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A COMPARISON FOR ENVIRONMENTAL SUSTAINABILITY PERFORMANCES OF THE TURKISH METROPOLITANS'

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ABSTRACT

Since 1950's, Turkey had to face with rapid urbanization caused by population growth and migration. Therefore, like many other developing countries, country has been experiencing environmental problems. The spread of residential areas transformed forests and agricultural lands into urban, increased water consumption and air pollution enhanced the stress on ecosystem. The objective of this study is to measure urban environmental sustainability of densely populated cities in Turkey and rank their environmental performances. With this aim an Analytic Hierarchy Process (AHP) model is proposed since AHP is an efficient method in complex decision making processes. Five indicators; particulate equivalent, forest area, drawn water, wastewater discharged and, wastes are employed in the model. The results indicate that Bursa has the highest environmental sustainability score. It is followed by İzmir, Adana, Kocaeli, Mersin, İstanbul and Antalya. The lowest rated cities are Konya, Ankara and Gaziantep. Besides, there exist a positive relationship between environmental performances of the metropolitans and income.

Keywords: Environmental Sustainability, Analytic Hierarchy Process, Sustainability, Sustainable Cities, Multi-Criteria Decision Making, Urban Sustainability

INTRODUCTION

Environmental problems such as climate change, over using the natural resources, land degradation, air pollution and destruction on biodiversity have increasingly became subject as a result of rising international concerns. The worldwide awareness about environmental stress, equity problem and poverty came together in the Sustainable Development Goals (SDGs) which commits to achieve seventeen goals by 2030. Among seventeen goals Goal 6 clean water and sanitation, Goal 7 affordable and clean energy, Goal 11 sustainable cities and communities, Goal 13 climate action, Goal 14 life below water and recently Goal 15 life on land should be evaluated from the perspective of environmental sustainability.

Turkey has been experiencing rising environmental stress due to unplanned urbanization. According to the Environmental Vulnerability Index (EVI, 2005) Turkey is considered as highly vulnerable country. Compared to the Environmental Performance Index (EPI) Turkey ranked as 72nd out of 149 countries in 2012 (EPI, 2012). According to the 2018 index report of EPI, the environmental performance declined 108th among 180 countries (EPI, 2018).

In 1950, the urban population rate in Turkey was 24.8%. However it has doubled in only three decades (UNICEF, 2010). The year 1985 was a turning point for urban and rural distribution of the population. For the first time, the urban population exceeded the rural population and the difference has been gradually increasing over the years. Another significant change in urban population experienced in 2012. With the metropolitan law no. 6360, the number of metropolitans was increased and the coverage of urban areas expanded. While the urban population was 77% in 2012, with the lawful change the rate increased to 92.5% in 2013. Recently urban population has reached to 92.5% (TURKSTAT, 2018).

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The main environmental concerns such as deforestation, air pollution, water shortages, amount of waste, and low percentage of clean energy resources obstruct to achieve environmental sustainability. The central motivation behind this research is to provide a tool to use in making strategic decisions that will ensure the environmental urban sustainability. Evaluating environmental sustainability requires an integrated approach. Hence, the model structured on a basic question; "can the environmental sustainability of different cities be compared with one value?" With this regard AHP developed by Saaty (1980) has been chosen. The urban environmental sustainability performances of densely populated ten provinces, namely Adana, Ankara, Antalya, Bursa, Gaziantep, İstanbul, İzmir, Kocaeli, Konya and Mersin, were evaluated.

1. THE ANALYTIC HIERARCHY MODEL

1.1. Methodology

The Analytic Hierarchy Process (AHP) is a widely used multi criteria decision making method by decision makers and researchers to deal with complex decision-making problems. The method provides an effective and easy-to-understand tool for selection or ranking of alternatives in a wide range of problem types (Russo & Camanho, 2015) and allows solving complex problems both with qualitative and quantitative criteria. The basic principles of AHP were summarized by Saaty (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. Synthesis of the hierarchy to find out the ranks of the alternatives.

AHP makes use of pair wise comparisons with 1-9 ratio scale to construct pair wise comparison matrix. The pair wise 1-9 comparison scale listed below in Table 1 (Saaty, 2000).

