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# Evaluation of the health performances of the regions affiliated to the the ministry of health by multi-criteria decision making techniques

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## ABSTRACT

**Aim:** The aim of this study is to determine the health performances of the regions in the 2019 Health Statistics Yearbook by using multi-criteria decision making techniques.

**Material and Method:** The study is a cross-sectional study and the data used in the study were obtained from the Ministry of Health Statistics Yearbook 2019. The population of the study consists of 12 regions (Western Anatolia, Western Black Sea, Eastern Black Sea, Eastern Black Sea, Eastern Marmara, Aegean, Istanbul, Central Anatolia, Mediterranean, Northeastern Anatolia, Western Marmara, Southeastern Anatolia, and Central Anatolia) included in the 2019 Health Statistics Yearbook. No sample was selected, and all regions were included in the study. ENTROPY Method was used for weighting the criteria and TOPSIS Method was used for ranking the alternatives. A total of 11 criteria, including six benefit criteria (number of general practitioners per 100,000 people, number of specialists per 100,000 people, number of hospital beds per 10,000 people, number of nurses and midwives per 100,000 people, number of hemodialysis devices per million people, and number of MRI devices per million people) and 5 cost criteria (infant mortality rate, maternal mortality rate, population per family medicine unit, crude mortality rate, population per 112 emergency aid station) were evaluated. Analyses were performed in Microsoft Excel program.

**Results:** In the study, the three most effective criteria used to determine the health performances of the regions were respectively determined as maternal mortality rate (28.68%), population per 112 emergency aid stations (17.43%), and crude death rate (15.63%). As a result of the analyzes of the TOPSIS Method, the five regions with the best health performance among the regions are Western Anatolia (0.68), Western Black Sea (0.66), Eastern Black Sea (0.65), Eastern Marmara (0.63), and Aegean (0.56) has been identified. While the average performance score of the regions is found as 0.53, Istanbul (0.51), Middle East Anatolia (0.50), Mediterranean (0.49), Northeast Anatolia (0.46), West Marmara (0.44), Southeastern Anatolia (0.40), and Central Anatolia (0.33) regions remained below this average.

**Conclusion:** The most important criteria in evaluating the health performances of regions are; maternal mortality rate, population per 112 emergency aid stations, and crude death rate. The regions with the best health performance are Western Anatolia, Western Black Sea and Eastern Black Sea. In order to improve the health performance of the regions, maternal mortality rate, crude death rate and population per family physician should be reduced.

**Keywords:** Multi-criteria decision making techniques, ENTROPY, health performance, TOPSIS

## INTRODUCTION

Health services are one of the criteria showing the level of development of societies and are provided especially for the protection and promotion of health. With today's technological developments, the health literacy levels of societies have increased and these increases have led to rising costs of health services. Assessing the effectiveness of health services in a country is important in many ways. These include investments to be made in the region, cost control of health services, more efficient use of scarce resources and fair and equal assignment of health workforce in the country (1,2). Comparing the health performance of countries and planning health services in more detail and in a better way are among the most important issues that make identifying general problems in the field of health and evaluating the effectiveness of health services important (3). Among the 13 goals set by the United Nations to improve health indicators are

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objectives such as reducing maternal mortality, reducing infant mortality and combating infectious diseases (4).

In Turkey, as a result of the implementation of the Health Transformation Program (HTP) in 2003, significant progress and improvements have been achieved in the field of health. However, in addition to all these advances and improvements, when the health performance of the regions is analyzed, it is concluded that there are still inequalities of opportunity. Turkey's population and the need for health personnel are increasing day by day in parallel with each other. Taking the necessary steps in response to this increase is only possible through an assessment of the health regions in Turkey (5).

The main criteria used to make comparisons between the health levels of countries, regions and provinces are a number of criteria such as mortality, morbidity, fertility and health personnel (6). In addition to these, measures such as the number of beds, number of devices, etc. have also been used quite frequently and have gained an important place in the comparison of health performances. Especially in the literature, it is stated that maternal mortality rate and infant mortality rate are the most important measures of the socio-economic status of a society (7). Determining health performance by analyzing health indicators helps countries to learn the factors affecting health and the effectiveness of health services provided in the country (8).

