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Measuring Environmental Sustainability of Turkish Metropolitan Municipalities

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Measuring environmental sustainability of Turkish metropolitan municipalities

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Abstract

Turkey has been experiencing rapid urbanization since 1950's. Statistics show the urbanization rate is 69% and it is estimated that the mentioned rate will rise up to 84% over the next four decades (UNDP, 2008). Rapid and unplanned urbanization have a large impact on the environment in terms of degradation of the urban environment, waste, water, air, and resource consumption. Since many urban environmental problems are the results of poor management, improving urban governance is essential to assure sustainable human settlements. As an initial step, the accurate assessment of urban areas' environmental sustainability is required. The objective of this study is to develop a tool in order to measure environmental sustainability of Turkish metropolitans and rank them regarding their environmental performance. To this aim, an Analytical Hierarchy Process (AHP) model is proposed since AHP provides means of measuring environmental performance. SuperDecisions software v.2.0.8 is used for the analysis and 16 metropolitan municipalities are ranked according to a set of five main criteria namely, air pollution, water, waste, biodiversity & forestry, and population stress. The results indicate that Antalya (0.0932) is the best performer and is followed by Mersin (0.0773) and İstanbul (0.0714). Gaziantep (0.0466), Kayseri (0.0441), and Diyarbakır (0.0428) on the other hand, are rated as the least environmental sustainable cities. The results also show that, high-income metropolitans achieve generally high levels of urban environment sustainability.

Keywords: Analytical hierarchy process; urban environmental sustainability; metropolitan municipalities; Turkey.
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INTRODUCTION

Since 1970's, rising concern for social and environmental costs of development has prompted a rethinking of development. Following the Brundtland Report "sustainable development" concept has dominated the literature, although there remains an ambiguity in definition (Kates et al., 2005). While sustainability consist three pillars namely, economic, social and environmental, urgent environmental problems in global level stress the need for environmental sustainability more than two other dimensions. Overusing natural resources, land degradation, climate change, waste management and loss of biodiversity have became major issues not only in global level but national and regional levels.

Turkey has been experiencing environmental problems stemming from population growth and unplanned urbanization like other developing countries. During the period between 1950 and 1985, the percentage of urban population doubled from 24.8% to 52.4% (UNICEF, 2010). By 1985 as a turning point of urbanization practice, rural population started to decrease for the first time along with the number of people living in urban areas had surpassed the number of people living in rural areas. The average annual growth rate of urban population was 4.4 in the period of 1970-1990 and decreased to 2.1 in last decade (UNICEF, 2010). Despite the decrease in this rate, rapid urbanization has possessed a daunting challenge from environmental sustainability perspective. Human activities generated an increasing stress on environment; such as deforestation, air pollution, water shortages, insufficient protected areas, low percentage of clean energy resources. Such effects obstructed to achieve environmental sustainability. Consequently, according to Environmental Vulnerability Index (EVI, 2004) Turkey takes part in highly vulnerable group and ranked by Environmental Performance Index (EPI, 2008) as 72nd out of 149 countries. To assure environmental sustainability, urban areas have to balance between economic growth, social well-being and environmental preservation.

The objective of this study is to measure and rank environmental sustainability of 16 cities (Figure 2) among 81 where 35.7 million people resided that represent 66.5%of total urban population in Turkey. Evaluating urban environmental sustainability presents a complex problem and needs integrating indicators with different units of measurement. Solving this problem requires an integrated approach. With this aim, an Analytical Hierarchy Process (AHP) model proposed since AHP is an efficient tool for developing new policies and providing substantial information for evaluating the urban conditions. The model is capable of ranking cities in terms of environmental sustainability.

METHODOLOGY

For evaluating multi-criteria decision making process AHP which was developed by Saaty (1980) is widely used method. AHP simplifies the complexity in the form of a simple hierarchy by decomposition of a problem into attributes and alternatives. AHP has an important advantage to deal with both quantitative and qualitative criteria. The basic principles of AHP can be summarized as (Saaty and Kearns 1985);

1. Defining and determining the problem,
2. Decomposing the problem in a hierarchy from top through the intermediate levels,
3. Constructing a set of pair wise comparison matrices
4. Testing the consistency index,
5. Synthesizing the hierarchy to find out the ranks of the alternatives.

AHP makes use of pair wise comparisons to simplify the judgment process with 1-9 ratio scaling (Table 1) to apply wrights to attributes. 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.

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

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;

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

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.

$$Ax = \lambda x \qquad (1)$$

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \qquad (2)$$

When we divide C.I. by the random consistency number the final value must be less than 0.10 (Saaty, 1999).

