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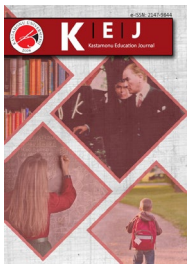

| Research Article / Araştırma Makalesi |

Evaluation of the Entrepreneurial and Innovative Universities in Turkey through Multiple-Criteria Decision Making Methods

Türkiye'deki Girişimci ve Yenilikçi Üniversitelerin Çok Kriterli Karar Verme Yöntemleri ile Değerlendirilmesi

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Keywords

1. Entrepreneurial and innovative university index
2. Multiple-criteria decision making methods
3. MCDM

Anahtar Kelimeler

1. Girişimci ve yenilikçi üniversite endeksi
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Abstract

Purpose: The purpose of this study is to examine the 2018 performances of the top 10 Entrepreneurial and Innovative Turkish universities through Multiple-Criteria Decision Making (MCDM) methods and to rank them.

Design/Methodology/Approach: While determining the criteria discussed within the scope of the analysis, TUBITAK's Entrepreneurial and Innovative University Index criteria were taken into consideration. This Index was created in order to obtain a success ranking based on the indicators determined among universities. In this context, first of all, objective weight values of the criteria were calculated by Entropy method. Then, the ranking was made among universities by using Edas and Topsis methods, which are among the MCDM methods.

Findings: Analyses performed through all two methods demonstrate that the Middle East Technical University ranks first. When the results of the analysis are evaluated in general, it is seen that the findings are consistent with the results of TUBITAK.

Highlights: Along with globalization, changes and developments taking place in information and communication technologies worldwide affect universities. Universities should support scientific studies, put emphasis on R&D activities, university-industry cooperation and patent studies in order to rise in performance rankings.

Öz

Çalışmanın amacı: Bu çalışmanın amacı, Türkiye'de bulunan Girişimci ve Yenilikçi ilk 10 üniversitenin 2018 yılı performanslarını Çok Kriterli Karar Verme Yöntemleri (ÇKKV) ile inceleyerek sıralama yapmaktır.

Materyal ve Yöntem: Analiz kapsamında ele alınan kriterler belirlenirken TÜBİTAK'ın Girişimci ve Yenilikçi Üniversite Endeksi kriterleri dikkate alınmıştır. Bu endeks, üniversiteler arasında belirlenen göstergelere bağlı olarak bir başarı sıralaması elde etmek amacıyla oluşturulmuştur. Bu kapsamda öncelikle Entropi yöntemi ile kriterlerin objektif ağırlık değerleri hesaplanmıştır. Daha sonra ÇKKV yöntemlerinden Edas ve Topsis yöntemleri kullanılarak üniversiteler arasında sıralama yapılmıştır.

Bulgular: Yapılan analizler her iki yöntemde de Orta Doğu Teknik Üniversitesi'nin ilk sırada yer aldığını göstermektedir. Analiz sonuçları genel olarak değerlendirildiğinde, bulguların TUBİTAK'ın sonuçları ile tutarlı olduğu görülmektedir.

Önemli Vurgular: Küreselleşme ile birlikte dünya genelinde bilgi ve iletişim teknolojilerinde meydana gelen değişim ve gelişmeler üniversiteleri de etkilemektedir. Üniversiteler performans sıralamalarında yükselmek için bilimsel çalışmaları desteklemeli, Ar-Ge faaliyetlerine, üniversite-sanayi işbirliğine ve patent çalışmalarına önem vermelidir.

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INTRODUCTION

In recent years, information-intensive new structures have been formed with entrepreneurial and innovative activities. Since these activities do not play an important role in the economy, there are many studies examining the factors affecting these activities (Guerrero et al., 2016). As well as being an economic value generator, entrepreneurship is closely associated with social, cultural and political dynamics due to the environment in which it takes place and the transformative mobility it creates. Although the interest of disciplines such as business, economics, finance, management and education in entrepreneurship continues, it draws attention that behavioral sciences, particularly sociology brings a different dimension to entrepreneurship research (Aytaç, 2006). Innovation, on the other hand, is based on knowledge. In this context, innovation is, changing, taking risks and most importantly being able to step out of what is already known. With the impact of developments in information and information technologies, global competition has increased, and innovativeness has become a necessity for even the most powerful businesses (Demirel and Seçkin, 2008).