Table 1: 1-9 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).

The pairwise comparison matrixes in AHP are formed as given in Equation (1).

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & 1 & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

Such that [aij]>0

After all pairwise comparisons are completed than the problem turns into general process of calculating the largest eigenvalue corresponding to the largest eigenvector to assess the Consistency Index (CI). A is the matrix, w is the eigenvector and λmax is the largest eigenvalue of the matrix A.

$$Aw = \lambda_{max} w \quad (2)$$

$$CI = {\lambda_{max} - n}/{n - 1} \quad (3)$$

$$CR = {CI}/{CR} \quad (4)$$

When CI is divided by the Random Consistency Index (RI) the final value must be less than 0.10 (Saaty, 1999). RI values provided for different matrix orders by Saaty (1980).

1.2. Building the Hierarchy

In order to assess environmental sustainability of densely populated urban areas, a hierarchy three has been created with SuperDecisions 2.8 software. The goal is placed at the top of the hierarchy. The goal is to measure the environmental sustainability performances of the selected provinces. Then at the second level of the hierarchy there exist criteria. To measure urban environmental sustainability five criteria were selected by the environmental sustainability experts. To determine the indicators, most frequently used indicators in the literature were eliminated by statistical availability, reliability, easy to understanding, measurability, and persistency principles by the experts. The criteria are; forest land, domestic solid waste, waste water, drawn water and particulate equivalent. Alternatives which are mostly populated cities in Turkey take place at the third and last level of the hierarchy. The generated hierarchy is presented in Figure 1.

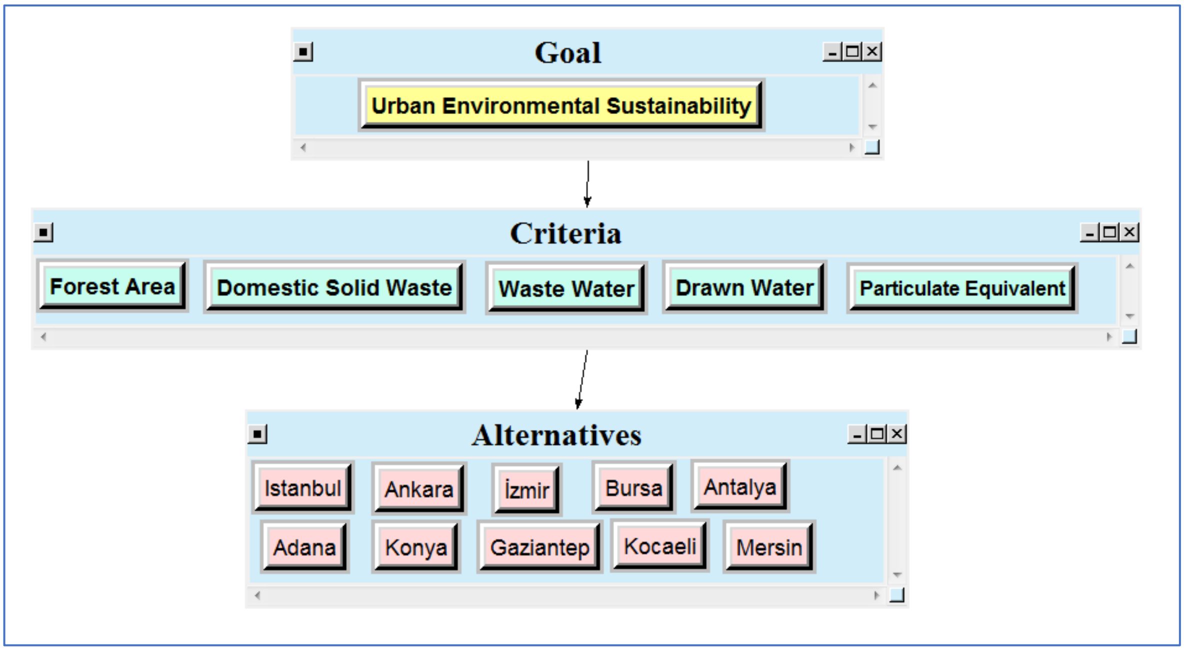

Figure 1: Hierarchy Tree of the Model

Quantitative data were obtained from different governmental sources but mainly from Turkish Statistical Institution (TURKSTAT). The analysis was limited by 2016 since the latest statistics published in 2016. Data cover 10 cities among 81. The population of selected metropolitans represents 49.54% of the total urban population in Turkey. In these cities 65% of GDP was created by the end of 2017 (TURKSTAT, 2019).

