AN ANALYSIS ON SOME FEATURES OF CLIMATE FRIENDLY AND CLIMATE RESILIENT CITIES

Araştırma Makalesi

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ABSTRACT

Over the years, increased human-induced activities due to globalization caused increase in environmental problems and hence change in seasonal normals. At this point, especially recently, climate-friendly and climate resilient city concepts have started to gain importance. With this study, by making literature review about the features and conceptual contents of climate friendly and climate resilient cities, a criteria list was created and the experts' opinions regarding criteria were taken and then the prioritization was made among some of the prominent features of these cities with fuzzy AHP Method. Based on weight levels, it is found that the overall weight is on Environment and City criteria. Therefore, future regulations and implementations should focus on Environment and City criteria in order to prevent global warming and climate changes resulting from human activities. As a result, the construction of climate friendly and climate resilient cities is very important for future generations to live in a healthier and safer environment. In this regard, local climate change action plans should be made, CO_2 emission inventories should be prepared and also audits should be carried out regularly.

Keywords: *Climate Friendly Cities, Climate Resilient Cities, Fuzzy AHP.*

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İKLİM DOSTU VE İKLİME DİRENÇLİ ŞEHİRLERİN BAZI ÖZELLİKLERİ ÜZERİNE BİR ANALİZ

ÖZET

Yıllar içerisinde, küreselleşme nedeniyle artan insan kaynaklı faaliyetler, çevre sorunlarının artmasına ve dolayısıyla mevsim normallerinin değişmesine neden olmuştur. Bu noktada, özellikle son zamanlarda, iklim dostu ve iklime dirençli şehir kavramları önem kazanmaya başlamıştır. Bu çalışma ile iklim dostu ve iklime dirençli kentlerin özellikleri ve kavramsal içerikleri hakkında literatür taraması yapılarak bir kriter listesi oluşturulmuş, uzmanların oluşturulan kriterleri değerlendirmesinden sonra görüşleri alınmış ve ardından bulanık AHP Yöntemi ile bu kentlerin öne çıkan birtakım özellikleri arasında önceliklendirme yapılmıştır. Ağırlık seviyelerine göre toplam ağırlığın Çevre ve Şehir kriterlerinde olduğu bulunmuştur. Bu nedenle, gelecekte yapılacak düzenlemeler ve uygulamalar için, küresel ısınmayı ve insan faaliyetlerinden kaynaklanan iklim değişikliklerini önlemek için Çevre ve Şehir kriterlerine odaklanmak yararlı olacaktır. Sonuç olarak, gelecek nesiller için daha sağlıklı ve daha güvenli ortamlarda yaşamak için iklim dostu ve iklime dirençli şehirlerin inşası çok önemlidir. Bu bağlamda, yerel iklim değişikliği eylem planları yapılmalı, CO_2 emisyon envanterleri hazırlanmalı ve düzenli olarak denetimler yapılmalıdır.

Anahtar Kelimeler: *İklim Dostu Şehirler, İklime Dirençli Şehirler, Bulanık AHP.*

1. INTRODUCTION

While increasing population and increasing demands of developing countries for different needs with globalization cause the increasing of prices of energy resources and other environmental problems; on the other hand they cause the decreasing of natural resources. As a result of these problems, stress on rural and urban areas increases rapidly and seasonal changes occur.

In 1950, 30 % of the population lived in urban areas; It is predicted that this ratio will be 66 % in 2050. Africa and Asia are becoming more urbanized than other regions and In 2050, the urban population is expected to be 56 % and 64 % respectively. In contrast, the global rural population is now close to 3.4 billion; It is expected to decrease to 3.2 billion by 2050. Africa and Asia are home to about 90 % of the world's rural population. The largest rural population in the world belongs to India as 857 million; followed by China with 635 million [1]. Today, there are some results arising from the activities in the urban area. Global warming, rising temperatures, drought, rising sea levels, increasing extraordinary weather events, changing seasonal norms, decreasing biodiversity, increasing health risks, increasing scarcity and migration, damage to agriculture and livestock sectors, economic losses, increasing poverty are some of these results [2,3]. In addition, more than 525,000 people lost their lives and 2.97 US $ trillion economic losses have occured as a direct result of approximately 15,000 extraordinary weather events between 1995 and 2014. Therefore, the Paris Climate Summit has been a cornerstone in the development of a number of international policy issues related to reducing the impact of extraordinary events [4]. A resilient city, dealing with issues and events that threaten, hurt or destroy the city, through their own systems; is the city that provides its own sustainability [5]. Therefore, the concepts of Climate Friendly City and Climate Resistant City have gained importance all over the world in line with the issues of adaptation to climate change and combating climate change. Also, greenhouse gases, traffic density, intense energy use, consumption habits increase the temperature in the city and are effective in the formation of heat islands [6]. Furthermore, in the report of the Worldwatch Institute (2008) it has been reported that 262 million people were affected by climate disasters annually during the period of 2000-2004, and it is expected that 1.8 billion people will suffer from fresh water shortage by 2025, mostly in Asia and Africa and by 2080, 600 million people will be threatened by food shortage and malnutrition, Also it is stated that 180 million people currently have food shortages and 2 million early deaths occur in the world due to pollution [7].

Therefore, the loss of life and property has become important due to the seasonal anomalies caused by the usage of especially urban aress by people. In this respect, in this study, the features that are planned to be analyzed are determined by making a literature search on the concepts of Climate Friendly City and Climate Resilient City. After the aforementioned features are determined, they were weighted by Fuzzy AHP Method which is well known multi-criteria decision making method. It has various applications in many fields of science and many subjects such as evaluation of wind power plants locations [22], location selection for landfill of industrial wastes [23], prioritizing the critical success factors of organizational culture [24]. Multi-Criteria Decision-Making Methods are methods that use many qualitative and quantitative data in calculations that take into account the different performance criteria and weights of the alternatives, which enable the selection of the best choice among multiple and simultaneous alternatives. In many studies in the literature in recent years, it is seen that Fuzzy AHP is preferred due to some deficiencies of AHP. When searching for a solution with AHP, AHP ranking is quite ambiguous. Secondly, AHP results are significantly influenced by subjective decision, choice and choice of decision makers. Again, AHP creates and manages a fairly unstable judicial scale. Here, to overcome these shortcomings, an extended AHP fuzzy set can be integrated with a binary comparison called Fuzzy-AHP. The Fuzzy-AHP method allows for a more precise description of the decision making process. Fuzzy AHP approach with fuzzy logic integration, since it uses precise numbers when making binary comparisons and is inadequate in handling uncertainty and uncertainty situations. In this context, Fuzzy AHP approach is defined as a more accurate decision making process for this study. According to the defined criteria the results were evaluated and ordered by Fuzzy AHP in the next chapters.

2. DETERMINATION OF FEATURES OF CLIMATE FRIENDLY AND CLIMATE RESILIENT CITIES AND PRIORITIZATION OF THEM VIA FUZZY AHP METHOD

There are many features of climate friendly and climate resilient cities but some of them are; multi level climate partnership and multi level governance in city regions, climate planning in integrated strategies and plans, urban-rural cooperation, climate friendly spatial structure of the city through planning and zoning, climate aware architectural solutions, be sensitive to disadventaged social groups and social effects, climate awareness in the city dwellers' lifestyle, and public and sectoral stakeholders supporting the climate friendly cities [8].

