THE ANALYTIC HIERARCHY PROCESS (AHP) APPROACH FOR ASSESSMENT OF REGIONAL ENVIRONMENTAL SUSTAINABILITY

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ID NO

ID # 226

Keywords:
Turkey, NUTS 2 regions, NUTS 3 regions, sub-regions, provinces.

ABSTRACT

Environment has had a relatively low priority in Turkey. Environmental concerns have been too often superseded by development interest in local decision-making. Strengthened environmental efforts from national government, provincial authorities, and municipalities are required to achieve environmental convergence with the European Union. Despite progress in providing environmental statistics and indicators, the need for integrated studies on environmental sustainability both national and sub-national levels is still urgent. The objective of this study is to measure and compare environmental sustainability at sub-national level by using AHP. The proposed model is implemented both the selected sub-regions (NUTS 2 level) and their provinces (NUTS 3 level). In the analysis, SuperDecisions software v.2.2.1 is used and two alternative groups are evaluated according to eleven criteria namely, population density, energy consumption, green area, land use, total disposal, non-treated wastewater, water consumption, number of cars, traffic accidents, SO_2 and PM_{10} emissions. The results indicate that at NUTS 2 level, İstanbul (TR10) the largest city in Turkey with 18% of total population and also one of the most populated cities in Europe is ranked (0.267133) first out of five. İstanbul is followed by regions TR42 Kocaeli, Sakarya, Düzce, Bolu, Yalova (0.189030) and TR41 Bursa, Eskişehir, Bilecik (0.186964) while TR21 Tekirdağ, Edirne, Kırklareli (0.170595) is rated as the least environmentally sustainable region. On the other hand, at NUTS 3 level TR424 Bolu has the highest ranking (0.132935), followed by TR412 Eskişehir (0.121052) and TR413 Bilecik (0.088625). The least environmentally sustainable provinces are TR211 Tekirdağ (0.046646) and TR421Kocaeli (0.037254), respectively. TR100 İstanbul (0.051545) is ranked 11th out of 14.

1. INTRODUCTION

A meaningful assessment of sustainable development encounters problems regarding the determination of appropriate scale of analysis. There is a vast range of studies which deals measuring and evaluating sustainable development and but most of them use global or national levels as units of analysis. However, several authors argue that measuring sustainable development at the national level or with national-level data might fail to capture critical issues at the regional level [1-3]. Indeed, in recent years regional sustainability assessment initiatives have flourished throughout the world [4]. However, their geographic scope lies between the country/state level, and the local level of cities, towns and other local communities [5]. Consequently, the question of what is the appropriate unit of analysis for regional sustainability assessment stands as a major problem [6, 7].

In European Union (EU), NUTS (nomenclature of territorial units for statistics) geographic areas classification has been introduced in order to collect and publish of standardised regional statistic information which can be used for socio-economic analysis for regions but also as a framework for

EU regional policies [8, 9]. Apart from the national level, territorial units on the level of NUTS 2 and eventually NUTS 3 are within the EU usually recognized as the basic cells for regional policy.

In 2002, Turkey established NUTS to both to comply with the EU Regional Policies and to use the pre-accession financial supports for regional development. Previous regional classification consisted of seven regions was introduced in 1950s. However, there were no governance institutions at the level of the seven regions given that Turkey's administrative hierarchy has consisted of provinces, counties, towns and villages [10]. Since the participation to the NUTS classification geographical statistical units have lost their relevance.

The objective of this study is to measure and compare environmental sustainability at different spatial scales. With this aim, an Analytical Hierarchy Process (AHP) model proposed since AHP is an efficient tool for integrating indicators with different units of measurement. The proposed AHP model is implemented to İstanbul, West Marmara and East Marmara regions and also their provinces.

2. SELECTION OF SAMPLE REGIONS

12 NUTS 1 units, 26 NUTS 2 units and 81 NUTS 3 units are defined under NUTS classification for Turkey, according to the sizes of population by regarding to social, economical, geographical factors. NUTS 3 level correspond to 81 provinces. The new classification groups the 81 provinces into 26 NUTS 2 clusters. The only exception to this is İstanbul. It is classified as province and region at all NUTS levels due to its characteristics. Visual representation of NUTS 2 and NUTS 3 regions in Turkey can be found in Fig. 1 and Fig. 2.

