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EVALUATION OF THE LIVABILITY LEVELS OF METROPOLITAN CITIES BY DEMATEL-BASED ANALYTIC NETWORK PROCESS (DANP) AND MAIRCA METHODS

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ABSTRACT

Businesses or organizations are constantly faced with the obligation to make decisions during their activities. In the decision-making problems encountered, decision alternatives are evaluated according to the criteria set for purposes, and it is aimed to choose the alternative that gives the best results according to all criteria. In these decision-making problems, heuristic methods are used, and data-based scientific methods are widely preferred to achieve more objective and accurate results. Multiple criteria decisions making (MCDM) methods are expressed as the evaluation of alternatives according to multiple decision criteria in decision making problems and the methods used to determine the appropriate alternative that best meets all criteria. In the literature, there are many MCDM methods applied for this purpose. DANP (Dematel Based Analytic Network Process) and MAIRCA (Multi Attributive Ideal-Real Comparative Analysis) are two of these MCDM methods. In this study, 30 metropolitan cities in Turkey were ranked according to the livability criteria by DANP and MAIRCA methods. The weights of the criteria determined by the DANP method were calculated, and metropolitan cities were ranked according to their livability level by the MAIRCA method.

Keywords: Dematel based analytical network process, MAIRCA, livability level.

INTRODUCTION

Businesses are faced with making choices among different alternatives according to their goals and targets in decision-making processes. These alternatives are evaluated according to the criteria determined in line with the aims and objectives and an optimal decision is tried to be made for the enterprise.

Businesses or organizations use multiple criteria decision-making methods to ensure that data-based scientific results are achieved instead of evaluating decisions according to multiple criteria and intuitive methods. Multiple criteria decision-making methods can be defined as the methods that enable the determination of the most suitable decision alternative according to multiple and many conflicting decision criteria (Ayçin, 2019).

The effort for livable city development is to assure a balanced development of a city and its composite parts by satisfying the wellbeing of its residents in the present while not harming their lifestyles in the future. Such a goal can be implemented by employing various social, economic, and environmental methods as well as methods from other scholarly fields. The endeavors for livable city development are for decreasing poverty, improving the quality of life and social contacts as well as community relationships by satisfying major human needs and fostering economic and political developments that are conducive while attempting to avoid damaging the natural resources. It is possible to perceive a unity of contradictions in the sustainable development of cities when some goals contradict others. Hence, the methods of multiple criteria analyses are most suitable for analyzing sustainable city developments (Kaklauskas et al., 2018).

Some of the most widely used multiple criteria decision-making methods applied in the literature are AHP, ANP, DEMATEL, TOPSIS, PROMETHEE and ELECTRE. The MAIRCA (Multi Attributive Ideal-Real Comparative Analysis) method is one of the multiple criteria decision-making methods used to determine the decision alternative that best meets all criteria. The MAIRCA method, which is based on the selection of the alternative with the lowest gap value according to the ideal rating values, has been used in the solution of different decision-making problems in the literature. In this study, 30 metropolitan cities in Turkey were ranked according to their livability with DANP (Dematel Based Analytic Network Process) and MAIRCA methods. For this purpose, firstly DANP method was applied to determine the weight values of the criteria, and in the next step, the metropolitan cities were ranked by their livability using MAIRCA method.

LITERATURE REVIEW

MAIRCA method has been used in the literature in the solution of enterprises' problems and the different decision-making problems together with many multiple criteria decision-making methods. Gigovic et al. (2016) used the GIS (Geographic Information Systems) and the MAIRCA method together in the selection of ammunition depots. Pamucar et al. (2017) introduced a hybrid decision-making model in which IR'DANP (Interval Rough DANP) and MAIRCA methods were implemented together to provide more objective decision-making. Chatterjee et al. (2017) used a model in the electronics industry in which the R'DEMATEL (Rough

DEMATEL) and the MAIRCA methods were used to evaluate the performance of suppliers in the green supply chain application. Pamucar et al. (2018) used DEMATEL and MAIRCA methods in the selection of a multi-purpose logistics centre. Stojic et al. (2018) conducted a comparative analysis of the results obtained by the R'WASPAS (Rough Weighted Aggregated Sum-Product Assessment) method with the results obtained by the Rough MAIRCA method in the selection of the PVC manufacturer. Arsic et al. (2019) used MAIRCA and BW (Best - Worst Method) methods in the selection of menus to be offered to customers in a restaurant.