While determining indicators for climate friendly and climate resilient cities, the criteria and indicators related to sources below were utilized [9,10,11,12,13,14,15,16,17]:

1. The European Foundation's Urban Sustainability Indicators
2. Eurostat Sustainable Development Indicators
3. ICLEI-URBAN LEDS Selection Criteria
4. C40 Selection Criteria
5. European Green Capital Award
6. European Green Leaf Award
7. Citta Slow Selection Criteria
8. European Green City Index

By examining these indicators and criteria regarding climate friendly and climate resilient cities are gathered under the main headings of Environment and City, Transportation, Construction, Energy and Ecosystem. In this direction, 24 criteria have been determined which are given in Table 1. These criteria were weighted according to experts' opinions and evaluations and then analyzed via Fuzzy AHP Method.

Table 1. Criteria for Climate Friendly and Climate Resilient Cities

Environment and City	Transportation, Construction, Energy	Ecosystem
EC 1. Having a local climate change action plan	**TCE 1.** Existence of projects and/or studies about gaining historical and/or cultural structures to tourism	**E 1.** Having biodiversity inventory and monitoring plans
EC 2. Having budgets allocated by local government about the climate change and combating climate change issues	**TCE 2.** Existence of smart systems such as lighting systems that provide energy efficiency in buildings	**E 2.** Existence of ecological, good, sustainable and/or organic agricultural practices
EC 3. Existence of inventory of CO_2 emissions and ensuring the controls for these emissions	**TCE 3.** The use of electrical/hybrid buses in public transport	**E 3.** Using drip irrigation method in agriculture
EC 4. Existence of natural disaster risk and action plans	**TCE 4.** Using renewable energy sources such as solar panels in buildings	**E 4.** Various measures have been taken for the usage of forest, pasture and agricultural lands

EC 5. Existence of monitoring, forecasting and early warning systems for natural disasters due to climate change	**TCE 5.** Existence of lighting tools using energy efficient and/or alternative energy sources in public lighting	**E 5.** Existence of water quality and hygiene monitoring systems
EC 6. Having urban security and monitoring systems	**TCE 6.** Existence of bicycle paths and bicycle parking points	**E 6.** Regarding water pollution control, being the values of various water resources within the determined value ranges according to the quality criteria specified in the law
EC 7. Participation in international platforms, networks and / or studies on climate change	**TCE 7.** Application of discounts in the use of transport systems for disadvantaged groups such as the elderly and needy women	**E 7.** Air pollution is within the parameters specified by law
EC 8. Existence of wastewater treatment and waste recovery and recycling facilities	**TCE 8.** Existence of rail and light rail systems	**E 8.** Existence of projects and/or implementations to reduce air pollution

3. BUCKLEY'S FUZZY AHP METHOD

Altough there have been several Fuzzy-AHP methods utilized in the literature, the Fuzzy-AHP that was presented by Buckley [18] utilized in this study due to easiness and computational efficiency. Buckleys' Fuzzy AHP method can be defined as follows;

Step 1: According the Buckley's Fuzzy AHP Method [18,19]; to digitize verbal values done with linguistic expressions, linguistic expressions are converted to trapezoidal fuzzy numbers. In order to determine criterion and sub-criterion weights, binary comparison matrices are created. Fuzzy set Ã is created.

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \tilde{d}_{22}^k & & \tilde{d}_{2n}^k \\ \vdots & & \cdots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & \tilde{d}_{nn}^k \end{bmatrix} \quad \textbf{(3.1)}$$

After determination of the criteria, fuzzy AHP method and steps to be used in determination of criterion weights are explained together. The linguistic variables to be used in the pairwise comparison of the criteria are shown in Table 2.

Table 2. Linguistic Variables to be Used in the Evaluation of Criteria [20]

Linguistic Variables	Value Scale	Triple Fuzzy Scale	Triple Fuzzy Reverse Scale
Equal Importance (E)	1	(1,1,1)	(1/1, 1/1, 1/1)
Low Importance (A)	3	(1,3,5)	(1/5, 1/3, 1/1)
Much Importance (C)	5	(3,5,7)	(1/7, 1/5, 1/3)
Very strong Importance (CK)	7	(5,7,9)	(1/9, 1/7, 1/5)
Extreme Importance (AS)	9	(7,9,9)	(1/9, 1/9, 1/7)
Close Provisions Between Two Values (YH)	2 4 6 8	(1,2,3) (3,4,5) (5,6,7) (7,8,9)	(1/3, 1/2, 1) (1/5, 1/4, 1/3) (1/7, 1/6, 1/5) (1/9, 1/8, 1/7)

Step 2: Then the fuzzy weight matrix is calculated.

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^{k}}{K} \quad \textbf{(3.2)}$$

Step 3: The binary comparison matrices are arranged according to the average values found.

$$\begin{bmatrix} \tilde{d}_{11} & \cdots & \tilde{d}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{d}_{n1} & \cdots & \tilde{d}_{nn} \end{bmatrix} \quad \textbf{(3.3)}$$

Step 4: Geometric Mean of Fuzzy Comparison Values Calculated according to Equation 4.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n}, i = 1,2,\dots,n \quad \textbf{(3.4)}$$

Step 5: Criterion weights are shown trapezoidal $\tilde{w}_i = (lw_i, mw_i, uw_i)$

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \dots\dots\dots \oplus \tilde{r}_n)^{-1} \quad \textbf{(3.5)}$$

Step 6: The fuzzy number given as M = (l, w, u) is clarified as in Equation 6.

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad \textbf{(3.6)}$$

Step 7: M_i Since the clarified values are a non-fuzzy number, the values obtained are normalized according to Equation 7.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad \textbf{(3.7)}$$

4. APPLICATION

In this study, in order to prioritize the criteria for climate-friendly cities, the algorithm of the intended approach is given in Figure 1. Accordin to this, which determined criteria are more important are pratically described below. First of all, criteria's weights should be determined. At this stage, weights were calculated by geometric mean method. In order to analyze the consistency of the binary comparison matrices created in line with the opinions received from the decision-makers, a consistency test was performed and it was determined that the consistency values for all binary comparison matrices were within the defined value range (0 - 0,1) defined by Saaty [21]. With the help of the linguistic variables shown in Table 2, the relative weights of the criteria were also determined. The paired comparison matrix and fuzzy equivalents of the criteria are shown in Table 2 and Table 3.