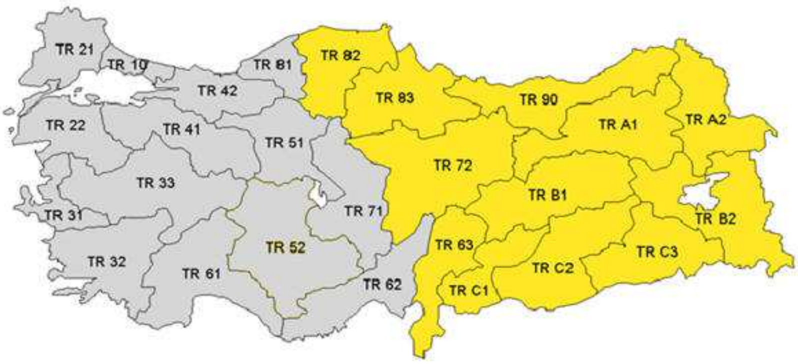

Fig. 1. NUTS level 2 regions in Turkey

Fig. 2. NUTS level 3 regions in Turkey

In order to compare similar regions, we consider geographical and economical factors together. In this study sub-regions of West Marmara, East Marmara and İstanbul are chosen to analyse their environmental sustainability performance. All those regions are located in the north-western part of the country and characterised by extremely rapid growth. Thus, they are the most industrialised and highly polluted areas in Turkey. Given that there are important linkages among these areas they represent a meaningful sample. The list of the selected regions and their key economic indicators are given in Table 1 and Table 2, respectively [11, 12].

Table 1. The selected regions.

NUTS 1 (regions)	**NUTS 2 (sub-regions)**	**NUTS 3 (provinces)**
TR1 İstanbul	TR10 İstanbul	TR100 İstanbul
TR2 West Marmara	TR21Tekirdağ, Edirne, Kırklareli	TR211 Tekirdağ TR212 Edirne TR213 Kırklareli
TR2 West Marmara	TR22 Balıkesir, Çanakkale	TR221 Balıkesir TR222 Çanakkale
TR4 East Marmara	TR41 Bursa, Eskişehir, Bilecik	TR411 Bursa, TR412 Eskişehir TR413 Bilecik
TR4 East Marmara	TR42 Kocaeli, Sakarya, Düzce, Bolu, Yalova	TR421 Kocaeli TR422 Sakarya TR423 Düzce TR424 Bolu TR425 Yalova

Table 2. Basic indicators of the selected regions.

Regions (NUTS 2 level)	**Population (2011)**	**Employment (2011)**	**Labour Force (2011)**	**GVA per capita (2008 TL)**
TR10 İstanbul	13624240	4211000	4773000	18689
TR21Tekirdağ, Edirne, Kırklareli	1569388	632000	693000	15682
TR22 Balıkesir, Çanakkale	1640759	575000	607000	11528
TR41 Bursa, Eskişehir, Bilecik	3637222	1237000	1339000	16630
TR42 Kocaeli, Sakarya, Düzce, Bolu, Yalova	3315463	1210000	1373000	16990
Turkey	74724269	24110000	26725000	12020

Sample regions have 32% of total population and contribute significantly to national economy. In 2008, while the national level of gross value added (GVA) per capita was 12020 TL, the average GVA per capita of the sample was 15903 TL. The selected regions have an exceptionally high proportion of labour force and employment, 33% for both indicators, around one third of the country, by the end of 2011.

Of these regions, İstanbul deserves further attention as the centre of both country and the Marmara region. Although, this mega-city is not functionally integrated has high economic interdependencies with Tekirdağ, Kocaeli, Yalova, Bursa and Sakarya. İstanbul has been ranking eighth out of 78 OECD metro-regions in terms of population size and first for population growth since the mid-1990s [10]. It is argued that over-concentration in İstanbul has reached its sustainable limit, necessitating a national strategy for managing future. Rapid urbanisation growth and a large influx of domestic and foreign migrants to İstanbul in a relatively short period of time have raised major development issues threatening its social and environmental sustainability.