Since universities are the new information resource centers in knowledge-based economies, they provide support to entrepreneurs in areas such as information transfer, guidance and consultancy, thereby producing entrepreneurial and innovative results beyond being an academic sector (Cunningham et al., 2019). When the development of universities is analyzed, it is seen that the last generation universities are entrepreneurial and innovative universities. This situation enables academicians and university students to use information along with entrepreneurship, that is, to encourage the transfer of information and technology (Koyuncuoğlu and Tekin, 2019). In the Higher Education Law No. 2547 enacted on November 4, 1981, universities were defined as “higher education institutions consisting of institutions and units like faculties, institutes, colleges etc, having scientific autonomy and public legal personality, who do high-level education, scientific research, publication and consultancy ”(YÖK, 2020). Universities have become centers of modern research by developing their activities such as knowledge generation and strengthening national culture over time. Therefore, universities both met the needs of the governments of the countries such as technology, managers and technical personnel, and provided the development of important concepts in the transformations caused by industrialization (Parlar & Palancı, 2020).

Universities are places that can meet important needs and opportunities and are positioned in fixed borders where entrepreneurship is realized. Raising graduates with entrepreneurial skills, highly qualified and able to create employment is among the primary goals of universities (Christensen & Eyring, 2011; Sutanto, 2017). An entrepreneurial approach helps universities identify challenges when formulating a strategy, seek ways to cope with these challenges, and identify what skills they need to achieve their goals (Klofsten et al., 2019).

TUBITAK, since 2012, has been publishing the "Entrepreneurial and Innovative University Index" report, in which universities are ranked according to their entrepreneurship and innovation performance and has been sharing the top 50 enterprising and innovative universities in Turkey with the public. The index study, which started to be published as from 2012, was evaluated under five dimensions and 23 indicators until 2018, and in 2018, the dimension of entrepreneurship and innovation culture was removed from the index study and the study was evaluated under four dimensions and 19 indicators. The dimensions of the entrepreneurial and innovative university index are as follows (TUBITAK, 2018).

1. Scientific and technological research competence,
2. Intellectual property pool,
3. Cooperation and interaction,
4. Economic contribution and commercialization.

This index aims to spread entrepreneurship among universities. In order for universities to reach their goals and make themselves mentioned in the performance rankings, they must follow the innovations required by the age and engage in entrepreneurial activities along with scientific and academic studies. There are studies in the literature where the performances of universities are analyzed with different multi criteria decision making methods (MCDM). Table 1 includes some of these studies.

Table 1. Literature summary

Authors	Year	Subject of the study	Method
Parlar and Palancı	2020	The performances of the universities of 81 countries in the World University Rankings 2018 list were measured.	Topsis, Maut, Saw and Aras
Karagöz, Kocakoç and Üçdoğruk	2020	The activities of 35 Entrepreneurial and Innovative universities between 2012 and 2017 were measured.	Data Envelopment Analysis
Ömürbek and Karataş	2019	The 2016 performances of 50 entrepreneurial and innovative universities were measured.	Entropy, Maut and Saw
Er and Yıldız	2018	Entrepreneurial and Innovative University Index values of Turkish universities for 2016 and 2017 were examined.	Oreste and Factor Analysis
Salimi and Rezaei	2015	The performances of three universities in the Netherlands were measured.	AHP and Fuzzy AHP
Özgüven	2011	For four foundation universities in Izmir, the selection problem was addressed.	AHP
Zangoueinezhad and Moshabaki	2011	The performance of one of the top 10 universities in Iran was measured with knowledge based indexes.	Fuzzy AHP

The aim of this study is to examine 2018 performances of the top 10 Innovative Entrepreneur universities in Turkey with MCDM. In this context, the Entrepreneurial and Innovative University Index criteria published by TUBITAK were taken into consideration. After the objective weights of the criteria were calculated with the Entropy method, performance evaluations were made using the Edas and Topsis methods. The methods used in the study were explained step by step in the methodology section, based on formulas. In the analysis part, these methods described were applied and interpreted. This study is expected to contribute to the universities in Turkey in terms of strengthening their entrepreneurship and innovation activities.