Table 3. Comparison Matrix for the Main Criteria

Ana Kriterler	EC	TCE	E
EC	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(3,00, 5,00, 7,00)
TCE	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)
E	(0,14, 0,20, 0,33)	(1,00, 2,00, 3,00)	(1,00, 1,00, 1,00)

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n} = \left[(1{,}00 \times 1{,}00 \times 3{,}00)^{\frac{1}{3}}; (1{,}00 \times 3{,}00 \times 5{,}00)^{\frac{1}{3}}; (1{,}00 \times 5{,}00 \times 7{,}00)^{\frac{1}{3}}\right] = [1{,}44; 2{,}47; 3{,}27]$$

$$\widetilde{r_2} = \left[(0{,}20 \times 1{,}00 \times 1{,}00)^{\frac{1}{3}}; (0{,}33 \times 1{,}00 \times 3{,}00)^{\frac{1}{3}}; (1{,}00 \times 1{,}00 \times 5{,}00)^{\frac{1}{3}}\right] = [0{,}41; 0{,}55; 1{,}00]$$

$$\widetilde{r_3} = \left[(0{,}14 \times 1{,}00 \times 1{,}00)^{\frac{1}{3}}; (0{,}20 \times 2{,}00 \times 1{,}00)^{\frac{1}{3}}; (0{,}33 \times 3{,}00 \times 1{,}00)^{\frac{1}{3}}\right] = [0{,}52; 0{,}74; 1{,}00]$$

Table 4. Geometric Mean of Fuzzy Comparison Values

Main Criteria	$\widetilde{r_i}$		
EC	1,44	2,47	3,27
TCE	0,41	0,55	1,00
E	0,52	0,74	1,00
Total	2,37	3,75	5,27
Inverse Value	0,42	0,27	0,19
Ascending Sort	0,19	0,27	0,42

$$\widetilde{w_1} = [(1{,}44 \times 0{,}19); (2{,}47 \times 0{,}27); (3{,}27 \times 0{,}42)] = [0{,}274; 0{,}657; 1{,}380]$$

$$\widetilde{w_2} = [(0{,}41 \times 0{,}19); (0{,}55 \times 0{,}27); (1{,}00 \times 0{,}42)] = [0{,}077; 0{,}147; 0{,}422]$$

$$\widetilde{w_3} = [(0{,}52 \times 0{,}19); (0{,}74 \times 0{,}27); (1{,}00 \times 0{,}42)] = [0{,}099; 0{,}196; 0{,}422]$$

Table 5. Weights of Fuzzy Comparison Values

Main Criteria	$\tilde{w}_i$		
EC	0,274	0,657	1,380
TCE	0,077	0,147	0,422
E	0,099	0,196	0,422

Table 6. Clarified and Normalized Values of Fuzzy Comparison Values

Main Criteria	M_i	N_i
EC	0,770	0,629
TCE	0,215	0,176
E	0,239	0,195

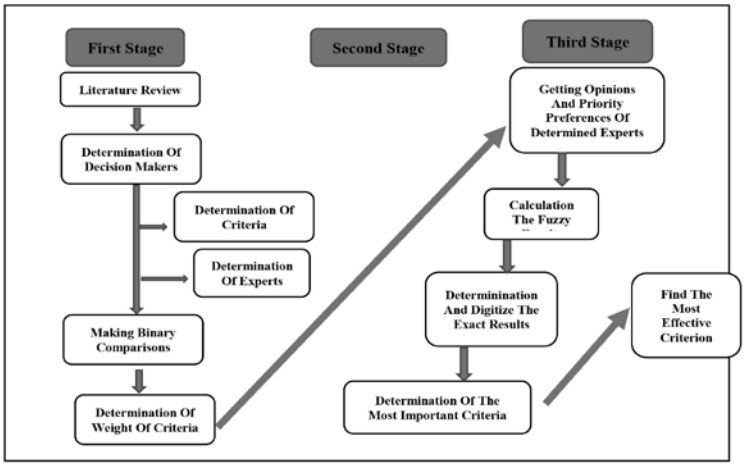

Figure 1. Algorithm of the Intended Approach

Comparison Matrix for EC Sub-Criteria

Table 7. Binary Comparison Matrix for the Main Criteria of Environment and City

Sub-Criteria	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8
EC1	(1,00, 1,00, 1,00)	(0,20, 0,25, 0,33)	(0,20, 0,25, 0,33)	(0,33, 0,50, 1,00)	(1,00, 2,00, 3,00)	(1,00, 3,00, 5,00)	(3,00, 4,00, 5,00)	(5,00, 6,00, 7,00)
EC2	(3,00, 4,00, 5,00)	(1,00, 1,00, 1,00)	(0,33, 0,50, 1,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(3,00, 5,00, 7,00)	(5,00, 6,00, 7,00)	(7,00, 8,00, 9,00)
EC3	(3,00, 4,00, 5,00)	(1,00, 2,00, 3,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(3,00, 5,00, 7,00)	(5,00, 6,00, 7,00)	(5,00, 7,00, 9,00)	(7,00, 9,00, 9,00)

EC4	(1,00, 2,00, 3,00)	(0,33, 0,50, 1,00)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(3,00, 5,00, 7,00)	(5,00, 7,00, 9,00)
EC5	(0,33, 0,50, 1,00)	(0,20, 0,25, 0,33)	(0,14, 0,20, 0,33)	(0,33, 0,50, 1,00)	(1,00, 1,00, 1,00)	(1,00, 2,00, 3,00)	(1,00, 3,00, 5,00)	(3,00, 5,00, 7,00)
EC6	(0,20, 0,33, 1,00)	(0,14, 0,17, 0,20)	(0,14, 0,17, 0,20)	(0,20, 0,25, 0,33)	(0,33, 0,50, 1,00)	(1,00, 1,00, 1,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)
EC7	(0,20, 0,25, 0,33)	(0,14, 0,17, 0,20)	(0,11, 0,14, 0,20)	(0,14, 0,20, 0,33)	(0,20, 0,33, 1,00)	(0,33, 0,50, 1,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)
EC8	(0,14, 0,17, 0,20)	(0,11, 0,13, 0,14)	(0,11, 0,11, 0,14)	(0,11, 0,14, 0,20)	(0,14, 0,20, 0,22)	(0,20, 0,25, 0,33)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n} = \left[(1{,}00 \times 0{,}20 \times 0{,}20 \times 0{,}33 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00)^{\frac{1}{8}};\ (1{,}00 \times 0{,}25 \times 0{,}25 \times 0{,}50 \times 2{,}00 \times 3{,}00 \times 4{,}00 \times 6{,}00)^{\frac{1}{8}};\ (1{,}00 \times 0{,}33 \times 0{,}33 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 5{,}00 \times 7{,}00)^{\frac{1}{8}}\right] = [0{,}82\ ;\ 1{,}21\ ;\ 1{,}66]$$

$$\widetilde{r_2} = \left[(3{,}00 \times 1{,}00 \times 0{,}33 \times 1{,}00 \times 3{,}00 \times 3{,}00 \times 5{,}00 \times 7{,}00)^{\frac{1}{8}};\ (4{,}00 \times 1{,}00 \times 0{,}50 \times 2{,}00 \times 4{,}00 \times 5{,}00 \times 6{,}00 \times 8{,}00)^{\frac{1}{8}};\ (5{,}00 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 7{,}00 \times 7{,}00 \times 9{,}00)^{\frac{1}{8}}\right] = [2{,}05\ ;\ 2{,}81\ ;\ 3{,}67]$$

$$\widetilde{r_3} = \left[(3{,}00 \times 1{,}00 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 5{,}00 \times 7{,}00)^{\frac{1}{8}};\ (4{,}00 \times 2{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 6{,}00 \times 7{,}00 \times 9{,}00)^{\frac{1}{8}};\ (5{,}00 \times 3{,}00 \times 1{,}00 \times 5{,}00 \times 7{,}00 \times 7{,}00 \times 9{,}00 \times 9{,}00)^{\frac{1}{8}}\right] = [2{,}51\ ;\ 3{,}82\ ;\ 4{,}83]$$