Nowadays, multi-criteria decision-making techniques are used in situations where alternatives need to be compared according to certain criteria. These methods, which have recently started to be used especially in the field of health, are utilized in situations where multiple alternatives or one alternative needs to be evaluated according to more than one criterion (9).

In this study, it is aimed to determine the health performance of the regions, which are in Health Statistics Yearbook 2019 of the Republic of Turkey Ministry of Health, through multi-criteria decision-making techniques. ENTROPY Method and TOPSIS Method, which are multi-criteria decision making techniques, were used in the study. The main purpose of the study is to determine the health performance of the regions according to certain criteria and to be included in the health strategies to be implemented in the future.

In the method part of the study, the ENTROPY and TOPSIS methods used in the study were explained, the results in the study were given in the results part, and the results of the study were compared with the results of other studies in the literature in the discussion part.

## MATERIAL AND METHOD

The study was carried out in accordance with the Declaration of Helsinki. Ethics committee approval is not required since the study was not conducted on humans and animals and secondary data were used.

The study is a cross-sectional study and the data used in the study were obtained from the Ministry of Health Statistics Yearbook 2019. The population of the study consists of 12 regions (Western Anatolia, Western Black Sea, Eastern Black Sea, Eastern Black Sea, Eastern Marmara, Aegean, Istanbul, Central Anatolia, Mediterranean, Northeastern Anatolia, Western Marmara, Southeastern Anatolia, and Central Anatolia) included in the 2019 Health Statistics Yearbook. No sample was selected, and all regions were included in the study. ENTROPY Method was used for weighting the criteria and TOPSIS Method was used for ranking the alternatives. A total of 11 criteria, including six benefit criteria (number of general practitioners per 100,000 people, number of specialists per 100,000 people, number of hospital beds per 10,000 people, number of nurses and midwives per 100,000 people, number of hemodialysis devices per million people, and number of MRI devices per million people) and 5 cost criteria (infant mortality rate, maternal mortality rate, population per family medicine unit, crude mortality rate, population per 112 emergency aid station) were evaluated. The criteria used in the study were determined as a result of the literature review and were finalized with the opinions of three experts. Analyses were performed in Microsoft Excel program.

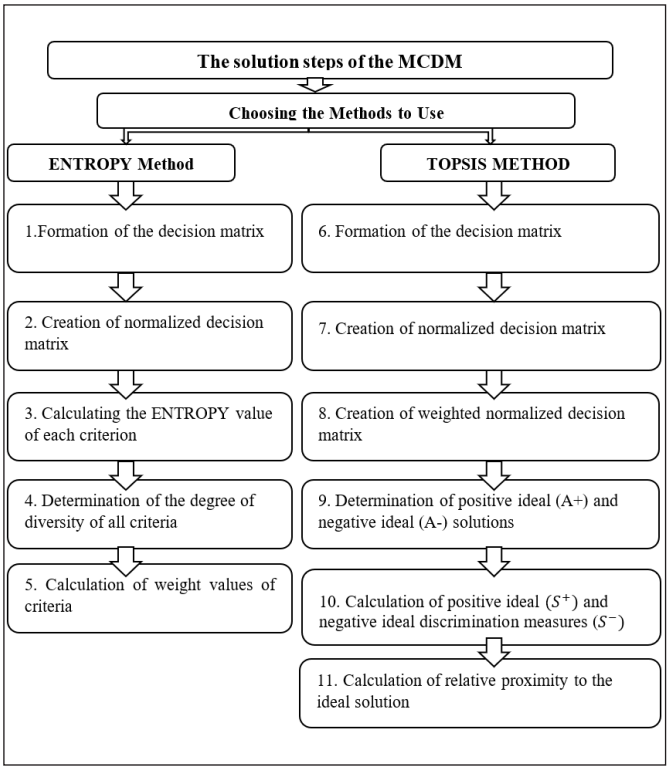


**Figure 1.** The solution steps of the MCDM

**ENTROPY Method**

The ENTROPY method consists of creating the initial decision matrix, creating the normalized decision matrix, calculating the ENTROPY value of each criterion, determining the degree of diversity of all criteria and calculating the weight values of the criteria. The analysis methods of these stages are as follows (10-12).