METHOD/MATERIALS

In this study, 2018 performances of top 10 entrepreneurial and innovative universities in Turkey were ranked with MCDM methods. The importance levels of the criteria in MCDM problems are not always equal. The effects of criteria having different degrees of importance on decision making are different from each other. Therefore, a weight value is assigned for all criteria and the importance levels of the criteria are determined. In this study, Entropy method was used to calculate the weight values of the criteria. After obtaining the weights of the criteria with the entropy method, the performance ranking was made using the Edas and Topsis methods from the MCDM methods. Microsoft Excel 2010 program was used for calculations.

Entropy Method

Entropy method is one of the most commonly used methods as it can be applied to many science and engineering fields. Entropy, a method developed by Rudolph Clausius in the field of thermodynamics in 1865, was adapted to information technologies by Claude E. Shannon in 1948 and started to be used as information entropy (Zhang et al., 2011: 444). The steps of the entropy method are shown below (Wu et al., 2011, Karami & Johansson, 2014, Ulutaş, 2019).

Step 1. Creating the decision matrix: First of all, a decision matrix containing all the alternatives and criteria in the selection problem is created.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} \\ x_{21} & x_{22} & \dots & x_{2j} \\ . & & & . \\ . & & & . \\ . & & & . \\ x_{i1} & x_{i2} & \dots & x_{ij} \end{bmatrix}$$

Step 2. Normalizing the decision matrix: After that, the decision matrix is normalized with the help of the following equation.

$$\mathrm{P}_{ij} = \frac{x_j}{\sum_{i=1}^{m} x_{ij}}$$

Step 3. Calculation of entropy value: In this step, the entropy value is calculated for all criteria.

$$\mathrm{E_j} = -\mathrm{k}\sum_{i=1}^{m} P_{ij} \ln\left(P_{ij}\right)$$

Step 4. Calculation of entropy weight: Finally, the weight value of all criteria (w_j) is calculated.

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

Edas Method

The Edas method was developed by Ghorabaee et al. in 2015. With this method, the performance of the alternatives is measured and a ranking is made among the alternatives. The Edas method consists of the following steps (Ghorabaee et al., 2015, Li et al., 2020)

Step 1. Creating the decision matrix: In the first step of the Edas method application, a decision matrix is formed regarding the decision problem. This study continues with the decision matrix created for the Entropy method.

Step 2. Creating the mean solutions matrix: In this step, the average of j criteria values in the decision matrix is obtained. Mean solutions matrix is being created by taking the mean solutions of the criteria (AV_j).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}$$

Step 3. Obtaining positive and negative distance matrices from the mean: Positive (PDA) and negative distance (NDA) matrices are obtained from the mean for each criterion. Each element of the matrices obtained ($_{ij}$, NDA_{ij}) is calculated with different equations depending on whether the criterion is benefit-based or cost-based. Here, while PDA shows the positive distance of i. alternative to the mean solution according to j. criteria, NDA shows the negative distance of i. alternative to the mean solution according to j. criteria.

$$PDA = [PDA_{ij}]_{nxm},$$
$$NDA = [NDA_{ij}]_{nxm}$$

For benefit-based criteria,

$$PDA_{ij} = \frac{\max(0,(Xij - AVj))}{AVj}$$
$$NDA_{ij} = \frac{\max(0,(AVj - Xij))}{AVj}$$

For cost-based criteria,

$$PDA_{ij} = \frac{\max(0,(AVj - Xij))}{AVj}$$
$$NDA_{ij} = \frac{\max(0,(Xij - AVj))}{AVj}$$

In the equations shown above, the benefit criterion represents the criteria that are desired to be maximum and the cost criterion represents the criteria that is desired to be minimum.

Step 4. Calculation of weighted total positive and negative values: In this step, using the positive and negative distance matrices from the mean, the weighted total positive (SPi) and negative (SNi) values are calculated. Criteria weights found by entropy method are added to the equation as a multiplier and the calculation is done.

$$SP_i = \sum_{j=1}^{m} w_j \, xPDA_{ij}$$
$$SN_i = \sum_{j=1}^{m} w_j \, xNDA_{ij}$$

Step 5. Normalizing the weighted total values: In this step, normalized SPi and SNi values are calculated for all criteria by the help of the following equation.

$$NSP_i = \frac{SPI_i}{\max_i(SPi)};$$
$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)}.$$

Step 6. Evaluation of alternatives: Finally, the evaluation scores for each alternative (AS_i) is calculated.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i)$$

Finally, evaluation scores regarding alternatives (AS_i) are ranked from high to low. The alternative with the highest value is determined as the best selection among other alternatives.