$$\widetilde{r_8} = \left[(0{,}14 \times 0{,}11 \times 0{,}11 \times 0{,}11 \times 0{,}14 \times 0{,}20 \times 0{,}20 \times 1{,}00)^{\frac{1}{8}};\ (0{,}17 \times 0{,}13 \times 0{,}11 \times 0{,}14 \times 0{,}20 \times 0{,}25 \times 0{,}33 \times 1{,}00)^{\frac{1}{8}};\ (0{,}20 \times 0{,}14 \times 0{,}14 \times 0{,}20 \times 0{,}22 \times 0{,}33 \times 1{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [0{,}18\ ;\ 0{,}22\ ;\ 0{,}31]$$

$$\widetilde{w_1} = [(0{,}82 \times 0{,}06);\ (0{,}21 \times 0{,}09);\ (1{,}66 \times 0{,}13)] = [0{,}051\ ;\ 0{,}103\ ;\ 0{,}209]$$

$$\widetilde{w_2} = [(2{,}05 \times 0{,}06);\ (2{,}81 \times 0{,}09);\ (3{,}67 \times 0{,}13)] = [0{,}128\ ;\ 0{,}241\ ;\ 0{,}462]$$

$$\widetilde{w_3} = [(2{,}51 \times 0{,}06);\ (3{,}82 \times 0{,}09);\ (4{,}83 \times 0{,}13)] = [0{,}157\ ;\ 0{,}327\ ;\ 0{,}608]$$

$$\widetilde{w_4} = [(1{,}15 \times 0{,}06);\ (1{,}76 \times 0{,}09);\ (2{,}70 \times 0{,}13)] = [0{,}072\ ;\ 0{,}151\ ;\ 0{,}340]$$

$$\widetilde{w_5} = [(0{,}56 \times 0{,}06);\ (0{,}88 \times 0{,}09);\ (1{,}36 \times 0{,}13)] = [0{,}035\ ;\ 0{,}076\ ;\ 0{,}171]$$

$$\widetilde{w_6} = [(0{,}41 \times 0{,}06);\ (0{,}57 \times 0{,}09);\ (0{,}87 \times 0{,}13)] = [0{,}026\ ;\ 0{,}049\ ;\ 0{,}110]$$

$$\widetilde{w_7} = [(0{,}27 \times 0{,}06);\ (0{,}40 \times 0{,}09);\ (0{,}62 \times 0{,}13)] = [0{,}017\ ;\ 0{,}034\ ;\ 0{,}078]$$

$$\widetilde{w_8} = [(0{,}18 \times 0{,}06);\ (0{,}22 \times 0{,}09);\ (0{,}31 \times 0{,}13)] = [0{,}011\ ;\ 0{,}019\ ;\ 0{,}039]$$

Table 8. Geometric Mean Values of Criteria Based on the Main Criterion of Environment and City

Sub-Criteria	$\tilde{r}_i$		
EC1	0,82	1,21	1,66
EC2	2,05	2,81	3,67
EC3	2,51	3,82	4,83
EC4	1,15	1,76	2,70
EC5	0,56	0,88	1,36
EC6	0,41	0,57	0,87
EC7	0,27	0,40	0,62
EC8	0,18	0,22	0,31
Total	7,95	11,67	16,03
Inverse Value	0,13	0,09	0,06
Increased Value	0,06	0,09	0,13

Table 9. Criteria Weights for Sub-Criteria Based on the Main Criterion of Environment and City

Main Criteria	$\tilde{w}_i$		
EC1	0,051	0,103	0,209
EC2	0,128	0,241	0,462
EC3	0,157	0,327	0,608
EC4	0,072	0,151	0,340
EC5	0,035	0,076	0,171
EC6	0,026	0,049	0,110
EC7	0,017	0,034	0,078
EC8	0,011	0,019	0,039

Table 10. Clarified and Normalized Values for Sub-Criteria Based on the Main Criterion of Environment and City

Main Criteria	M_i	N_i
EC1	0,121	0,104
EC2	0,277	0,236
EC3	0,364	0,311
EC4	0,187	0,160
EC5	0,094	0,080
EC6	0,061	0,052
EC7	0,043	0,037
EC8	0,023	0,020

Comparison Matrix for Sub-Criteria of TCE

Table 11. Binary Comparison Matrix for the Main Criteria of Transportation, Construction, Energy

Sub-Criteria	TCE1	TCE2	TCE3	TCE4	TCE5	TCE6	TCE7	TCE8
TCE1	(1,00, 1,00, 1,00)	(0,14, 0,17, 0,20)	(0,14, 0,20, 0,33)	(0,20, 0,33, 1,00)	(0,11, 0,11, 0,14)	(0,20, 0,25, 0,33)	(0,33, 0,50, 1,00)	(0,11, 0,14, 0,20)
TCE2	(5,00, 6,00, 7,00)	(1,00, 1,00, 1,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(0,20, 0,33, 1,00)	(1,00, 3,00, 5,00)	(3,00, 5,00, 7,00)	(0,33, 0,50, 1,00)
TCE3	(3,00, 5,00, 7,00)	(0,33, 0,50, 1,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(0,14, 0,20, 0,33)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(0,20, 0,33, 1,00)
TCE4	(1,00, 3,00, 5,00)	(0,20, 0,25, 0,33)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(0,11, 0,14, 0,20)	(0,33, 0,50, 1,00)	(1,00, 2,00, 3,00)	(0,14, 0,20, 0,33)
TCE5	(7,00, 9,00, 9,00)	(0,20, 0,33, 1,00)	(3,00, 5,00, 7,00)	(5,00, 7,00, 9,00)	(1,00, 1,00, 1,00)	(5,00, 6,00, 7,00)	(7,00, 8,00, 9,00)	(1,00, 2,00, 3,00)
TCE6	(3,00, 4,00, 5,00)	(0,20, 0,33, 1,00)	(0,33, 0,50, 1,00)	(1,00, 2,00, 3,00)	(0,14, 0,17, 0,20)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(0,20, 0,25, 0,33)
TCE7	(1,00, 2,00, 3,00)	(0,14, 0,20, 0,33)	(0,20, 0,25, 0,33)	(0,33, 0,50, 1,00)	(0,11, 0,13, 0,14)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(0,14, 0,17, 0,20)
TCE8	(5,00, 7,00, 9,00)	(1,00, 2,00, 3,00)	(1,00, 3,00, 5,00)	(3,00, 5,00, 7,00)	(0,33, 0,50, 1,00)	(3,00, 4,00, 5,00)	(5,00, 6,00, 7,00)	(1,00, 1,00, 1,00)

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n} = \left[(1{,}00 \times 0{,}14 \times 0{,}14 \times 0{,}20 \times 0{,}11 \times 0{,}20 \times 0{,}33 \times 0{,}11)^{\frac{1}{8}};\ (1{,}00 \times 0{,}17 \times 0{,}20 \times 0{,}33 \times 0{,}11 \times 0{,}25 \times 0{,}50 \times 0{,}14)^{\frac{1}{8}};\ (1{,}00 \times 0{,}20 \times 0{,}33 \times 1{,}00 \times 0{,}14 \times 0{,}33 \times 1{,}00 \times 0{,}20)^{\frac{1}{8}}\right] = [0{,}21\ ;\ 0{,}26\ ;\ 0{,}40]$$