**1. Formation of the Decision Matrix:** It is a matrix representing m number of alternatives and n number of criteria. Xij in the matrix indicates the value of alternative i according to criterion j.

$$D=\begin{bmatrix} X_{11} & X_{12} & X_{13} & \dots & X_{1j} & \dots & X_{1n} \\ X_{21} & X_{22} & X_{23} & \dots & X_{2j} & \dots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{i1} & X_{i2} & X_{i3} & \dots & X_{ij} & \dots & X_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & X_{m3} & \dots & X_{mj} & \dots & X_{mn} \end{bmatrix} \quad (1)$$

**2. Creation of Normalized Decision Matrix:** A normalized decision matrix (R Matrix) is created by normalizing with the formula below.

$$r_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij}$$

$$R=\begin{bmatrix} R_{11} & R_{12} & R_{13} & \dots & R_{1j} & \dots & R_{1n} \\ R_{21} & R_{22} & R_{23} & \dots & R_{2j} & \dots & R_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ R_{i1} & R_{i2} & R_{i3} & \dots & R_{ij} & \dots & R_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ R_{m1} & R_{m2} & R_{m3} & \dots & R_{mj} & \dots & R_{mn} \end{bmatrix} \quad (2)$$

**3. Calculating the ENTROPY Value of Each Criterion:** The ENTROPY values of each criterion are calculated using the formula below. The number k in the formula is obtained by the formula 1/lnm.

$$e_j = -k / \sum_{i=1}^{m} r_{ij} \ln r_{ij} \quad (3)$$

**4. Determination of the Degree of Diversity of All Criteria:** The degree of diversity of each criterion is calculated with the help of the following formula.

$$d_j = 1 - e_j \quad (4)$$

**5. Calculation of Weight Values of Criteria:** The weights of all criteria are calculated using the formula below. The important point here is that the sum of the weights of all criteria should be equal to 1.

$$w_j = d_j / \sum_{j=1}^{n} d_j \quad (5)$$

**TOPSIS Method**

The TOPSIS method consists of the following stages: construction of the initial decision matrix, construction of the normalized decision matrix, construction of the weighted normalized decision matrix, determination of the positive ideal and negative ideal solutions, calculation of the positive ideal and negative ideal separation measures and calculation of the relative proximity to the ideal solution. The analysis methods of these stages are shown below (13-15).

**1. Formation of the Decision Matrix:** It is a matrix representing m number of alternatives and n number of criteria. The aij in matrix indicates the value of alternative i according to criterion j.

$$A=\begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1j} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2j} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{i1} & a_{i2} & a_{i3} & \dots & a_{ij} & \dots & a_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \dots & a_{mj} & \dots & a_{mn} \end{bmatrix} \quad (6)$$

**2. Creation of Normalized Decision Matrix:** The data are normalized using the formula below and the Normalized Decision Matrix (R Matrix) is generated

$$r_{ij} = a_{ij} / \sqrt{\sum_{i=1}^{m} a_{ij}^2}$$

$$i = 1,2,3,4 \dots\dots, m$$

$$j = 1,2,3,4 \dots\dots, n$$

$$R=\begin{bmatrix} r_{11} & r_{12} & r_{13} & \dots & r_{1j} & \dots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \dots & r_{2j} & \dots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{i1} & r_{i2} & r_{i3} & \dots & r_{ij} & \dots & r_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & r_{m3} & \dots & r_{mj} & \dots & r_{mn} \end{bmatrix} \quad (7)$$

**3. Creation of Weighted Normalized Decision Matrix:** The weights of the criteria are calculated with one of the criterion weighting methods and the values obtained are multiplied by each value in the normalized decision matrix. While the weighted normalized value is denoted with vij, the weight value is denoted with wj.

$$V=\begin{bmatrix} w_1r_{11} & w_2r_{12} & w_3r_{13} & \dots & w_jr_{1j} & \dots & w_nr_{1n} \\ w_1r_{21} & w_2r_{22} & w_3r_{23} & \dots & w_jr_{2j} & \dots & w_nr_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1r_{i1} & w_2r_{i2} & w_3r_{i3} & \dots & w_jr_{ij} & \dots & w_nr_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1r_{m1} & w_2r_{m2} & w_3r_{m3} & \dots & w_jr_{mj} & \dots & w_nr_{mn} \end{bmatrix} \quad (8)$$