Topsis Method

Topsis method is a MCDM method developed by Hwang and Yoon in 1980. This method is based on two basic points: positive ideal solution and negative ideal solution. The application steps of the Topsis method are as follows (Çakır & Perçin, 2013; Özbek, 2017; Yıldırım & Önder, 2018).

Step 1. Normalization of the decision matrix: First of all, as shown in the equation below, the values of the criteria are normalized by dividing by the square root of the sum of the squares of those criteria.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}} \qquad j=1, \ldots, m,\ i=1 \ldots, n.$$

The decision matrix is obtained by being normalized using the equation shown above, and with the standard decision matrix (R_{ij}).

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{bmatrix}$$

Step 2. Weighting the normalized decision matrix: In this step, by multiplying the predetermined criteria weights (w_j) by the elements of R_{ij} in the equation above, the weighted standard decision matrix (V_{ij}) is obtained

$$V_{ij} = \begin{bmatrix} w_1 n_{11} & w_2 n_{12} & \ldots & w_n n_{1n} \\ w_1 n_{21} & w_2 n_{22} & \ldots & w_n n_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 n_{m1} & w_2 n_{m2} & \ldots & w_n n_{mn} \end{bmatrix}$$

Step 3. Calculation of positive and negative ideal solution points: Taken as the positive ideal solution point, A^+ represents the best performance values in the weighted normalized matrix. The negative ideal reference point A^- indicates the worst performance values in the same matrix.

$$A^* = \left\{ (\max_i v_{ij} \,|\, j \in J), (\min_i v_{ij} \,|\, j \in J') \right\}$$

$$A^- = \left\{ (\min_i v_{ij} \,|\, j \in J), (\max_i v_{ij} \,|\, j \in J') \right\}$$

Step 4. Calculation of distances to positive and negative ideal solution points: In the Topsis method, there are two distinction measures: S_i^* and S_i^- Values of S_i^*, showing Euclidean distances of alternatives to positive ideal solution points, and S_i^-, indicating their distances to negative ideal solution points are calculated as follows.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

Step 5. Calculation of the relative proximity to the ideal solution point: C_i^*, which is the proximity coefficient, shows the proximity of the alternatives to the positive ideal solution point and is calculated by the following equation. Then the performance rankings of the alternatives C_i^* are ranged in order of magnitude of their values. The alternative with the highest value in the ranking is the first.

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

FINDINGS

The performances of the universities taken within the scope of the study were evaluated according to four criteria determined by TUBİTAK and ranked. The analyzes were carried out by applying the formulas shown in the method section. The universities and criteria considered within the scope of the analysis are shown in Table 2 and Table 3, respectively.

Table 2. Universities evaluated within the scope of the analysis

Code	University Name
U1	Middle East Technical University
U2	Istanbul Technical University
U3	Sabancı University
U4	İhsan Doğramacı Bilkent University
U5	Boğaziçi University
U6	Yıldız Technical University
U7	Gebze Technical University
U8	Hacettepe University
U9	Izmir Institute of Technology
U10	Ege University

Table 3. Criteria used within the scope of the analysis

Code	Criteria name
C1	Scientific and technological research competence
C2	Intellectual property pool
C3	Cooperation and interaction
C4	Economic contribution and commercialization

Table 4 shows the decision matrix of 2018 performance scores of the top 10 entrepreneurial and innovative universities. This matrix shows the criterion scores of 10 universities taken within the scope of analysis in the Entrepreneurial and Innovative University Index published by TUBITAK. When the analysis was performed, all values after the comma were taken into account in the TUBITAK ranking.