About investigating and measuring the environmental sustainability various types of approaches used such as Environmental Performance Index and Environmental Sustainability Index, Environmental Progress Index, Environmental Footprint, Genuine Progress Indicator, Genuine Saving Rate etc. Apart from all these measurement approaches, Analytic Hierarchy

Process has been applied in different types of environmental studies such as; environmental impact assessment (Ramanatan, 2001), environmental quality indexing (Solnes, 2003), environmental vulnerability assessment (Tran et al., 2002), energy resources allocation (Ramanatan and Ganesh, 1995), livable cities (Saaty, 1986), environmental impacts of manufacturing (Pineda-Henson et al., 2002), solving a landfill site selection problem (Mummolo, 1996), land use pattern (Malczewski et al., 1997), and resource allocation of agricultural activities (Alphonce, 1997).

3. HIERARCHY TREE

In order to assess environmental sustainability of metropolitans, a hierarchy three has been created (Figure 1) with SuperDecisions software for the application of the AHP. At the top of the control hierarchy, there exists the goal of the problem. The goal is to measure and rank environmental sustainability of the metropolitans. There are five main criteria presented in level 2 of the hierarchy that are; air quality, water, waste, biodiversity and forestry, and population stress. These are further divided into 13 sub criteria as the third level of the hierarchy. The criterion of sub criteria clusters are connected to the criteria clusters. 16 metropolitans are alternatives of the model and can be called as the fourth level of the hierarchy.

The environmental issues investigated refer to five main themes, which were emphasized in explanation of hierarchy tree. The determinants of this model are specified using quantitative variables that available in Turkish Statistical Institution database. Due to significant data gaps of some indicators limited the analysis with year 2008. Data cover 16 cities (Figure 2) among 81 and represent 66.5% of total urban population in Turkey. In these cities, 52.6% of total GDP was created. Besides the four groups of environmental indicators, population density and population growth rate were included to the analysis since urban environmental quality is highly affected by these factors. The indicators are listed as follows;

1. **Average Particulate Matter (PM10) (µg/m3)**: Average concentrations of particulate matter obtained from the measurement stations in provincial and district centers
2. **Average Sulphur Dioxide (SO2) (µg/m3):** Average concentrations of sulphur dioxide obtained from the measurement stations in provincial and district centers
3. **Abstracted water per person (1000m3 year/population):** Total water quantity abstracted from spring lake, artificial lake, river, dam and well
4. **Waste water (1000m3 year/person):** Total quantity of waste water discharged to the sea, lake, artificial lake, river, dam and other
5. **Water Expenditure per person (TL)**: Total current and investment expenditures by public sector for water and sewerage services and water management services
6. **Yearly waste amount (kg/capita-day)**: Collected amount of waste by or on behalf of municipalities
7. **Waste disposal (%):** Percentage of harmless disposal
8. **Waste expenditure per person:** Total current and investment expenditures of waste management by public sector
9. **Protected Areas (%):** The percentage of national parks, nature parks, wildlife reproduction sites and nature protection areas in total surface

10. **Forest Land (%):** The percentage of the surface area of natural or planted forests
11. **Forest Expenditures per capita:** Amount of loans granted to support oriented forests conservation and development
12. **Population Density**: Percentage of the urban population in total population
13. **Population growth rate (thousandth):** Average annual increased population, for each 1000 people

4. RESULTS AND DISCUSSIONS

In this study environmental indicators analyzed to compare environmental sustainability of 16 metropolitans in Turkey. Criteria weights represent the importance of each criterion and sub criterion against the alternatives. It is assumed that the five criteria clusters; namely air pollution, biodiversity and forestry, water, waste, and population stress have equal importance so do sub criteria. For the analysis SuperDecisions 2.0.8 was employed. The data normalized by dividing each entry by the total to construct the pair wise comparison matrix. After constructing a set of pair wise comparison matrices, the consistency indexes were calculated for each by the software. Since the inconsistency ratios obtained from the model were less than 0.10, all pair wise comparison matrices were accepted as consistent. Thereafter synthesis gives the overall score and ranking of the 16 metropolitans.

Overall synthesized priorities for the alternatives are presented in Table 1. According to the results, Antalya (0.093) is the most environmental sustainable city followed by Mersin (0.077) and İstanbul (0.073). The worst rated cities are Gaziantep (0.0466), Kayseri (0.0441) and Diyarbakir (0.0428). Figure 3 depicts graphically the environmental sustainability of the cities. Under equal weighting assumption, Izmir and Erzurum have identical scores. According to the AHP results, low rated cities authorities should take environmental sustainability to their agenda.

GDP besides environmental quality play an important role for quality of life. To evaluate the relationship between environmental sustainability and GDP Figure 4 represented. The positive relationship is obvious. The richer cities have higher environmental sustainability scores relatively to cities with lower GDP.