3. METHODOLOGY

It is important for policymakers to set their policies with data-driven approaches. Here the major problem lies behind complexity of sustainability concept. Thus, as an initial step, current situations of the selected areas have to be identified and discussed with one value with the help of data sets. Although there are various sustainability assessment methodologies, models and tools developed so far, the certain characteristics of the Analytic Hierarchy Process (AHP) make it useful tool for environmental sustainability assessment and decision-making [13].

In environmental performance studies field, AHP has been widely employed such as; environmental impact assessment [14], environmental quality indexing [15], environmental vulnerability assessment [16], energy resources allocation [17], environmental impacts of manufacturing [18], landfill site selection problem [19], land use pattern [20], and resource allocation of agricultural activities [21]. In literature, there are also some examples of AHP applications on urban sustainability [22, 23].

AHP decomposes the complexity in the form of a simple hierarchy, descending from overall goal to criteria, sub-criteria (if exist) and alternatives (see Fig. 3); allocates relative weights of criteria and sub-criteria to compare the alternatives.

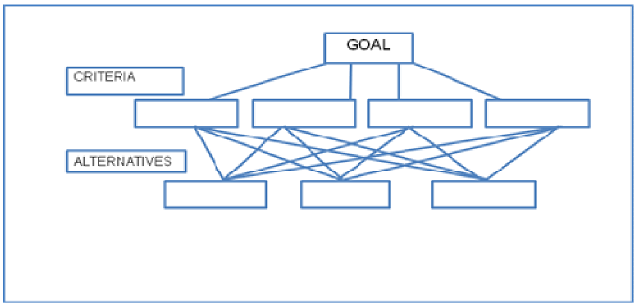

Fig. 3. Graphic representation of AHP

The basic principles of AHP can be summarized as defining and determining the problem; decomposing the problem in a hierarchy from top through the intermediate levels; constructing a set of pair-wise comparison matrices; testing the consistency index; synthesizing the hierarchy to find out the ranks of the alternatives [24]. AHP makes use of pair-wise comparisons to simplify the judgment process with 1-9 ratio scaling [25] (see Table 3).

Table 3. The pairwise comparison scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8		Intermediate values

When it is assumed (A_1, A_2,…A_n) is any set of n elements than a sample of square matrix can be produced as below by pair wise comparisons of each element. Here, each (A_i, A_j) judgment represented as "a_{ij}". Because a_{ii}=1 for all *i* diagonal of the matrix contains entries of 1.

$$\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{pmatrix} \tag{1}$$

When (w_1, w_2,…,w_n) are the elements corresponding weights; the dominance of an element in the row over the element in the column represented as w_i/w_j . AHP method compares the related weights of each element in a set with respect to the goal. The general form of comparison matrix of AHP is given as follows;

$$A = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_n} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \tag{2}$$

Than the problem turns in to general process to calculating the largest eigenvalue corresponding to eigenvector to assess the Consistency Index (C.I.) where *A* is the matrix, *x* is the eigenvector and λ is the eigenvalue. When we divide C.I. by the random consistency number the final value must be less than 0.10 [26].

$$Ax = \lambda x \tag{3}$$

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \tag{4}$$

4. BUILDING THE AHP MODELS

In order to assess environmental sustainability at different spatial scales, two hierarchy trees, in other words two models are developed. The only difference between Model A and Model B is the sample or in AHP terms the alternatives. Although both models cover the same geographical area, Model A focuses sub-regions while Model B deals with the provinces of these sub-regions. This means that the alternatives of Model A are at NUTS 2 level and Model B's alternatives are at NUTS 3 level. As a result Model A consists of 5 alternatives and Model B has 14 alternatives.

The elements of the hierarchies for each model are presented in Table 4. At the top of the control hierarchy for both models, there exists the goal of the problem. The goal is to measure the environmental sustainability of the alternatives and compare their environmental performances. The selection of criteria is based on the urban environmental sustainability indicators determined by Markandya and Dale [27]. The 11 urban environmental indicators out of 15 are employed for the analyses. 4 indicators are eliminated due to data limitations and also difficulties in adapting them to Turkey's urban concept. SO_2 (ųg /m^3), PM_{10} (ųg /m^3), total disposal (kg per capita/year), non-treated wastewater (litre per capita/day), energy consumption (toe), water consumption (1000 m^3 per capita), population density (population per km^2), number of cars (car per 1000 capita), traffic accidents (victims per million cars), land use (m^2), and green area (ha per inhabitants capita) are the eleven criteria and they are presented in the second levels of the hierarchies. For both models, the criteria clusters are connected to the goal and equal weights are assigned for the second levels of the hierarchies.