In the literature, there are some studies where the livability assessments of countries or cities are made by MCDM methods. Karaatlı et al. (2015), in their studies considering the criteria of economy, education, health, security, urban life and culture-art, evaluated the livability levels of the provinces comparatively with SAW, TOPSIS and Gray Relational Analysis methods. Şahin and Öztel (2017) evaluated the BRIC countries and Turkey's livability levels using the COPRAS method. As evaluation criteria, they considered the gross domestic product, population density, average life expectancy, unemployment rate, human development index. Kaklauskas et al. (2018) conducted a study comparing the rankings obtained with the INVAR and COPRAS method to evaluate the quality of life related to the sustainable development of cities. Onnom et al. (2018) has presented a ranking index determined as “Livable City Index” which is determined by using analytical hierarchy process and geographic information system to analyze the livability levels of cities. Aksoy and Yaylagul (2019) have applied a model that uses the analytical hierarchy process to analyze the livability of cities for the older people. Özbek (2019) evaluated the provinces in Turkey based on the livability criteria determined according to the life index data and obtained the livability rankings of the provinces by using EDAS and WASPAS methods. Chen (2020) used an integrated model using fuzzy neural network, principal component analysis, TOPSIS method and Hopfield Neural Network methods to analyze the livability of cities.

METHODOLOGY

This section reviews some definitions about Dematel based Analytical Network Process (DANP) and MAIRCA methods.

Dematel Based Analytical Network Process (DANP)

DEMATEL-based Analytical Network Process (DANP) is a technique applied with the combination of DEMATEL and Analytical network process techniques. By applying DEMATEL and analytical network process methods together, both the relationships between criteria and the weights of the criteria can be determined (Çakın & Özdemir, 2015: 125). DANP is a convenient method for solving real-life decision-making problems with interactively connected criteria and dimensions. DANP provides an opportunity to evaluate the relationships of features and variables with each other since it is conducive to reveal the relationships in a concrete way (Chiu et al., 2013: 50). In addition to determining the influential weights of the criteria sets in the DANP method, the total influence matrix of the DEMATEL method is normalized and included in the unweighted supermatrix formed in the ANP method. In this way, the interaction between criteria sets, which are important in terms of the solution of the problem, is determined by the DEMATEL method, and the solution is reached by the analytic network process algorithm (Lee et al., 2011: 8378).

When the interactions of the criteria are determined using ANP method only, after determining the relationships between the criteria, the superiority value determined in the pairwise comparison is determined as the opposite of each other. However, since the level of the relationship between the criteria in the DANP method is determined according to the DEMATEL scale, the direct impact coefficient of the criteria can be determined independently from each other.

In the implementation of the DANP method, firstly the stages of DEMATEL method are followed and the direct-relation matrix is reached. In the first step, the DEMATEL scale given in Table 1 is used in the formation of the direct-relation matrix (Wu, 2008).

Table 1. DEMATEL Scale

Influence Score	Linguistic Term
0	No Influence
1	Very Low Influence
2	Moderate Influence
3	High Influence
4	Extremely High Influence

A direct relation matrix is created in the form of a n*n matrix to show the degree of influence of the criteria on each other. The coefficient of the effect of factor i on factor j may be different from the coefficient of the effect of factor j on factor i. An example direct relation matrix is shown in Equation (1).

$$D = \begin{bmatrix} d_{11} & d_{1j} & d_{1n} \\ \vdots & \vdots & \vdots \\ d_{i1} & d_{ij} & d_{in} \\ \vdots & \vdots & \vdots \\ d_{n1} & d_{nj} & d_{nn} \end{bmatrix} \qquad (1)$$

In the second step, the direct correlation matrix will be normalized. It is obtained by multiplying the inverse of the largest value in rows and columns by its values in the matrix, depending on the direct relationship matrix. The normalization process is shown in Equations (2) and (3).

$$X = s.D \qquad (2)$$

$$s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n} |d_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |d_{ij}|}\right] \qquad (3)$$

In the third step, the total relation matrix, which will form the basis for determining cause and effect criteria, is obtained by multiplying the matrix obtained by subtracting the normalized direct relation matrix from the unit matrix as shown in Equation 5.

$$T = X + X^2 + \cdots + X^h = X(I - X)^{-1} \quad (4)$$

$$T = \begin{bmatrix} t_{11} & t_{1j} & t_{1n} \\ \vdots & \vdots & \vdots \\ t_{i1} & t_{ij} & t_{in} \\ \vdots & \vdots & \vdots \\ t_{n1} & t_{nj} & t_{nn} \end{bmatrix} \quad (5)$$

After the total effect matrix is obtained, the rows of the matrix are summed separately, and the value in each row is divided by the row total and the matrix is normalized as shown in Equation (6) (Çakın and Özdemir, 126).