**4. Determination of Positive Ideal (A+ ) and Negative Ideal (A- ) Solutions:** Ideal and Negative ideal solution points are determined. If the criterion evaluated is the utility criterion, the positive ideal solution consists of

the best values of V and the negative ideal solution consists of the worst values. If the evaluated criterion is the cost criterion, the positive ideal solution consists of the smallest value of V, while the negative ideal solution consists of the largest value. The following formulas are used to calculate the ideal solutions.

$$A^{+} = (v_1^{+}, v_2^{+}, v_3^{+}, \ldots, v_n^{+})$$

$$A^{+} = \{(\max_j v_{ij} \setminus j \in J), (\min_j v_{ij} \setminus j \in J')\}$$

$$A^{-} = (v_1^{-}, v_2^{-}, v_3^{-}, \ldots, v_n^{-}) \quad (9)$$

$$A^{-} = \{(\min_j v_{ij} \setminus j \in J), (\max_j v_{ij} \setminus j \in J')\}$$

In the formula, the benefit criterion is shown as J and the cost criterion is shown as J'.

**5. Calculation of Positive Ideal ($S^{+}$) and Negative Ideal Discrimination Measures ($S^{-}$):** Discrimination measures are a calculation between alternatives and follow a mathematical formula called Euclidean distances. This separation is based on the previous step of the TOPSIS method. The distance of each alternative from the positive-ideal and negative-ideal solution is calculated with the following formulas.

$$S^{+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_i^{+})^2}$$

$$S^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_i^{-})^2} \quad (10)$$

$$i = 1,2,3,\ldots, m$$

**6. Calculation of Relative Proximity to the Ideal Solution:** $C_i^*$ in the formula is between $0 \leq C_i^* \leq 1$ After these calculations, the alternative closest to 1 is the most successful alternative, and the alternatives are ranked in descending order of success

$$C_i^* = \frac{s_i^-}{s_i^- - s_i^+}$$

$$i = 1,2,3,\ldots, m \quad (11)$$

**Table 1.** Criteria used in this study

| Criteria Code | Criteria |
|---|---|
| K1 | Number of general practitioners per 100,000 people* |
| K2 | Number of Specialist Physicians per 100,000 people* |
| K3 | Number of hospital beds per 10,000 people* |
| K4 | Number of Nurses and Midwives per 100,000 people* |
| K5 | Number of actually used hemodialysis devices per million people* |
| K6 | Number of MRI devices per million people* |
| K7 | Infant mortality rate** |
| K8 | Maternal Mortality Rate** |
| K9 | Population per family medicine unit** |
| K10 | Crude Mortality Rate** |
| K11 | Population Per 112 Emergency Aid Station** |

*Benefit Criterion
**Cost Criterion

The criteria used in the study were determined as a single score at the end of the study, thus enabling the regions to be ranked according to their performance (**Table 1**).

## RESULTS

The initial decision matrix in **Table 2** was created using Health Statistics Yearbook 2019 of the Republic of Turkey Ministry of Health. The initial decision matrix is used in both the ENTROPY method and the TOPSIS method in studies where weights are based on the ENTROPY method and ranking is based on the TOPSIS method (**Table 2**).

To determine the weights of the criteria evaluated in the study, the stages of the ENTROPY method were applied, and the criteria weights determined as a result of the analyzes are shown in **Table 3**. According to the results of the study, the three most effective criteria used in determining the health performance of the regions are maternal mortality rate (28.68%), population per 112 emergency aid station (17.43%) and crude mortality rate (15.63%) (**Table 3**).

Using the initial decision matrix in **Table 2**, the Si+, Si- and Ci values of the regions were determined as a result of the application of the stages of the TOPSIS method and these values are shown in **Table 4**.

The health performance ranking of the regions according to TOPSIS is shown in **Table 5.**

As a result of the analysis of TOPSIS method, the five regions with the most successful health performance among the regions are West Anatolia (0.78), West Black Sea (0.66), East Black Sea (0.65), East Marmara (0.63) and Aegean (0.56). While the average performance score of the regions was 0.54, Istanbul (0.51), Central Anatolia (0.50), Mediterranean (0.49), Northeast Anatolia (0.46), West Marmara (0.44), Southeast Anatolia (0.40) and Central Anatolia (0.33) regions were below this average.