$\tilde{r}_2 = \left[(5{,}00 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 0{,}20 \times 1{,}00 \times 3{,}00 \times 0{,}33)^{\frac{1}{8}};\ (6{,}00 \times 1{,}00 \times 2{,}00 \times 4{,}00 \times 0{,}33 \times 3{,}00 \times 5{,}00 \times 0{,}50)^{\frac{1}{8}};\ (7{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 1{,}00 \times 5{,}00 \times 7{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [1{,}15\ ;\ 1{,}82\ ;\ 2{,}79]$

$\tilde{r}_3 = \left[(3{,}00 \times 0{,}33 \times 1{,}00 \times 1{,}00 \times 0{,}14 \times 1{,}00 \times 3{,}00 \times 0{,}20)^{\frac{1}{8}};\ (5{,}00 \times 0{,}50 \times 1{,}00 \times 3{,}00 \times 0{,}20 \times 2{,}00 \times 4{,}00 \times 0{,}33)^{\frac{1}{8}};\ (7{,}00 \times 1{,}00 \times 1{,}00 \times 5{,}00 \times 0{,}33 \times 3{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [0{,}74\ ;\ 1{,}19\ ;\ 1{,}91]$

$\tilde{r}_4 = \left[(1{,}00 \times 0{,}20 \times 0{,}20 \times 1{,}00 \times 0{,}11 \times 0{,}33 \times 1{,}00 \times 0{,}14)^{\frac{1}{8}};\ (3{,}00 \times 0{,}25 \times 0{,}33 \times 1{,}00 \times 0{,}14 \times 0{,}50 \times 2{,}00 \times 0{,}20)^{\frac{1}{8}};\ (5{,}00 \times 0{,}33 \times 1{,}00 \times 1{,}00 \times 0{,}20 \times 1{,}00 \times 3{,}00 \times 0{,}33)^{\frac{1}{8}}\right] = [0{,}35\ ;\ 0{,}54\ ;\ 0{,}87]$

$\tilde{r}_5 = \left[(7{,}00 \times 0{,}20 \times 3{,}00 \times 5{,}00 \times 1{,}00 \times 5{,}00 \times 7{,}00 \times 1{,}00)^{\frac{1}{8}};\ (9{,}00 \times 0{,}33 \times 5{,}00 \times 7{,}00 \times 1{,}00 \times 6{,}00 \times 8{,}00 \times 2{,}00)^{\frac{1}{8}};\ (9{,}00 \times 1{,}00 \times 7{,}00 \times 9{,}00 \times 1{,}00 \times 7{,}00 \times 9{,}00 \times 3{,}00)^{\frac{1}{8}}\right] = [2{,}79\ ;\ 4{,}17\ ;\ 5{,}20]$

$\tilde{r}_6 = \left[(3{,}00 \times 0{,}20 \times 0{,}33 \times 1{,}00 \times 0{,}14 \times 1{,}00 \times 1{,}00 \times 0{,}20)^{\frac{1}{8}};\ (4{,}00 \times 0{,}33 \times 0{,}50 \times 2{,}00 \times 0{,}17 \times 1{,}00 \times 3{,}00 \times 0{,}25)^{\frac{1}{8}};\ (5{,}00 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 0{,}20 \times 1{,}00 \times 5{,}00 \times 0{,}33)^{\frac{1}{8}}\right] = [0{,}52\ ;\ 0{,}80\ ;\ 1{,}22]$

$\tilde{r}_7 = \left[(1{,}00 \times 0{,}14 \times 0{,}20 \times 0{,}33 \times 0{,}11 \times 0{,}20 \times 1{,}00 \times 0{,}14)^{\frac{1}{8}};\ (2{,}00 \times 0{,}20 \times 0{,}25 \times 0{,}50 \times 0{,}13 \times 0{,}33 \times 1{,}00 \times 0{,}17)^{\frac{1}{8}};\ (3{,}00 \times 0{,}33 \times 0{,}33 \times 1{,}00 \times 0{,}14 \times 1{,}00 \times 1{,}00 \times 0{,}20)^{\frac{1}{8}}\right] = [0{,}27\ ;\ 0{,}37\ ;\ 0{,}56]$

$\tilde{r}_8 = \left[(5{,}00 \times 1{,}00 \times 1{,}00 \times 3{,}00 \times 0{,}33 \times 3{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}};\ (7{,}00 \times 2{,}00 \times 3{,}00 \times 5{,}00 \times 0{,}50 \times 4{,}00 \times 6{,}00 \times 1{,}00)^{\frac{1}{8}};\ (9{,}00 \times 3{,}00 \times 5{,}00 \times 7{,}00 \times 1{,}00 \times 5{,}00 \times 7{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [1{,}72\ ;\ 2{,}66\ ;\ 3{,}67]$

$\tilde{w}_1 = [(0{,}21 \times 0{,}06);\ (0{,}26 \times 0{,}08);\ (0{,}40 \times 0{,}13)] = [0{,}012\ ;\ 0{,}022\ ;\ 0{,}051]$

$\tilde{w}_2 = [(1{,}15 \times 0{,}06);\ (1{,}82 \times 0{,}08);\ (2{,}79 \times 0{,}13)] = [0{,}069\ ;\ 0{,}154\ ;\ 0{,}361]$
$\tilde{w}_3 = [(0{,}74 \times 0{,}06);\ (1{,}19 \times 0{,}08);\ (1{,}91 \times 0{,}13)] = [0{,}044\ ;\ 0{,}101\ ;\ 0{,}246]$
$\tilde{w}_4 = [(0{,}35 \times 0{,}06);\ (0{,}54 \times 0{,}08);\ (0{,}87 \times 0{,}13)] = [0{,}021\ ;\ 0{,}046\ ;\ 0{,}113]$
$\tilde{w}_5 = [(2{,}79 \times 0{,}06);\ (4{,}17 \times 0{,}08);\ (5{,}20 \times 0{,}13)] = [0{,}168\ ;\ 0{,}353\ ;\ 0{,}672]$

$\tilde{w}_6 = [(0{,}52 \times 0{,}06);\ (0{,}80 \times 0{,}08);\ (1{,}22 \times 0{,}13)] = [0{,}032\ ;\ 0{,}068\ ;\ 0{,}158]$
$\tilde{w}_7 = [(0{,}27 \times 0{,}06);\ (0{,}37 \times 0{,}08);\ (0{,}56 \times 0{,}13)] = [0{,}016\ ;\ 0{,}031\ ;\ 0{,}072]$
$\tilde{w}_8 = [(1{,}72 \times 0{,}06);\ (2{,}66 \times 0{,}08);\ (3{,}67 \times 0{,}13)] = [0{,}103\ ;\ 0{,}225\ ;\ 0{,}474]$

Table 12. Geometric Mean Values of the Criteria Based on the Main Criteria of Transportation, Construction, Energy

Sub-Criteria	$\tilde{r}_i$		
TCE1	0,21	0,26	0,40
TCE2	1,15	1,82	2,79
TCE3	0,74	1,19	1,91
TCE4	0,35	0,54	0,87
TCE5	2,79	4,17	5,20
TCE6	0,52	0,80	1,22
TCE7	0,27	0,37	0,56
TCE8	1,72	2,66	3,67
Total	7,74	11,81	16,62
Inverse Value	0,13	0,08	0,06
Increased Value	0,06	0,08	0,13