All data have been drawn from TURKSTAT database. However the availability of the data has restricted the time scope of the study with the year 2008. The analysis has been performed by SuperDecisions v.2.2.1 software.

Table 4. Hierarchy elements for the models.

Models	Goal	Criteria	Alternatives
Model A	Environmental Sustainability	SO_2 PM_{10} Total disposal Non-treated wastewater Energy consumption Water consumption Population density Number of cars Traffic accidents with victims Land use Inhabitants per green area	Sub-regions: TR10, TR21, TR22 TR41, TR42
Model B			Provinces: TR100, TR211, TR212, TR213, TR221, TR222, TR411, TR412, TR413, TR421, TR422, TR423, TR424, TR425

5. RESULTS AND DISCUSSION

After constructing hierarchy trees, the same process was applied both for Model A and Model B. The data was normalised by dividing each entry by the total. Than the criteria were pair-wise compared and computed via SuperDecisions v.2.2.1. Since the consistency ratios were less than 0.10, the pair wise comparison matrixes were accepted as consistent. The results of the models are summarised below.

5.1. Model A

According to the results of Model A, TR10 İstanbul is the most environmentally sustainable region (0.267133) at NUTS 2 level, followed by TR42 (0.189030) and TR41 (0.186964). TR21 (0.170595) is rated as the least environmentally sustainable region among the alternatives (see Table 5 and Fig. 4).

Table 5. Results of the Model A.

Alternatives	Ideals	Normals	Raw
TR10 İstanbul	1.000000	0.267133	0.133567
TR21 Tekirdağ, Edirne, Kırklareli	0.638616	0.170595	0.085298
TR22 Balıkesir, Çanakkale	0.697322	0.186278	0.093139
TR41 Bursa, Eskişehir, Bilecik	0.699889	0.186964	0.093482
TR42 Kocaeli, Sakarya, Düzce, Bolu, Yalova	0.707624	0.189030	0.094515

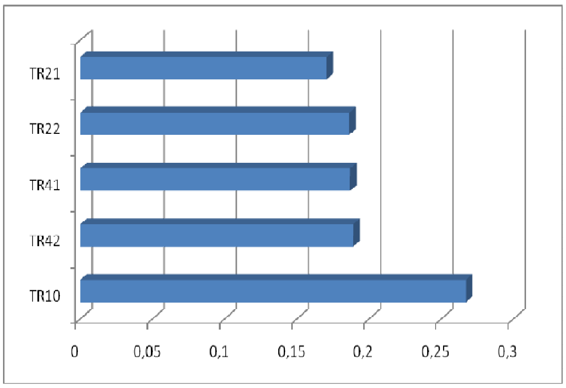

Fig. 4. Graphical results of Model A

5.2. Model B

According to the environmental sustainability ranking based on the results from Model B, TR424 Bolu is the best performer (0.132935), followed by TR412 Eskişehir (0.121052) and TR413 Bilecik (0.088625). TR100 İstanbul and its surrounding provinces (TR421 Kocaeli, TR211 Tekirdağ, TR411 Bursa, TR422 Sakarya and TR425 Yalova) are ranked as the least sustainable provinces. The results are presented in Table 5 and Fig. 5.

Table 5. Results of the Model B.

Alternatives	Ideals	Normals	Raw
TR100 İstanbul	0.387743	0.051545	0.025772
TR211 Tekirdağ	0.350890	0.046646	0.023323
TR212 Edirne	0.510647	0.067883	0.033941
TR213 Kırklareli	0.654465	0.087001	0.043501
TR221 Balıkesir	0.493155	0.065557	0.032779
TR222 Çanakkale	0.539147	0.071671	0.035836
TR411 Bursa	0.370406	0.049240	0.024620
TR412 Eskişehir	0.910612	0.121052	0.060526
TR413 Bilecik	0.666682	0.088625	0.044313
TR421 Kocaeli	0.280243	0.037254	0.018627
TR422 Sakarya	0.417587	0.055512	0.027756
TR423 Düzce	0.496040	0.065941	0.032970
TR424 Bolu	1.000000	0.132935	0.066467
TR425 Yalova	0.444870	0.059139	0.029569