**Table 2.** Initial decision matrix

| Initial Decision Matrix | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Regions** | **Criteria** | | | | | | | | | | |
| | **K1** | **K2** | **K3** | **K4** | **K5** | **K6** | **K7** | **K8** | **K9** | **K10** | **K11** |
| Southeast Anatolia | 61 | 63 | 23.3 | 254 | 128.6 | 8.7 | 13.5 | 18 | 3155 | 9.2 | 30323 |
| Middle East Anatolia | 67 | 70 | 30.5 | 326 | 161.1 | 10.2 | 11.5 | 15.9 | 3105 | 8.4 | 20686 |
| Northeast Anatolia | 75 | 72 | 29.6 | 313 | 171.4 | 9.1 | 10 | 17.3 | 2953 | 12.1 | 20000 |
| Central Anatolia | 62 | 81 | 31 | 335 | 274.1 | 9.6 | 9.9 | 24.4 | 3039 | 15.3 | 19785 |
| Mediterranean | 58 | 95 | 28.7 | 310 | 228 | 12 | 8.8 | 14.7 | 3100 | 13.8 | 30106 |
| Aegean | 57 | 114 | 29 | 315 | 256.9 | 10.6 | 8 | 11.7 | 3161 | 21.4 | 29414 |
| Western Black Sea | 67 | 82 | 32.6 | 351 | 294.7 | 8.6 | 7.4 | 10.1 | 3107 | 17.7 | 19124 |
| Western Anatolia | 51 | 145 | 33.9 | 349 | 223.6 | 12.7 | 7.3 | 2.9 | 3236 | 16.1 | 33162 |
| West Marmara | 57 | 90 | 29.5 | 325 | 230.7 | 10.8 | 7.3 | 15.8 | 3135 | 25.5 | 23542 |
| Istanbul | 46 | 136 | 26.2 | 264 | 178.8 | 12.3 | 7.1 | 11.1 | 3123 | 16.1 | 50551 |
| East Marmara | 52 | 92 | 26.2 | 297 | 222.5 | 10.1 | 7 | 8.5 | 3241 | 20.8 | 32115 |
| Eastern Black Sea | 68 | 87 | 32.9 | 372 | 268 | 11.2 | 5.9 | 10.2 | 3154 | 20.7 | 16013 |

**Table 3.** ENTROPY method weighting and ratios of criteria

| **Criteria** | **K1** | **K2** | **K3** | **K4** | **K5** | **K6** | **K7** | **K8** | **K9** | **K10** | **K11** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ej Value | 0.99648 | 0.98709 | 0.99793 | 0.99781 | 0.9898 | 0.99684 | 0.98865 | 0.96588 | 0.99988 | 0.9814 | 0.97927 |
| Diversity (dj) | 0.00352 | 0.01291 | 0.00207 | 0.00219 | 0.0102 | 0.00316 | 0.01135 | 0.03412 | 0.00012 | 0.0186 | 0.02073 |
| Criteria Weights wj | 0.0296 | 0.10853 | 0.01737 | 0.01841 | 0.08575 | 0.02657 | 0.09538 | 0.2868 | 0.00097 | 0.15632 | 0.17429 |
| Criteria Weights wj (%) | 2.96% | 10.85% | 1.74% | 1.84% | 8.57% | 2.66% | 9.54% | 28.68% | 0.10% | 15.63% | 17.43% |

**Table 4.** Si+, Si- and Ci values of TOPSIS method alternatives

| **Regions** | **SI+** | **SI-** | **CI** |
|---|---|---|---|
| Southeast Anatolia | 0.09899 | 0.06685 | 0.4031 |
| Middle East Anatolia | 0.08229 | 0.08515 | 0.5085 |
| Northeast Anatolia | 0.08899 | 0.07723 | 0.4646 |
| Central Anatolia | 0.12758 | 0.06388 | 0.3337 |
| Mediterranean | 0.07637 | 0.07622 | 0.4995 |
| Aegean | 0.06681 | 0.08724 | 0.5663 |
| Western Black Sea | 0.05283 | 0.10486 | 0.665 |
| Western Anatolia | 0.03763 | 0.13436 | 0.7812 |
| West Marmara | 0.09003 | 0.07274 | 0.4469 |
| Istanbul | 0.08094 | 0.08635 | 0.5162 |
| East Marmara | 0.05740 | 0.10091 | 0.6374 |
| Eastern Black Sea | 0.05634 | 0.10678 | 0.6546 |