Table 13. Criteria Weights for Sub-Criteria Based on Transportation, Construction, Energy Main Criterion

	$\tilde{w}_i$		
TCE1	0,012	0,022	0,051
TCE2	0,069	0,154	0,361
TCE3	0,044	0,101	0,246
TCE4	0,021	0,046	0,113
TCE5	0,168	0,353	0,672
TCE6	0,032	0,068	0,158
TCE7	0,016	0,031	0,072
TCE8	0,103	0,225	0,474

Table 14. Clarified and Normalized Values for Sub-Criteria Based on the Main Criterion of Transportation, Construction, Energy

Sub-Criteria	M_i	N_i
TCE1	0,029	0,024
TCE2	0,195	0,162
TCE3	0,130	0,108
TCE4	0,060	0,050
TCE5	0,398	0,330
TCE6	0,086	0,071
TCE7	0,040	0,033
TCE8	0,268	0,222

Comparison Matrix for the Criteria of E

Table 15. Binary Comparison Matrix for Ecosystem Main Criterion

Sub-Criteria	E1	E2	E3	E4	E5	E6	E7	E8
E1	(1,00, 1,00, 1,00)	(1,00, 1,00, 1,00)	(7,00, 8,00, 9,00)	(5,00, 6,00, 7,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(5,00, 7,00, 9,00)	(1,00, 3,00, 5,00)
E2	(1,00, 1,00, 1,00)	(1,00, 1,00, 1,00)	(7,00, 9,00, 9,00)	(5,00, 7,00, 9,00)	(3,00, 4,00, 5,00)	(5,00, 6,00, 7,00)	(7,00, 8,00, 9,00)	(3,00, 5,00, 7,00)
E3	(0,11, 0,13, 0,14)	(0,11, 0,11, 0,14)	(1,00, 1,00, 1,00)	(0,20, 0,33, 1,00)	(0,14, 0,17, 0,20)	(0,20, 0,25, 0,33)	(0,33, 0,50, 1,00)	(0,14, 0,20, 0,33)
E4	(0,14, 0,17, 0,20)	(0,11, 0,14, 0,20)	(1,00, 3,00, 5,00)	(1,00, 1,00, 1,00)	(0,14, 0,20, 0,33)	(0,25, 0,33, 1,00)	(3,00, 4,00, 5,00)	(0,20, 0,25, 0,33)
E5	(0,33, 0,50, 1,00)	(0,20, 0,25, 0,33)	(5,00, 6,00, 7,00)	(3,00, 5,00, 7,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(5,00, 6,00, 7,00)	(1,00, 2,00, 3,00)
E6	(0,20, 0,25, 0,33)	(0,14, 0,17, 0,20	(3,00, 4,00, 5,00)	(1,00, 3,00, 5,00)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(1,00, 3,00, 5,00)	(0,33, 0,50, 1,00)
E7	(0,11, 0,14, 0,20)	(0,11, 0,13, 0,14)	(1,00, 2,00, 3,00)	(0,20, 0,25, 0,33)	(0,14, 0,17, 0,20)	(0,20, 0,33, 1,00)	(1,00, 1,00, 1,00)	(0,20, 0,25, 0,33)
E8	(0,20, 0,33, 1,00)	(0,14, 0,20, 0,33)	(3,00, 5,00, 7,00)	(3,00, 4,00, 5,00)	(0,33, 0,50, 1,00)	(1,00, 2,00, 3,00)	(3,00, 4,00, 5,00)	(1,00, 1,00, 1,00)

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \widetilde{a_{ij}}\right)^{1/n} = \left[(1{,}00 \times 1{,}00 \times 7{,}00 \times 5{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}};\ (1{,}00 \times 1{,}00 \times 8{,}00 \times 6{,}00 \times 2{,}00 \times 4{,}00 \times 7{,}00 \times 3{,}00)^{\frac{1}{8}};\ (1{,}00 \times 1{,}00 \times 9{,}00 \times 7{,}00 \times 3{,}00 \times 5{,}00 \times 9{,}00 \times 5{,}00)^{\frac{1}{8}}\right] = [2{,}19\ ;\ 3{,}08\ ;\ 3{,}79]$$

$$\tilde{r}_2 = \left[(1{,}00 \times 1{,}00 \times 7{,}00 \times 5{,}00 \times 3{,}00 \times 5{,}00 \times 7{,}00 \times 3{,}00)^{\frac{1}{8}};\ (1{,}00 \times 1{,}00 \times 9{,}00 \times 7{,}00 \times 4{,}00 \times 6{,}00 \times 8{,}00 \times 5{,}00)^{\frac{1}{8}};\ (1{,}00 \times 1{,}00 \times 9{,}00 \times 9{,}00 \times 5{,}00 \times 7{,}00 \times 9{,}00 \times 7{,}00)^{\frac{1}{8}}\right] = [3{,}20\ ;\ 3{,}96\ ;\ 4{,}53]$$

$$\tilde{r}_3 = \left[(0{,}11 \times 0{,}11 \times 1{,}00 \times 0{,}20 \times 0{,}14 \times 0{,}20 \times 0{,}33 \times 0{,}14)^{\frac{1}{8}};\ (0{,}13 \times 0{,}11 \times 1{,}00 \times 0{,}33 \times 0{,}17 \times 0{,}25 \times 0{,}50 \times 0{,}20)^{\frac{1}{8}};\ (0{,}14 \times 0{,}14 \times 1{,}00 \times 1{,}00 \times 0{,}20 \times 0{,}33 \times 1{,}00 \times 0{,}33)^{\frac{1}{8}}\right] = [0{,}21\ ;\ 0{,}26\ ;\ 0{,}38]$$

$$\tilde{r}_4 = \left[(0{,}14 \times 0{,}11 \times 1{,}00 \times 1{,}00 \times 0{,}14 \times 0{,}25 \times 3{,}00 \times 0{,}20)^{\frac{1}{8}};\ (0{,}17 \times 0{,}14 \times 3{,}00 \times 1{,}00 \times 0{,}20 \times 0{,}33 \times 4{,}00 \times 0{,}25)^{\frac{1}{8}};\ (0{,}20 \times 0{,}20 \times 5{,}00 \times 1{,}00 \times 0{,}33 \times 1{,}00 \times 5{,}00 \times 0{,}33)^{\frac{1}{8}}\right] = [0{,}36\ ;\ 0{,}51\ ;\ 0{,}76]$$

$$\tilde{r}_5 = \left[(0{,}33 \times 0{,}20 \times 5{,}00 \times 3{,}00 \times 1{,}00 \times 1{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}};\ (0{,}50 \times 0{,}25 \times 6{,}00 \times 5{,}00 \times 1{,}00 \times 3{,}00 \times 6{,}00 \times 2{,}00)^{\frac{1}{8}};\ (1{,}00 \times 0{,}33 \times 7{,}00 \times 7{,}00 \times 1{,}00 \times 5{,}00 \times 7{,}00 \times 3{,}00)^{\frac{1}{8}}\right] = [1{,}22\ ;\ 1{,}85\ ;\ 2{,}54]$$