The environmental issues investigated refer to five main criteria are presented in Table 2. Among the selected criteria particulate equivalent was calculated. To do so particulate equivalent (PE) formula is employed (Equation 5). This equation is widely used in order to calculate the total effect of PM and SO2 emissions.

$$PE = PM_{10} + (0.54 * SO_2) \quad (5)$$

Urban air pollution is a significant problem especially in winter season. Between 1990 and 1996 it is estimated that approximately 15 million inhabitants of major Turkish cities are exposed to Sulphur dioxide (SO2) and particulate concentrations (PM) above World Health Organization (WHO) guidelines (OECD, 1999). The major sources of air pollution are transportation, combustion of fossil fuels and consumption of low quality coal by households.

Table 2: Indicator List

Indicators	Unit	Source
Particulate equivalent	µg/m^3	TURKSTAT
Municipal Solid Waste	Per capita-kg	TURKSTAT
Water abstraction	1000m^3/person	TURKSTAT
Wastewater	1000m^3/person	TURKSTAT
Forest area	%	General Directorate of Forestry

Due to expanded urban areas within the last few decades created pressure on the forests around cities. The forest reserves of Turkey represented in Figure 2. According to the survey by Ministry of Environment and Forestry the surface of forests covered 26.1% in 1975 and 28.6% in 2015 of the country (GDF, 2015). According to the statistics compared for the last four decades, there has not been a significant development in forest areas. The total protected areas cover only 5.3% of Turkey's total surface. Turkey's rich biodiversity are threatened due to the effects of tourism, urbanization, industrial and agricultural developments (OECD, 2008).

Figure 2. Forest Reserves of Turkey

There are steps taken by the central government to minimize and manage solid waste in cities. For this purpose, "Waste Management Regulation" was published in 2015. Then, a new draft regulation was created in 2018 within the scope of "Zero Waste Project". These steps are expected to have positive consequences for environmental sustainability in the long term. Another important component of evaluating environmental performance is water. The demand for water increased and the water reserves threatened in consequence of population growth, economic development, and rising industrial and agricultural production. According to the State Hydraulic Works (SHW, 2012) Turkey's annual exploitable amount of water has been approximately 1,500 m3 per capita which results her to take place in "insufficient/water stressed" water health countries group. According to the future estimation this value will decrease to 1,000 m3 per capita and the country will be classified in "poor water health" countries group. Turkey is a water scarce country and shows high vulnerability about water governance and footprint (Al-Saidi et al., 2016). Thus, another important criterion for achieving environmental sustainability is drawn water and wastewater management.

1.3. Determination of the weights

There are studies conducted with different number of experts in the literature. In AHP studies, the experience and the knowledge level of the experts' is more important than the number of experts. There are studies implemented with different numbers of experts in the literature. Gomez-Navarro et al. (2009) worked with 5 experts from the public and private sector in their study. Saaty (1986) determined the weights of the indicators with 6 experts. Köne and Büke (2017) studied with twenty-five experts.

In this study, it was consulted to five experts' opinions. Selected experts are environmental engineers, specialized on environmental sustainability studies. Face-to-face interviews were made to weight the importance of the indicators than the pairwise comparison matrices were generated. Since the geometric mean method recommended evaluating the expert's pairwise comparisons (Aczel& Saaty, 1983) the weights were calculated by geometric mean method. The calculated weights of the environmental sustainability indicators are given in Table 3. The highest weighted factor is water abstraction amount. It is followed by wastewater, particulate equivalent, municipal solid waste and forest area respectively.