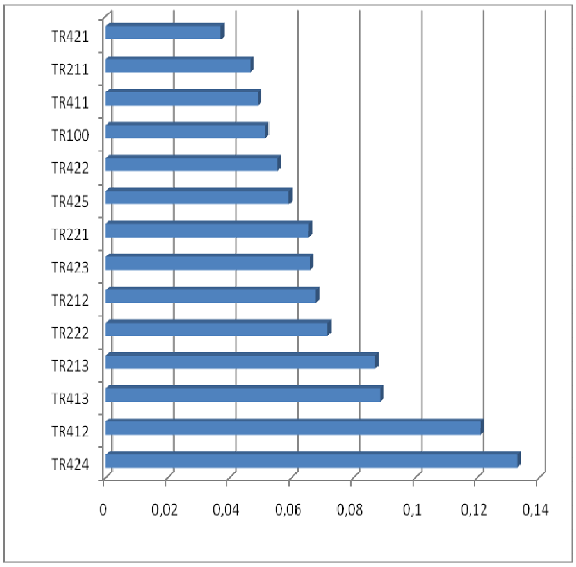

Fig. 5. Graphical results of Model B

5.3 Discussion

Environment has had a relatively low priority in Turkey and environmental concerns have been too often superseded by development interest in decision-making. Now, after decades of neglect, environmental degradation caused by economic development is widely accepted. Nevertheless, despite serious attempts to transition toward sustainable development, Turkey's environmental problems are worsening in scope, intensity, and impact [28]. According to Environmental Vulnerability Index [29] Turkey takes part in highly vulnerable group and it is ranked by Environmental Performance Index [30] as 72nd out of 149 countries.

As a candidate state to the EU, Turkey has been harmonising the national environmental legislation with the EU environmental acquis. Besides, important efforts have been made to increase access of the public to environmental information. Despite progress in providing environmental statistics and indicators [31, 32], the need for integrated studies on environmental sustainability both national and sub-national levels is urgent. Devising strategies to ensure environmental sustainability requires an accurate assessment of environmental performance. Beyond the assessment purpose, these are also crucial in developing awareness of environmental problems, and in advocating the need for achieving environmental sustainability.

In this paper a multiple criteria decision-making model is presented to rank and compare regions in terms of environmental sustainability. The proposed AHP model is applied to north-western regions of Turkey. Two different groups of alternatives -one from NUTS 2 level and the other from NUTS 3 level- are defined. Environmental sustainability of the selected alternatives is examined with 11 criteria.

Comparing the results of the models, it can be said that the selected spatial level affects the rankings significantly. The most striking case is İstanbul. While it ranks the first at NUTS 2 level, at NUTS 3 level it ranks poorly, in 11th place out of 14. TR42 Kocaeli, Sakarya, Düzce, Bolu, Yalova the second ranked region in Model A is another example. When the results of two models are compared, it can be seen the vast differences among the performance of TR42 provinces. The best (TR424 Bolu) and the worst performer (TR421 Kocaeli) are both appeared in TR42. These results emphasise the crucial importance of the units of analysis. Working with sub-regional level indicators might mask the problems in finer spatial levels, in our case in province-level. For that reason working with aggregated data might lead to inaccurate assessments. At this point once more the question arises as to what the unit of analysis should be, and how to deal with the cross-level nature of the data. It can be interpreted from the results that NUTS 3 or province-level is more appropriate, but more research is needed to confirm these findings.

Comparison of relative position of NUTS 3 regions also reveals some interesting results. İstanbul and its surrounding regions (Kocaeli, Tekirdağ, Bursa, Yalova and Sakarya) which have important economic interdependencies with it are relatively least environmentally sustainable regions. İstanbul -centred this area needs special attention to achieve sustainable development objective since the practices of these regions have consequences for the country as a whole.

Finally, it is also noted that in order to provide robust information and building effective environmental governance solutions we need approaches that address the complexities of multiple scales and multiple levels.

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