$$T = \begin{bmatrix} t_{11}/t_1 & . & t_{1j}/t_1 & . & t_{1m}/t_1 \\ . & & . & & . \\ t_{i1}/t_2 & . & t_{ij}/t_2 & . & t_{im}/t_2 \\ . & & . & & . \\ t_{m1}/t_3 & . & t_{mj}/t_3 & . & t_{mm}/t_3 \end{bmatrix} = \begin{bmatrix} t_{nor}^{11} & . & t_{nor}^{1j} & . & t_{nor}^{1m} \\ . & & . & & . \\ t_{nor}^{i1} & . & t_{nor}^{ij} & . & t_{nor}^{im} \\ . & & . & & . \\ t_{nor}^{m1} & . & t_{nor}^{mj} & . & t_{nor}^{mm} \end{bmatrix} \quad (6)$$

After normalization, transpose of the matrix is obtained by the row and column values being displaced, resulting in unweighted supermatrix. However, here, unlike ANP applications, having a space or "0" value in the matrix means that the criterion does not affect the other one and that they are independent of each other (Chiu et al., 2013: 52). Unweighted supermatrix is shown in Equation (7).

$$U = (T_{nor})' \begin{bmatrix} u_{11} & . & u_{i1} & . & u_{m1} \\ . & & . & & . \\ u_{1j} & . & u_{ij} & . & u_{mj} \\ . & & . & & . \\ u_{1m} & . & u_{im} & . & u_{mm} \end{bmatrix} \quad (7)$$

After obtaining the unweighted supermatrix, the weighted supermatrix is obtained by multiplying the unweighted supermatrix with the normalized total relation matrix as shown in Equation (8) (Govindan et al., 2015: 6352).

$$W = (T_{nor} * U) \begin{bmatrix} u_{11} * t_{nor}^{11} & . & u_{i1} * t_{nor}^{1j} & . & u_{m1} * t_{nor}^{1m} \\ . & & . & & . \\ u_{1j} * t_{nor}^{i1} & . & u_{ij} * t_{nor}^{ij} & . & u_{mj} * t_{nor}^{im} \\ . & & . & & . \\ u_{1m} * t_{nor}^{m1} & . & u_{im} * t_{nor}^{mj} & . & u_{mm} * t_{nor}^{mm} \end{bmatrix} \quad (8)$$

In the last step, as in the analytic network process method, the limit supermatrix is obtained by taking the power of the weighted supermatrix multiple times, and the final weight values are calculated (Hu et al., 2014: 4407).

MAIRCA

MAIRCA (MultiAttributive Ideal-Real Comparative Analysis) method is one of the multiple criteria decision-making methods introduced to literature by Gigovic et al. The MAIRCA method is based on defining gaps between ideal and empirical ratings. By summing the gaps for each criterion, the total gap for decision alternatives is obtained. At the end of the process, the alternative with the values closest to the ideal ratings according to most of the criteria, or in other words the alternative with the lowest total gap value, will obtain the best ranking (Gigovic et al., 2016: 11; Pamucar et al., 2017: 58).

The MAIRCA method has an implementation process consisting of eight steps (Pamucar et al., 2018: 1646-1648):

Step 1: Forming the Initial Decision Matrix (X): The criterion values $(\mathrm{C_j})$ obtained from each alternative $(\mathrm{A_i})$ are shown in Equation (9).

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{matrix} \mathrm{C_1} & \mathrm{C_2} & \dots & \mathrm{C_n} \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{array} \tag{9}$$

The criteria in the X matrix can be qualitative or quantitative. While the values that an alternative receives from quantitative criteria are directly reflected, the values of qualitative criteria are created with the priorities of the decision-makers.

Step 2: Determining the priorities of alternatives: The decision-maker's neutrality in choosing alternatives means that none of the proposed alternatives has a priority. It is an assumption of the method that the probability values for selecting any alternative of the decision maker are not assigned and that there is no priority in the alternative selection process. The priority of the alternative i $(\mathrm{P_{Ai}})$ is calculated as shown in the equation (10) m as the total number of alternatives.

$$P_{Ai} = \frac{1}{m}; \qquad \sum_{i=1}^{m} P_{Ai} = 1 \qquad i = 1, 2, \dots, m \tag{10}$$

The decision-maker is at an equal distance to each alternative. Therefore, all priorities are equal, as shown in Equation (11).

$$P_{A1} = P_{A2} = \cdots = P_{Am} \tag{11}$$

Step 3: Creation of the Theoretical Evaluation Matrix (T_p): The elements of the matrix $(\mathrm{t_{pij}})$ are calculated by multiplying the priorities of the alternatives $(\mathrm{P_{Ai}})$ and the criteria weights $(\mathrm{w_j})$.