Table 3. Weights of Environmental Sustainability Criteria

Environmental Sustainability	Weights (%)
Particulate equivalent	23.73
Municipal Solid Waste	9.80
Water abstraction	40.83
Wastewater	28.36
Forest area	7.36
Total	**100.00**

2. RESULTS

To analyze the AHP model SuperDecisions 2.8 was employed. The weights of the indicators derived by the experts were added to the model. The data were normalized by dividing each entry by the total to construct the pairwise comparison matrix. After construction the pairwise comparison matrixes, the consistency indexes were calculated. Since the inconsistency rate obtained from the model was less than 0.10 the model was accepted as consistent. According to the results, the urban sustainability performances of the alternatives are presented in Table 4 and Figure 3 with graphic version.

Table 4. Urban Environmental Sustainability Scores of the Cities

Name	Ranks	Ideals	Normals	Raw
Adana	3	0.969775	0.109591	0.054796
Ankara	9	0.780620	0.088216	0.044108
Antalya	7	0.852899	0.096384	0.048192
Bursa	1	1.000000	0.113007	0.056504
Gaziantep	10	0.726521	0.082102	0.041051
İstanbul	6	0.907182	0.102518	0.051259
İzmir	2	0.971297	0.109763	0.054882
Kocaeli	4	0.926908	0.104747	0.052374
Konya	8	0.789888	0.089263	0.044631
Mersin	5	0.923918	0.104409	0.052205

The "normals" column in Table 4 presents the sustainability results of alternatives. The "idealized values" column was derived from the normals column. These values were obtained by dividing the value of each alternative in the normals column by the highest value in the normals column. Therefore, in the idealized column of values, the best alternative with the highest score has a value of “1”. The "raws" result column was obtained directly from the supermatrix. In the hierarchical models, the column of raws and the column of normals are the same. According to the results Bursa is the most environmentally sustainable province followed by İzmir and Adana. Comparatively least environmental sustainable provinces are Gaziantep and Ankara.