$$\tilde{r}_6 = \left[(0{,}20 \times 0{,}14 \times 3{,}00 \times 1{,}00 \times 0{,}20 \times 1{,}00 \times 1{,}00 \times 0{,}33)^{\frac{1}{8}};\ (0{,}25 \times 0{,}17 \times 4{,}00 \times 3{,}00 \times 0{,}33 \times 1{,}00 \times 3{,}00 \times 0{,}50)^{\frac{1}{8}};\ (0{,}33 \times 0{,}20 \times 5{,}00 \times 5{,}00 \times 1{,}00 \times 1{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [0{,}52\ ;\ 0{,}84\ ;\ 1{,}30]$$

$$\tilde{r}_7 = \left[(0{,}11 \times 0{,}11 \times 1{,}00 \times 0{,}20 \times 0{,}14 \times 0{,}20 \times 1{,}00 \times 0{,}20)^{\frac{1}{8}};\ (0{,}14 \times 0{,}13 \times 2{,}00 \times 0{,}25 \times 0{,}17 \times 0{,}33 \times 1{,}00 \times 0{,}25)^{\frac{1}{8}};\ (0{,}20 \times 0{,}14 \times 3{,}00 \times 0{,}33 \times 0{,}20 \times 1{,}00 \times 1{,}00 \times 0{,}33)^{\frac{1}{8}}\right] = [1{,}72\ ;\ 2{,}66\ ;\ 3{,}67]$$

$$\tilde{r}_8 = \left[(0{,}20 \times 0{,}14 \times 3{,}00 \times 3{,}00 \times 0{,}33 \times 1{,}00 \times 3{,}00 \times 1{,}00)^{\frac{1}{8}};(0{,}33 \times 0{,}20 \times 5{,}00 \times 4{,}00 \times 0{,}50 \times 2{,}00 \times 4{,}00 \times 1{,}00)^{\frac{1}{8}};\ (1{,}00 \times 0{,}33 \times 7{,}00 \times 5{,}00 \times 1{,}00 \times 3{,}00 \times 5{,}00 \times 1{,}00)^{\frac{1}{8}}\right] = [0{,}84\ ;\ 1{,}23\ ;\ 1{,}91]$$

$$\widetilde{w_1} = [(2{,}19 \times 0{,}06);\ (3{,}08 \times 0{,}08);\ (3{,}79 \times 0{,}11)] = [0{,}147\ ;\ 2{,}497\ ;\ 4{,}491]$$
$$\widetilde{w_2} = [(3{,}20 \times 0{,}06);\ (3{,}96 \times 0{,}08);\ (4{,}53 \times 0{,}11)] = [1{,}168\ ;\ 3{,}212\ ;\ 5{,}373]$$
$$\widetilde{w_3} = [(0{,}21 \times 0{,}06);\ (0{,}26 \times 0{,}08);\ (0{,}38 \times 0{,}11)] = [0{,}108\ ;\ 0{,}209;\ 0{,}453]$$
$$\widetilde{w_4} = [(0{,}36 \times 0{,}06);\ (0{,}51 \times 0{,}08);\ (0{,}76 \times 0{,}11)] = [0{,}188\ ;\ 0{,}416\ ;\ 0{,}900]$$
$$\widetilde{w_5} = [(1{,}22 \times 0{,}06);\ (1{,}85 \times 0{,}08);\ (2{,}54 \times 0{,}11)] = [0{,}641\ ;\ 1{,}498\ ;\ 3{,}006]$$
$$\widetilde{w_6} = [(0{,}52 \times 0{,}06);\ (0{,}84 \times 0{,}08);\ (1{,}30 \times 0{,}11)] = [0{,}275\ ;\ 0{,}682\ ;\ 1{,}545]$$
$$\widetilde{w_7} = [(0{,}25 \times 0{,}06);\ (0{,}32 \times 0{,}08);\ (0{,}46 \times 0{,}11)] = [0{,}130\ ;\ 0{,}264\ ;\ 0{,}542]$$
$$\widetilde{w_8} = [(0{,}84 \times 0{,}06);\ (1{,}23 \times 0{,}08);\ (1{,}91 \times 0{,}11)] = [0{,}442\ ;\ 1{,}000\ ;\ 2{,}260]$$

Table 16. Geometric Mean Values of the Criteria Based on the Main Criterion of the Ecosystem

Sub-Criteria	$\tilde{r}_i$		
E1	2,19	3,08	3,79
E2	3,20	3,96	4,53
E3	0,21	0,26	0,38
E4	0,36	0,51	0,76
E5	1,22	1,85	2,54
E6	0,52	0,84	1,30
E7	0,25	0,32	0,46
E8	0,84	1,23	1,91
Total	8,79	12,05	15,67
Inverse Value	0,11	0,08	0,06
Ascending Sort	0,06	0,08	0,11

Table 17. Criteria Weights for Sub-Criteria Based on the Main Criterion of Ecosystem

Main Criteria	$\widetilde{w_i}$		
E1	1,147	2,497	4,491
E2	1,168	3,212	5,373
E3	0,108	0,209	0,453
E4	0,188	0,416	0,900
E5	0,641	1,498	3,006
E6	0,275	0,682	1,545
E7	0,130	0,264	0,542
E8	0,442	1,000	2,260

Table 18. Clarified and Normalized Values for Sub-Criteria Based on the Main Criterion of the Ecosystem

Main Criteria	M_i	N_i
E1	2,712	2,197
E2	3,421	2,772
E3	0,257	0,208
E4	0,501	0,406
E5	1,715	1,390
E6	0,834	0,676
E7	0,312	0,253
E8	1,234	1,000

Table 19. Result Weight Table for all Criteria

Main Criteria	Local Weights of Main Criteria	Sub-Criteria	Local Weights of Sub-Criteria	Global Weights of the Criteria
EC	0,629	EC1	0,104	0,065
		EC2	0,236	0,149
		EC3	0,311	0,196
		EC4	0,160	0,101
		EC5	0,080	0,050
		EC6	0,052	0,033
		EC7	0,037	0,023
		EC8	0,020	0,012
TCE	0,176	TCE1	0,024	0,004
		TCE2	0,162	0,028
		TCE3	0,108	0,019
		TCE4	0,050	0,009
		TCE5	0,330	0,058
		TCE6	0,071	0,013
		TCE7	0,033	0,006
		TCE8	0,222	0,039
E	0,195	E1	0,247	0,048
		E2	0,314	0,061
		E3	0,023	0,005
		E4	0,045	0,009
		E5	0,155	0,030
		E6	0,075	0,015
		E7	0,028	0,006
		E8	0,112	0,022

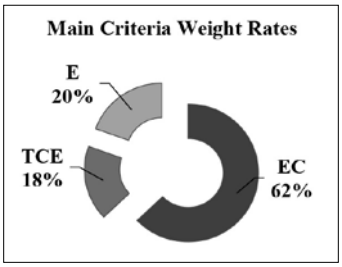

Figure 2. Evaluation of the Main Criteria by Fuzzy AHP

As a result of evaluating the main criteria with the Fuzzy AHP approach, the most important main criterion according to Figure 2 is the Environment and City criteria with 62 % ratio, followed by Ecosystem criteria with 20 % ratio and Transportation, Construction and Energy criteria with 18 % ratio.