$$T_p = \begin{array}{c} \\ P_{A1} \\ P_{A2} \\ \vdots \\ P_{Am} \end{array} \begin{array}{c} \begin{matrix} w_1 & w_2 & \dots & w_n \end{matrix} \\ \begin{bmatrix} t_{p11} & t_{p12} & \dots & t_{p1n} \\ t_{p21} & t_{p22} & \dots & t_{p2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{pm1} & t_{pm2} & \dots & t_{pmn} \end{bmatrix} \end{array} \begin{array}{c} \\ P_{A1} \\ P_{A2} \\ \vdots \\ P_{Am} \end{array} \begin{array}{c} \begin{matrix} w_1 & w_2 & \dots & w_n \end{matrix} \\ \begin{bmatrix} P_{A1}.w_1 & P_{A1}.w_2 & \dots & P_{A1}.w_n \\ P_{A2}.w_1 & P_{A2}.w_2 & \dots & P_{A2}.w_n \\ \vdots & \vdots & \ddots & \vdots \\ P_{Am}.w_1 & P_{Am}.w_2 & \dots & P_{Am}.w_n \end{bmatrix} \end{array} \tag{12}$$

Since all alternatives have equal priorities (T_p), their matrix can be represented as the row vector as in Equation (13).

$$T_p = \begin{matrix} & w_1 & w_2 & \dots & w_n \\ P_{Ai} & [t_{p1} & t_{p2} & \dots & t_{pn}] \end{matrix} \qquad \begin{matrix} & w_1 & w_2 & \dots & w_n \\ P_{Ai} & [P_{Ai}.w_1 & P_{Ai}.w_2 & \dots & P_{Ai}.w_n] \end{matrix} \tag{13}$$

Step 4: Defining the Real Evaluation Matrix (T_r)*:* The elements of the real evaluation matrix are shown in Equation (14).

$$T_r = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} t_{r11} & t_{r12} & \dots & t_{r1n} \\ t_{r21} & t_{r22} & \dots & t_{r2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{rm1} & t_{rm2} & \dots & t_{rmn} \end{bmatrix} \end{matrix} \tag{14}$$

To obtain the matrix (T_r), the theoretical evaluation matrix (T_p) and the initial decision matrix (X) are used. Matrix elements should be calculated using Equation (15) for utility-based criteria and by using the Equation (16) for cost-based criteria.

$$t_{rij} = t_{pij} \cdot \left(\frac{x_{ij} - x_{ij}^-}{x_{ij}^+ - x_{ij}^-} \right) \tag{15}$$

$$t_{rij} = t_{pij} \cdot \left(\frac{x_{ij} - x_{ij}^+}{x_{ij}^- - x_{ij}^+} \right) \tag{16}$$

x_{ij}^+ the largest value $(x_{ij}^+ = \max(x_1, x_2, \dots, x_m))$ that the criterion receives from the alternative, and x_{ij}^- the smallest value $(x_{ij}^- = \min(x_1, x_2, \dots, x_m))$ that the criterion receives from the alternative.

Step 5: Calculation of the Total Gap Matrix (G)*:* The Gap Matrix is calculated as shown in Equation (17) - (18) by subtracting the real evaluation matrix $(\mathrm{T_r})$ from the theoretical evaluation matrix $(\mathrm{T_p})$.

$$G = T_p - T_r = \begin{bmatrix} g_{11} & g_{12} & \dots & g_{1n} \\ g_{21} & g_{22} & \dots & g_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ g_{m1} & g_{m2} & \dots & g_{mn} \end{bmatrix} \tag{17}$$

$$g_{ij} = t_{pij} - t_{rij} \qquad g_{ij} \in [0, \infty) \tag{18}$$

Step 6: Defining the Total Gap with Alternatives: If the theoretical rating (t_{pij}) and the actual rating of an alternative (t_{rij}) for a criterion(C_j) are equal and different from zero, the gap will be zero $(g_{ij} = 0)$, in this case, this alternative (A_i) would be the ideal alternative (A_i^+) for this criterion(C_j).

If the theoretical rating (t_{pij}) and the actual rating of an alternative (t_{rij}) for a criterion (C_j) are equal to zero: $(t_{pij} = t_{rij} = g_{ij} = 0)$, in this case, this alternative (A_i) would be the worst alternative (A_i^-) for this criterion (C_j).

Step 7: Calculation of the Value of the Final Criteria Functions of Alternatives $(\mathrm{Q_i})$*:* The value of the criteria functions is calculated as shown in Equation (19) by summing the columns of the gap matrix (G) for each alternative.

$$Q_i = \sum_{j=1}^{n} g_{ij} \ , \quad i = 1, 2, \dots, m \qquad (19)$$

Step 8: Selection of the Best Alternative: Alternatives are ranked according to their final criterion function values. The alternative with the smallest final criterion function value is determined as the best alternative.