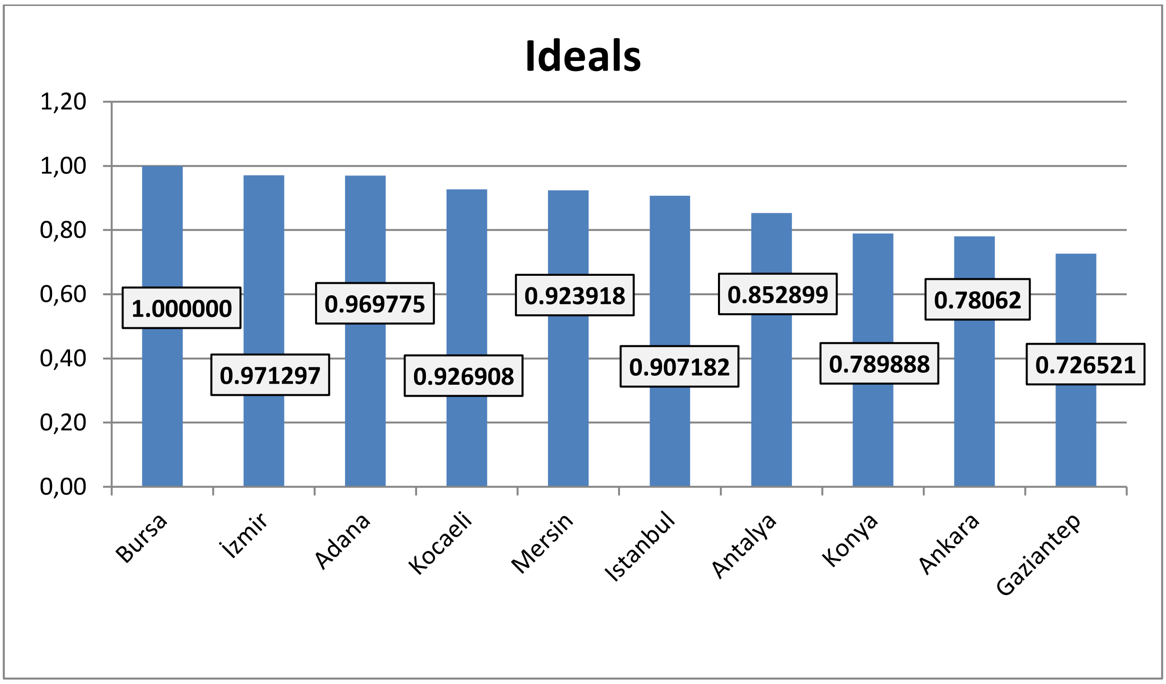

Figure 3. Environmental Sustainability Rankings of Metropolitans

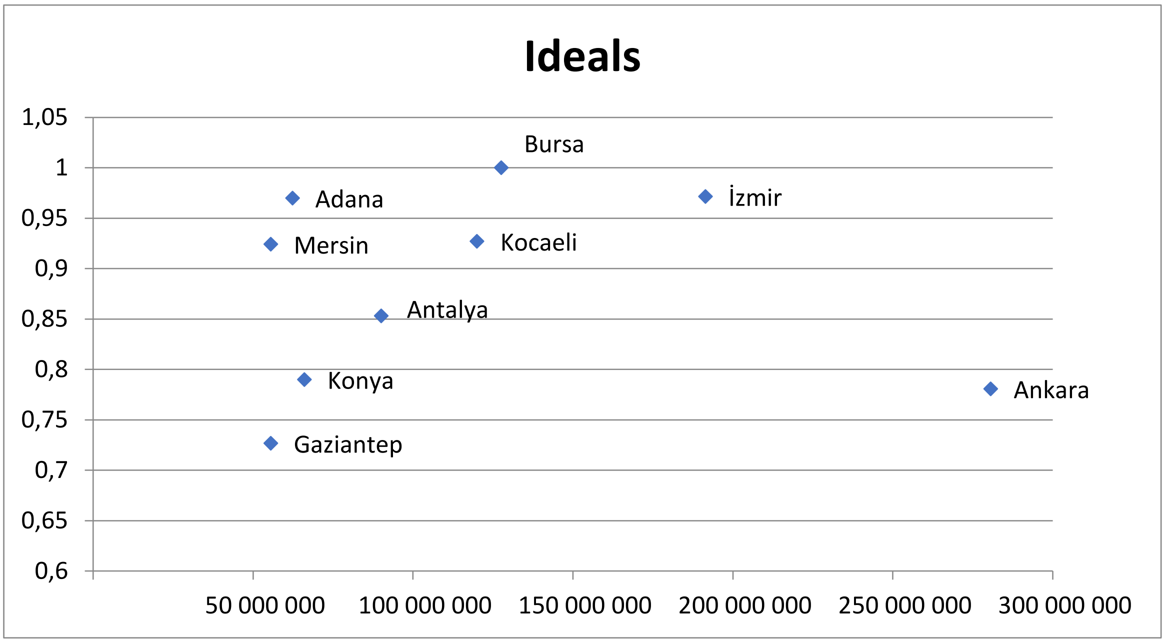

Figure 4. The Link between GDP and Environmental Performance

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 between environmental performance and the income of the metropolitans is obvious. The richer cities have higher environmental sustainability scores relatively to cities with lower GDP. İstanbul is excluded in the Figure 4 since she has extreme value of income compared to others.

3. CONCLUSIONS

In this study environmental sustainability of 10 metropolitans as alternatives in Turkey were analyzed. The alternatives were evaluated with regard to particulate equivalent, forest area, drawn water, wastewater and, solid wastes criteria. According to the AHP scores Bursa has shown the highest environmental sustainability performance. It is followed by İzmir, Adana, Kocaeli, Mersin, İstanbul and Antalya. Environmentally less sustainable alternatives are Konya, Ankara and Gaziantep among other alternatives.

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 others. According to the results, low rated cities' authorities should take environmental sustainability to their agenda.

The model can be adapted to other cities in Turkey for the future studies. Criteria weights assigned by the experts in this study however, different scenarios could be practiced by applying questionnaire to the stakeholders to determine the criteria weight. Besides, the model could be practical to apply past performances of the each alternative.

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