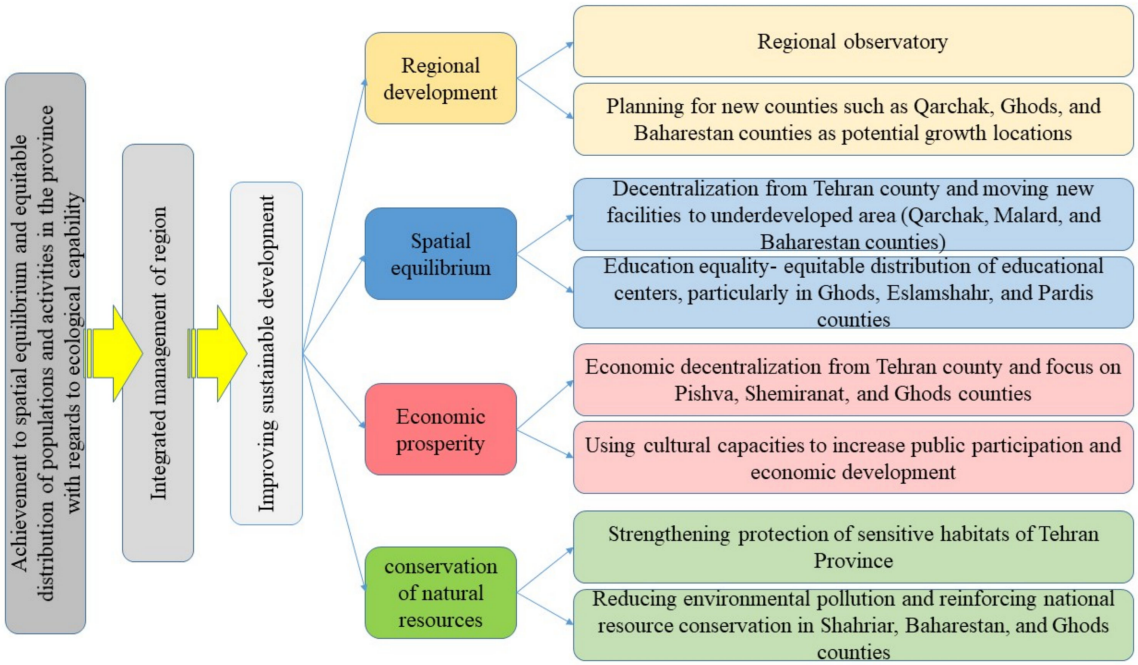

Figure 13. Strategic planning of regional sustainable development of Tehran Province.

These presented projects were then prioritized with the help of Super Decision software by considering four different criteria such as the costs of projects, time of the projects, theoretical approach realization, and reaching sustainable development goals. Figure 14 shows the hierarchical analysis structure of presented projects. Different colors of arrows demonstrate the relations among criteria and projects. Following this figure, Figure 15 illustrates the priority of projects after implementing the model.

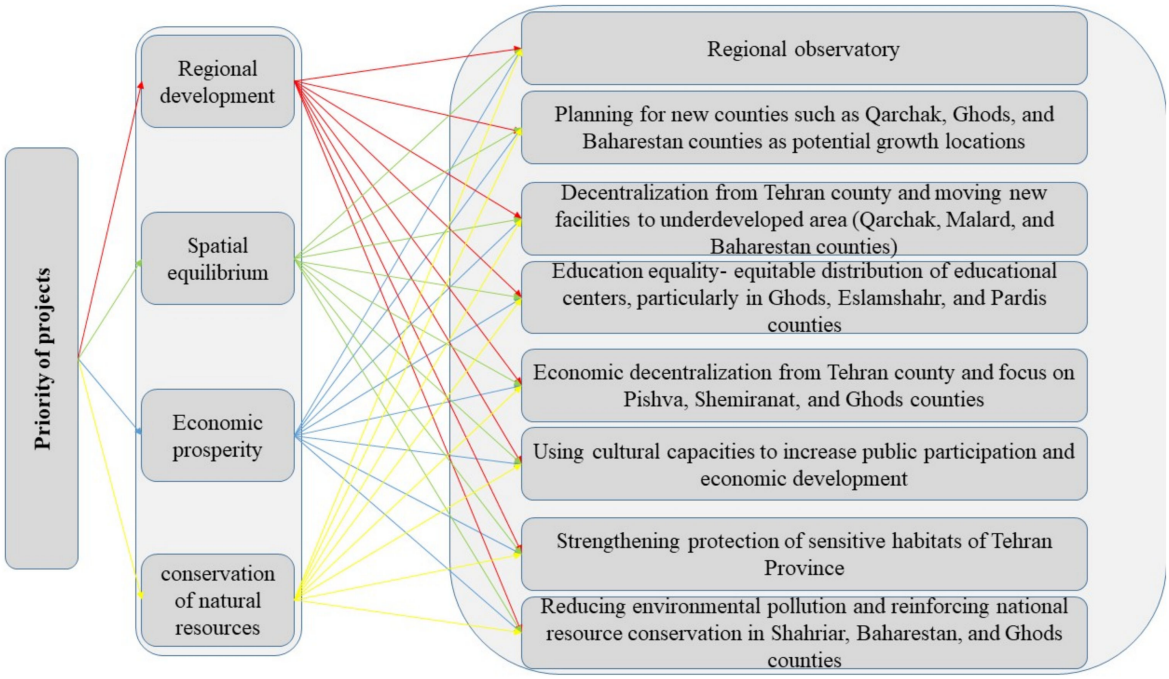

Figure 14. Hierarchical analysis structure of projects priority.

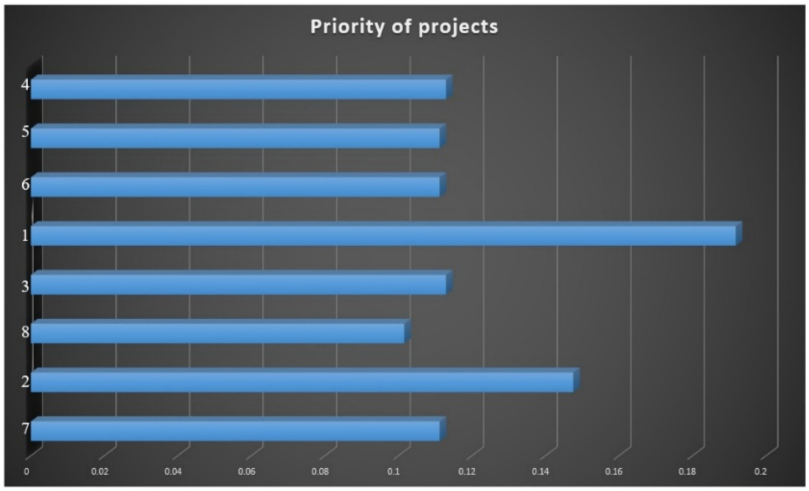

Figure 15. Priority of projects.

1. Regional observatory;
2. Planning for new counties such as Qarchak, Ghods, and Baharestan counties as potential growth locations;
3. Reducing environmental pollution and reinforcing national resource conservation in Shahriar, Baharestan, and Ghods counties;
4. Economic decentralization from Tehran County and focus on Pishva, Shemiranat, and Ghods counties;
5. Decentralization from Tehran County and moving new facilities to underdeveloped areas (Qarchak, Malard, and Baharestan counties);
6. Strengthening the protection of sensitive habitats of Tehran Province;
7. Using cultural capacities to increase public participation and economic development;
8. Education equality—equitable distribution of educational centers, particularly in Ghods, Eslamshahr, and Pardis counties.

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