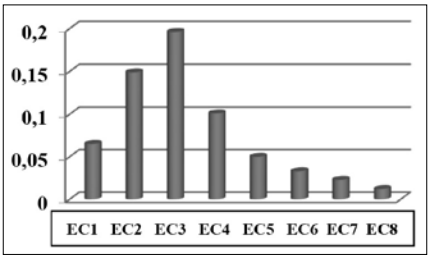

Figure 3. Assessment of the Environment and City Main Criteria

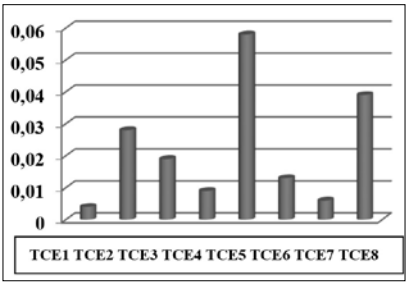

Figure 4. Evaluation of the Main Criteria of Transportation, Construction, Energy

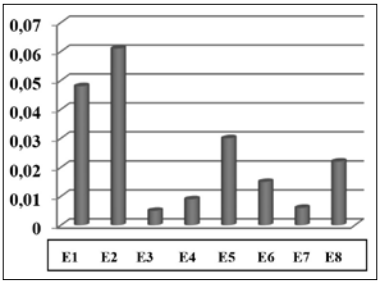

Figure 5. Evaluation of the Ecosystem Main Criteria

When the main criteria of Environment and City in Figure 3 are considered, "Existence of inventory of CO_2 emissions and ensuring the controls for these emissions" is determined as the most important criterion. And the second most important criterion is "Having budgets allocated by local government about the climate change and combating climate change issues". The least important criterion is determined as "Existence of wastewater treatment and waste recovery and recycling facilities". When the main criterion of Environment and City in Figure 4 is considered, "Existence of lighting tools using energy efficient and/or alternative energy sources in public lighting" is determined as the most important criterion. And the second most important criterion is determined as "Existence of smart systems such as lighting systems that provide energy efficiency in buildings." "Existence of projects and/or studies about gaining historical and/or cultural structures to tourism" is determined as the least important criterion. And finally, when the main criteria of Environment and City in Figure 5 are considered, **"**Existence of ecological, good, sustainable and/or organic agricultural practices**"** is determined as the most important criterion. And the second most important criterion is determined as "Having biodiversity inventory and monitoring plans". "Using drip irrigation method in agriculture" is determined as the least important criterion.

When the data in Figure 6 is examined, as a result of reflecting the main criteria weights to the sub-criteria and considering all of them together, it is seen that the most prominent criterion is "Existence of inventory of CO_2 emissions and ensuring the controls for these emissions". When weight levels are taken into consideration, it is seen that there are much-weighted criteria that are concentrated in sub-criteria related to Environment and City main criterion and less weighted criteria are concentrated in sub-criteria related to Transportation, Construction and Energy main criterion. The reason for this can be said that the weight levels of the main criteria have a significant effect on the result and ultimately affect the criteria ranking.

When viewed spatially; it is known that especially some types of fuels used in transportation and construction are effective in increasing greenhouse gas emissions. Therefore, in order to provide energy efficiency in urban, the use of alternative energy sources and alternative modes of transportation and spatial structuring in harmony with nature are important. In this regard, countries are taking various measures and implementing various plans such as national and local climate change action plans. In this context, findings obtained from the analysis show that parallel results are formed in this direction.

Finally, the integrity and balance within the ecosystem in rural and non-urban areas are mainly impaired by human activities; hence, these criteria seem to have less importance. Because environmental problems and climate changes due to human activities and the effects of globalization are mostly caused by global warming and the activites in urban area. It is seen that the findings obtained in this analysis are in this direction also.

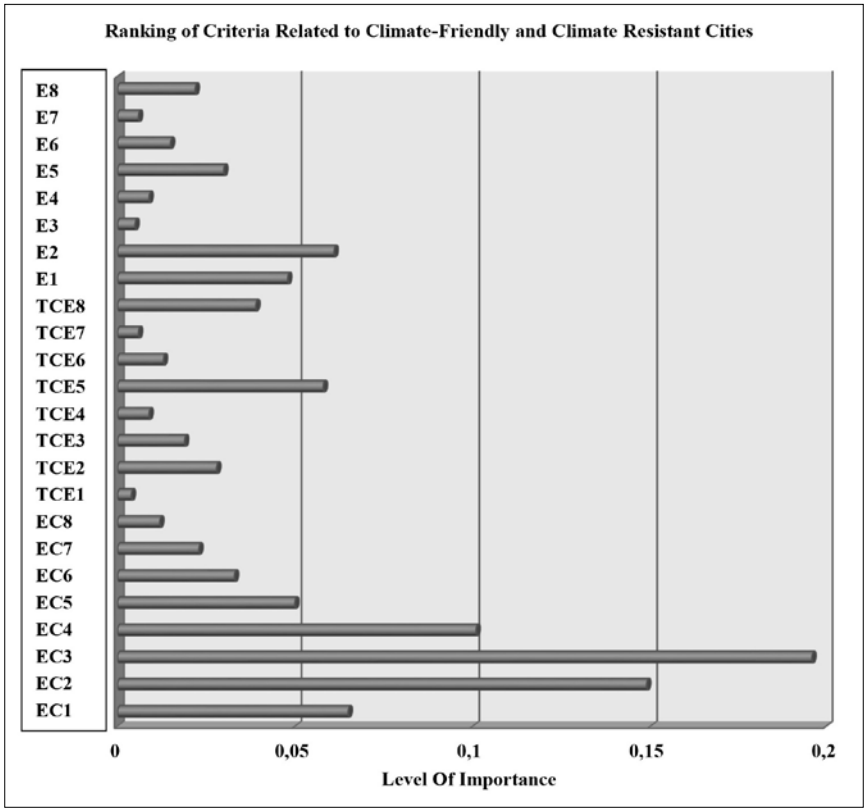

Figure 6. Sequencing of Weighting all Criteria with Fuzzy AHP Approach

5. CONCLUSION

In this study, primarily climate friendly and climate resilient cities have been identified and then In order to prioritize and weighting the criteria that are to be expected in these cities, in line with the opinions of experts a solution was searched with Fuzzy AHP approach which is one of the Multi-Criteria Decision Making approaches. Literature was used in the process of determining criteria and after evaluation of the created criteria list by different evaluators the final results were obtained. According to this, when all the main criteria and sub-criteria are considered, the most important criterion is determined as "Existence of inventory of CO_2 emissions and ensuring the controls for these emissions" and the least important criterion is determined as "Existence of projects and/or studies about gaining historical and/or cultural structures to tourism". After the ranking of the criteria obtained according to these results, it was observed that the main criteria of environment and city were more dominant than the other criteria. Based on the findings obtained in this study, by focusing on the main criteria of the environment and the city for future strategic regulations and applications, it would be beneficial to prepare the mentioned inventories both at provincial level and sectoral level. As a result, climate-friendly and climate-resilient cities and local climate change action plans, which are tried to be put forward conceptually, should be created especially for future generations, and urban transformation should be transformed into an opportunity to transform into climate-friendly and climate-resilient cities.

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