CASE STUDY

In this study, it was aimed to rank metropolitan cities in Turkey according to their livability level. In order to rank the metropolitan cities according to their livability level, multiple criteria decision-making methods, DANP (Dematel-based analytic network process) and MAIRCA were used. In the first stage, livability criteria were determined for the metropolitan cities. The first of these criteria was determined as population density (C1) and the second criterion as the life satisfaction scores in metropolitan cities (C6) were taken based on the results of the life satisfaction survey by provinces conducted by TUİK (C2). The third criterion was determined as the gross domestic product per capita-TL (C3) and the fourth criterion as the average life expectancy (C4). The fifth criterion was determined as the number of physicians per thousand person (C5) and the sixth criterion as the number of students per class (C5) in primary and secondary education According to the six criteria, the decision matrix is generated with the data of 2018 and presented in Table 2.

Table 2. Decision Matrix

Cities/Criteria	C1	C2	C3	C4	C5	C6
Adana	159,29	53,00	28.221	77,4	2	29
Ankara	222,06	56,23	52.000	79,4	3	25
Antalya	114,10	49,79	38.408	79,2	2	22
Aydın	137,67	53,46	28.072	78,7	2	18
Balıkesir	84,26	70,73	32.127	77,6	1	19
Bursa	281,79	61,10	43.707	77,5	2	28
Denizli	87,13	56,74	35.745	78,8	2	19
Diyarbakır	112,89	48,67	18.251	78,2	1	30
Erzurum	30,03	65,68	23.122	77,3	2	20
Eskişehir	62,17	62,69	40.639	77,5	2	22
Gaziantep	294,11	58,09	27.933	76,7	1	32
Hatay	270,29	50,31	25.846	77,9	1	26
Mersin	115,85	52,84	31.151	78,3	1	26
İstanbul	2.892,46	58,40	65.041	78,7	2	30
İzmir	356,28	58,24	45.034	78,8	3	25
Kayseri	80,78	58,11	33.027	78	2	25
Kocaeli	521,39	57,19	64.659	77,9	2	23
Konya	56,08	65,57	30.461	78,1	2	22
Malatya	66,8	53,92	22.546	78,8	2	22
Manisa	107,9	63,92	35.367	77,4	2	20
Kahramanmaraş	78,6	68,19	22.968	79,1	1	26
Mardin	91,95	51,60	19.758	80,3	1	28
Muğla	73,05	52,40	37.461	80,5	2	17
Ordu	124,72	58,19	21.867	79,8	2	20
Sakarya	204,67	69,64	36.314	77,5	2	22
Samsun	144,55	61,01	27.272	78,1	2	20
Tekirdağ	159,27	57,33	47.479	77,1	1	27

Trabzon	168,59	56,54	30.789	79,8	2	18
Şanlıurfa	105,82	57,59	14.185	77,4	1	34
Van	57,35	58,69	14.080	75,6	1	28

After determining the criteria for the livability level, the weight value of each criterion was determined by the DANP method at the first stage. In the second stage, metropolitan cities were ranked according to their livability levels by MAIRCA method based on the determined criteria.

DANP RESULTS

A group of four experts consisting of faculty members of the Department of Economic Development and Urbanization and Environment was interviewed and asked to make an evaluation according to DEMATEL scale. The direct relation matrix in Table 3 was obtained by taking the arithmetic mean of the values in the matrix formed by the experts.

Table 3. Direct Relation Matrix

	C1	C2	C 3	C 4	C 5	C 6
C1	0	2	2,25	0,75	3	4
C2	1,75	0	0	2	0	0
C3	2,5	2,5	0	1,5	1,5	1,25
C4	1,5	0,75	0,5	0	1	0
C5	0	0,75	0	2,75	0	0
C6	0	0,25	0	0	0	0

After the creation of the direct relation matrix, the criterion weights were calculated by applying the DANP steps shown in Equation (2)-(8). DANP results shown in Figure 1. According to the Figure 1, the "Population Density (C1)", "Gross National Product Per Capita (C3)", "Happiness Level(C2)" and "Life Expectancy (C4)" was the most important criteria respectively for the livability level of the metropolitan cities.