Using AHP as a tool for combining large number of environmental criteria simplifies the comparison thus decision makers can manage their policies effectively. Measuring environmental sustainability degree with AHP can guide the local authorities about their performance while the scores show the condition of the city relatively to the others.

The score and rank of environmental sustainability can be adapted to other cities in Turkey as well. While criteria weights assumed equal in this study, different scenarios by applying questionnaire to the stakeholders to determine the criteria weights can be applied.

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Table 1: 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 favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8		Intermediate values

Source: Saaty, 2000.

Table 2: Environmental Sustainability Rankings

	Score	**Rank**		**Score**	**Rank**
Antalya	0.0932	1	Eskisehir	0.0628	9
Mersin	0.0773	2	Sakarya	0.0600	10
İstanbul	0.0714	3	İzmir	0.0547	11
Adana	0.0709	4	Erzurum	0.0547	12
Ankara	0.0681	5	Kocaeli	0.0535	13
Konya	0.0673	6	Gaziantep	0.0466	14
Samsun	0.0661	7	Kayseri	0.0441	15
Bursa	0.0657	8	Diyarbakir	0.0428	16

Figure 1: Hierarchy Tree

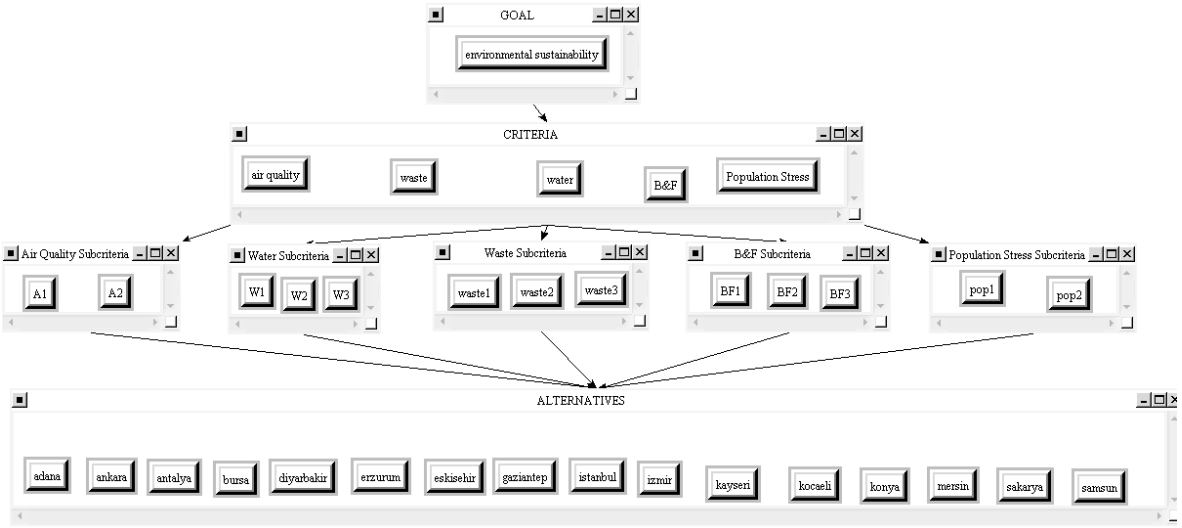

Figure 2: Metropolitans in Turkey

Figure 3: Environmental Sustainability Rates of the Cities

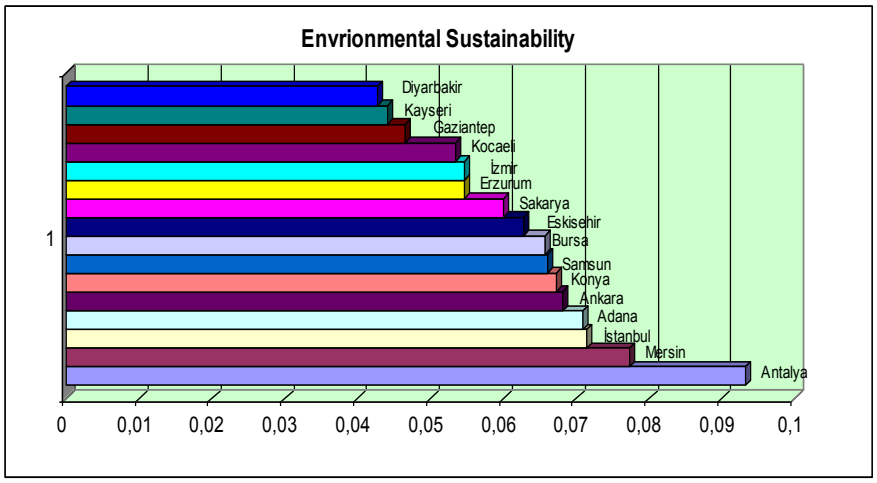

Figure 4: The Link between GDP and Environmental Performance