**Table 5.** Health performance ranking of regions in the Health Statistics Yearbook 2019

| **Item no.** | **Regions** | **Performance Scores** |
|---|---|---|
| 1. | West Anatolia | 0.781 |
| 2. | West Black Sea | 0.665 |
| 3. | East Black Sea | 0.655 |
| 4. | East Marmara | 0.637 |
| 5. | Aegean | 0.566 |
| | Region Average | 0.540 |
| 6. | İstanbul | 0.516 |
| 7. | Middle East Anatolia | 0.509 |
| 8. | Mediterranean | 0.499 |
| 9. | Northeast Anatolia | 0.465 |
| 10. | West Marmara | 0.447 |
| 11. | Southeast Anatolia | 0.403 |
| 12. | Central Anatolia | 0.334 |

## DISCUSSION

In the study, the three most effective criteria used to determine the health performance of the regions were maternal mortality rate (28.68%), population per 112 emergency aid station (17.43%) and crude mortality rate (15.63%). As a result of the analysis of TOPSIS method, the five regions with the most successful health performance among the regions were identified as West Anatolia (0.78), West Black Sea (0.66), East Black Sea (0.65), East Marmara (0.63) and Aegean (0.56). While the average performance score of the regions was 0.54, Istanbul (0.51), Central Anatolia (0.50), Mediterranean (0.49), Northeast Anatolia (0.46), West Marmara (0.44), Southeast Anatolia (0.40) and Central Anatolia (0.33) regions were below this average.

Şantaş et al. (16) examined the health performance of statistical regions and concluded that the Western Anatolia Region has the best health performance, and the Southeastern Anatolia Region has the worst health performance. Although multi-criteria decision-making techniques were not used in this study by Şantaş et al., it is seen that it has a similar result with this study.

Öksüzkaya (17) used data envelopment analysis to analyze the health performance of statistical regions and found that the hospitals affiliated to the Ministry of Health in the Western Anatolia region were active .

Özdemir (18) also used the data envelopment analysis to analyze the health performance of the regions and concluded that West Anatolia, West Marmara and Aegean

regions are active only in terms of Banker, Charnes, Cooper (BCC) models.

## CONCLUSION

Nowadays, multi-criteria decision-making techniques is being used in the field of health in various new subjects. However, there has not been any study in which the health performance of the regions classified according to the Classification of Statistical Region Units in the Annals of Health Statistics published by the Ministry of Health has been examined using the ENTROPY-based TOPSIS Method. While the study with this aspect has an original value, it also has the quality of setting an example for subsequent studies.

In the study, the most important criteria for evaluating the health performance of the regions were determined as maternal mortality rate, population per 112 emergency aid stations, and crude mortality rate. The regions with the best health performance were determined as West Anatolia, West Black Sea and East Black Sea regions. In order for the health performance of the regions to improve, the maternal mortality rate, the crude mortality rate, the population per 112 emergency aid stations, and the population per family physician should be reduced. With all these, it is recommended that the strategies in the West Anatolia Region, which is the best region in terms of health performance, be well analyzed and implemented in other regions so that other regions can have the same scores as the West Anatolia Region.

There is no person/organization that supports the study financially and the authors do not have any interest-based relationship

## ETHICAL DECLARATIONS

**Ethics Committee Approval:** Ethics committee approval is not required since the study was not conducted on humans and animals and secondary data were used in the study.

**Informed Consent:** Since the study was not performed on patients, informed consent is not required.

**Peer Review Process:** Externally peer reviewed.

**Conflict of Interest Statement:** The authors have no conflict of interest to declare.

**Financial Disclosure:** The authors of this study did not receive any financial support.

**Author Contributions:** All authors declare that: They participated in the design, implementation and design processes.

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