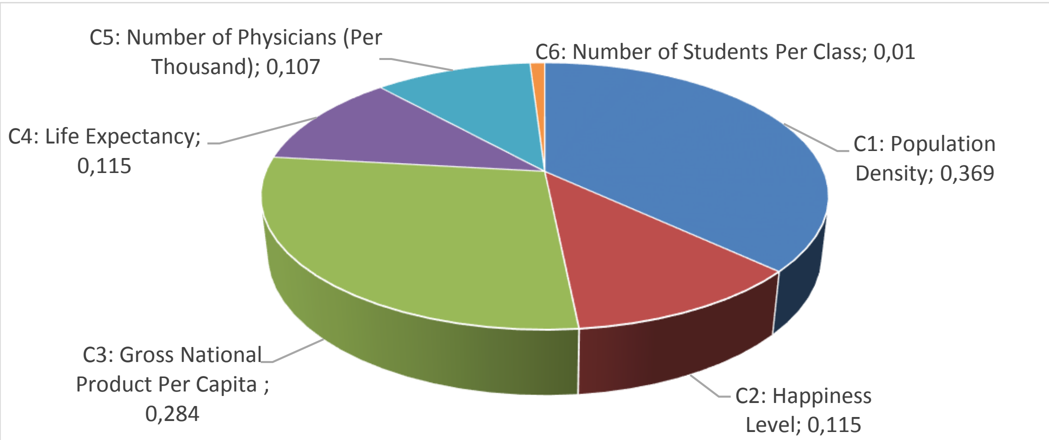

Figure 1. Importance Weights of the Criteria

MAIRCA RESULTS

Following the determination of the criteria importance weights, the ranking of metropolitan cities' livability levels will be obtained by MAIRCA method. In the first stage of the method, priority values (Pai) of alternatives were determined with the help of Equation (10). Afterward, the theoretical evaluation matrix (Tp) was obtained by using Equation (12) as shown in Table 4.

Table 4. Theoretical Evaluation Matrix

Cities/Criteria	C1	C2	C3	C4	C5	C6	P_{Ai}
Adana	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Ankara	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Antalya	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Aydın	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Balıkesir	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Bursa	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Denizli	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Diyarbakır	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Erzurum	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Eskişehir	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Gaziantep	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Hatay	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Mersin	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
İstanbul	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
İzmir	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Kayseri	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Kocaeli	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Konya	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Malatya	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Manisa	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Kahramanmaraş	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Mardin	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Muğla	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Ordu	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Sakarya	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Samsun	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Tekirdağ	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Trabzon	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Şanlıurfa	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033
Van	0,0123	0,0038	0,0095	0,0038	0,0036	0,0003	0,033

By normalizing the theoretical evaluation matrix by using Equation (15)-(16), the real evaluation matrix (Tr) was formed as shown in Table 5.

Table 5. Real Evaluation Matrix

Cities/Criteria	C1	C2	C3	C4	C5	C6
Adana	0,0117	0,0008	0,0026	0,0014	0,0018	0,0001
Ankara	0,0115	0,0013	0,0070	0,0030	0,0036	0,0002
Antalya	0,0119	0,0002	0,0045	0,0028	0,0018	0,0002
Aydın	0,0118	0,0008	0,0026	0,0024	0,0018	0,0003
Balıkesir	0,0121	0,0038	0,0034	0,0016	0,0000	0,0003
Bursa	0,0112	0,0022	0,0055	0,0015	0,0018	0,0001
Denizli	0,0121	0,0014	0,0040	0,0025	0,0018	0,0003

Diyarbakır	0,0119	0,0000	0,0008	0,0020	0,0000	0,0001
Erzurum	0,0123	0,0030	0,0017	0,0013	0,0018	0,0003
Eskişehir	0,0122	0,0024	0,0049	0,0015	0,0018	0,0002
Gaziantep	0,0112	0,0016	0,0026	0,0009	0,0000	0,0000
Hatay	0,0113	0,0003	0,0022	0,0018	0,0000	0,0002
Mersin	0,0119	0,0007	0,0032	0,0021	0,0000	0,0002
İstanbul	0,0000	0,0017	0,0095	0,0024	0,0018	0,0001
İzmir	0,0109	0,0017	0,0058	0,0025	0,0036	0,0002
Kayseri	0,0121	0,0016	0,0035	0,0019	0,0018	0,0002
Kocaeli	0,0102	0,0015	0,0094	0,0018	0,0018	0,0002
Konya	0,0122	0,0029	0,0030	0,0020	0,0018	0,0002
Malatya	0,0121	0,0009	0,0016	0,0025	0,0018	0,0002
Manisa	0,0120	0,0026	0,0040	0,0014	0,0018	0,0003
Kahramanmaraş	0,0121	0,0034	0,0017	0,0027	0,0000	0,0002
Mardin	0,0120	0,0005	0,0011	0,0037	0,0000	0,0001
Muğla	0,0121	0,0006	0,0043	0,0038	0,0018	0,0003
Ordu	0,0119	0,0017	0,0014	0,0033	0,0018	0,0003
Sakarya	0,0115	0,0036	0,0041	0,0015	0,0018	0,0002
Samsun	0,0118	0,0021	0,0025	0,0020	0,0018	0,0003
Tekirdağ	0,0117	0,0015	0,0062	0,0012	0,0000	0,0001
Trabzon	0,0117	0,0014	0,0031	0,0033	0,0018	0,0003
Şanlıurfa	0,0120	0,0016	0,0000	0,0014	0,0000	0,0000
Van	0,0122	0,0017	0,0000	0,0000	0,0000	0,0001

The gap matrix obtained by subtracting the real ratings from theoretical ratings is shown in Table 6.

Table 6: Gap Matrix

Cities/Criteria	C1	C2	C3	C4	C5	C6
Adana	0,0006	0,0031	0,0068	0,0024	0,0018	0,0002
Ankara	0,0008	0,0025	0,0024	0,0009	0,0000	0,0002
Antalya	0,0004	0,0036	0,0049	0,0010	0,0018	0,0001
Aydın	0,0005	0,0030	0,0069	0,0014	0,0018	0,0000
Balıkesir	0,0002	0,0000	0,0061	0,0023	0,0036	0,0000
Bursa	0,0011	0,0017	0,0040	0,0023	0,0018	0,0002
Denizli	0,0002	0,0024	0,0054	0,0013	0,0018	0,0000
Diyarbakır	0,0004	0,0038	0,0087	0,0018	0,0036	0,0003
Erzurum	0,0000	0,0009	0,0078	0,0025	0,0018	0,0001
Eskişehir	0,0001	0,0014	0,0045	0,0023	0,0018	0,0001
Gaziantep	0,0011	0,0022	0,0069	0,0030	0,0036	0,0003
Hatay	0,0010	0,0035	0,0073	0,0020	0,0036	0,0002
Mersin	0,0004	0,0031	0,0063	0,0017	0,0036	0,0002
İstanbul	0,0123	0,0021	0,0000	0,0014	0,0018	0,0003
İzmir	0,0014	0,0022	0,0037	0,0013	0,0000	0,0002
Kayseri	0,0002	0,0022	0,0059	0,0020	0,0018	0,0002
Kocaeli	0,0021	0,0024	0,0001	0,0020	0,0018	0,0001
Konya	0,0001	0,0009	0,0064	0,0019	0,0018	0,0001
Malatya	0,0002	0,0029	0,0079	0,0013	0,0018	0,0001
Manisa	0,0003	0,0012	0,0055	0,0024	0,0018	0,0001
Kahramanmaraş	0,0002	0,0004	0,0078	0,0011	0,0036	0,0002
Mardin	0,0003	0,0033	0,0084	0,0002	0,0036	0,0002
Muğla	0,0002	0,0032	0,0051	0,0000	0,0018	0,0000
Ordu	0,0004	0,0022	0,0080	0,0005	0,0018	0,0001

Sakarya	0,0008	0,0002	0,0053	0,0023	0,0018	0,0001
Samsun	0,0005	0,0017	0,0070	0,0019	0,0018	0,0001
Tekirdağ	0,0006	0,0023	0,0033	0,0027	0,0036	0,0002
Trabzon	0,0006	0,0025	0,0064	0,0005	0,0018	0,0000
Şanlıurfa	0,0003	0,0023	0,0094	0,0024	0,0036	0,0003
Van	0,0001	0,0021	0,0095	0,0038	0,0036	0,0002

Using the values in the gap matrix and the Equation (19), the final criterion function values (Qi) were calculated for each metropolitan city, and the livability ranking was obtained as shown in Table 7.

Table 7. Final Criterion Function Values and Livability Ranking of the Cities

Cities	Qi	Ranking Values
Adana	0,0149	22
Ankara	0,0068	1
Antalya	0,0118	12
Aydın	0,0135	20
Balıkesir	0,0122	13
Bursa	0,0111	7
Denizli	0,0113	9
Diyarbakır	0,0185	29
Erzurum	0,0130	18
Eskişehir	0,0103	5
Gaziantep	0,0171	25
Hatay	0,0176	26
Mersin	0,0152	23
İstanbul	0,0179	27
İzmir	0,0088	3
Kayseri	0,0123	14
Kocaeli	0,0085	2
Konya	0,0112	8
Malatya	0,0142	21
Manisa	0,0113	10
Kahramanmaraş	0,0133	19
Mardin	0,0159	24
Muğla	0,0103	4
Ordu	0,0130	17
Sakarya	0,0105	6
Samsun	0,0129	16
Tekirdağ	0,0126	15
Trabzon	0,0118	11
Şanlıurfa	0,0184	28
Van	0,0193	30

As shown in Table 7 Ankara was selected as the most livable city with the lowest Qi value (***0,0068***) for this case study. Kocaeli was the second and İzmir was the third ranking with their Qi values (***0,0085; 0,0088***), respectively. The cities with the lowest Qi values were Van, Diyarbakır and Şanlıurfa (***0,0193; 0,0185; 0,0184***), respectively.

CONCLUSION & DISCUSSION

Determining the livability levels of metropolitan cities is a decision-making problem that involves many criteria. Therefore, it is a rational way to obtain solutions by using MCDM methods in an integrated way. In this study, the ranking of the metropolitan cities in Turkey according to their livability level was obtained by using the MCDM methods. In the evaluation of the livability level, gross domestic product-TL, population density, average life expectancy of individuals, number of physicians per capita, number of students per class in primary and secondary education, and life satisfaction scores of metropolitan cities according to TUIK life satisfaction survey were accepted as the criteria. The criteria weights for these criteria were calculated by DANP method. The opinions of a group of four experts consisting of faculty members in the Department of Economic Development and Urbanization and Environment were used to implement the DANP method. According to the results of the DANP method, the most important criteria were determined as population density and gross domestic product per capita, respectively. After determining the criteria importance weights, MAIRCA method was used to obtain the rankings regarding the livability of metropolitan cities. According to the livability ranking obtained by MAIRCA method, Ankara, Kocaeli, and İzmir ranked in the first three, respectively. The cities with the lowest livability levels were Van, Diyarbakır and Şanlıurfa, respectively.

The study employed the interviews with local experts and authorities which can be considered reliable sources of information regarding the livability of metropolitan cities in Turkey. According to the evaluation results of livable level of cities, population density, gross domestic product per capita, happiness level and life expectancy are the most important criteria in terms of livability level of the metropolitan cities. It is shown that, these top-four criteria should be developed firstly for building a livable city.

Furthermore, metropolitan cities were ranked according to their livability level. Considering the livable rankings, the metropolitan cities located in the western Turkey are at the top whereas located in the east and southeast are at the bottom. Similar findings were found in the study of Özbek in the related literature (Özbek, 2019).

When the results of some related works regarding the livable cities examined, some different criteria about determining of livable cities encountered. In the study of Chen, the evaluation criteria were determined according to environment protection standards of the European Environment Agency and the Technical Criterion for Ecosystem Status Evaluation of PRC and included the average temperature, urban greening coverage, population density, sewage treatment rate, equivalent sound level, days of good air quality, per capita urban road area, and per capita GDP (Chen, 2020). It has been determined that this study is different from the current study in terms of considering environmental criteria more.

In the study of Aksoy and Yaylagül, analytic hierarchy process and geographic information systems were used to evaluate the livable level of a region of a city in Turkey for older people. Health care services, transportation facilities, social and recreational facilities of the cities and neighborhoods are determined criteria in terms of livable environments for older people from a local perspective. According to the results of this study, the weight of health services has the highest score compared to other criteria (Aksoy and Yaylagül, 2019). There are some differences between these studies in terms of the methods and the evaluation criteria. However, it has considered that this study is similar to the current study in terms of evaluating the livable levels of cities in a local perspective.

The purpose of this work was to evaluate city livability and potentially improve quality of life in the future. We hope that the government and local authorities can establish countermeasures for the management of life quality in the future. Moreover, the findings from this research can contribute to the literature on the implementation of livable city concept using DANP and MAIRCA analysis process and evaluating this process from the local perspective. Hereby, local, and national authorities can use the model to prioritize different aspects of the city or to select which areas to develop first based on their significance levels.

This research has some limitations. It focused within the context of metropolitan cities of Turkey, which has a unique culture and is quite different from many countries. Because culture influences, it is necessary to expand this type of research into the different countries and cultures.

RECOMMENDATIONS

The authors of this paper make some original contributions. First, it is a pioneering work on determining livability levels of metropolitan cities with MAIRCA method. Second there are limited studies about MAIRCA method in the national literature especially. Hence it is thought that this study will make a contribution to the national literature. This paper presented a real case study and demonstrated the applicability of the proposed framework. It is suggested to apply this integrated approach in livability levels of other countries/cities in terms of different criteria. Moreover, future studies can compare the reliability and validity of other MCDM approaches under different cities and conditions.

ETHICAL CONSIDERATION

In this article, writing rules and publishing policies of the journal are followed. The author is responsible for the ethical rules in terms of the research and publishing policies of the journal. Submitted article contains no matter that can be construed as infringing in any way on the copyright of another party.

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