Table 4. Decision matrix

Universities	C1	C2	C3	C4
U1	23,63	16,24	28,54	24,75
U2	21,93	15,89	27,59	24,75
U3	18,08	15,16	27,9	24,36
U4	21,3	14,02	26,05	23,05
U5	20,55	15,46	28,06	19,26
U6	17,18	17,54	24,1	22,58
U7	18,18	9,93	24,64	25,07
U8	20,18	12,51	24,44	18,8
U9	20,99	9,3	24,93	20,42
U10	18,37	10,29	25	17

When evaluating universities, the weights of the four criteria used were calculated by Entropy method first. First, the entropy values were calculated by normalizing the decision matrix, then the weights of the criteria were obtained. Criterion weights are as shown in Table 3. When the table is examined, it is seen that the criteria are ranked as C2> C4> C1> C3 according to their weights. According to the results of the entropy method, the most important criterion was found to be the intellectual property pool (C2).

Table 5. Criterion weights

C1	C2	C3	C4
0.2393422	0.28014	0.232865	0.247652

Decision making is the process of choosing the most suitable alternative among the available options considering the criteria determined to achieve a specified goal (Özbek, 2017). Accordingly, the criterion weights obtained by Entropy method were

moved to Edas and Topsis methods and a ranking was done among the alternatives. The ranking results are shown in Table 6 and Table 7, respectively.

Table 6. Edas ranking results

Universities	NSP_I	NSN_I	AS_I	Ranking
U1	1	1	1	1
U2	0,75841824	1	0,879209119	2
U3	0,49502137	0,8357768	0,665399082	3
U4	0,23352846	0,99530631	0,614417385	4
U5	0,4088857	0,79395225	0,601418978	6
U6	0,58266361	0,63359998	0,608131796	5
U7	0,2317985	0,29273247	0,262265484	8
U8	0,01131255	0,514827	0,263069775	7
U9	0,07629954	0,2697953	0,173047419	9
U10	0	0	0	10

It is seen that the university with the best performance according to the evaluation scores obtained by Edas method is Middle East Technical University (U1). This university is followed by Istanbul Technical University (U2), Sabancı University (U3) and Bilkent University (U4), respectively.

Table 7. Topsis ranking results

Universities	S_i^*	S_i^-	C_i^*	Ranking
U1	0,009228	0,066177	0,877623	1
U2	0,014272	0,060692	0,809617	2
U3	0,030128	0,052255	0,634297	4
U4	0,029203	0,04542	0,608664	6
U5	0,030697	0,04851	0,612449	5
U6	0,033808	0,062053	0,647321	3
U7	0,060168	0,032829	0,353011	8
U8	0,047906	0,027236	0,362456	7
U9	0,063085	0,021984	0,258427	9
U10	0,065736	0,009246	0,123316	10

It is seen that the university with the best performance according to the evaluation scores obtained by Topsis method, just like in Edas method, is Middle East Technical University (U1). This university is followed by Istanbul Technical University (U2), Yildiz Technical University (U6) and Sabancı University (U3), respectively.

Table 8. Comparative ranking results of entrepreneurial and innovative universities

Universities	TUBITAK	Edas	Topsis
Middle East Technical University	1	1	1
Istanbul Technical University	2	2	2
Sabancı University	3	3	4
İhsan Doğramacı Bilkent University	4	4	6
Boğaziçi University	5	6	5
Yıldız Technical University	6	5	3
Gebze Technical University	7	8	8
Hacettepe University	8	7	7
Izmir Institute of Technology	9	9	9
Ege University	10	10	10

Table 8 contains the comparative ranking results of Entrepreneurial and Innovative universities. According to Edas and Topsis methods, while Middle East Technical University (U1) ranks first in both methods, Istanbul Technical University (U2) ranks second in the performance evaluation rankings. Sabancı University (U3) ranks third for the Edas method, while Yildiz Technical University (U6) ranks third for the Topsis method. When the results of the analysis are evaluated in general, it is seen that the findings are consistent with the results of TUBITAK.

CONCLUSION AND RECOMMENDATIONS

In the information society, universities have undertaken new tasks and relationships to contribute to economic and social development while maintaining their own sustainability. Therefore, they have begun to play a greater role in the economy and society as organizations that produce, disseminate and have the potential to apply information (Schmitz et al., 2017). Along with globalization, changes and developments taking place in information and communication technologies worldwide affect universities, too. Universities contribute to the development and increasing levels of well-being of their countries thanks to their research findings, as well as being education and research institutions. For these reasons, it is extremely important to educate individuals with the vision and capabilities of entrepreneurship and innovation and to make it widespread throughout the country. Besides, universities are in cooperation and interaction with various fields of industry. This interaction not only strengthens technology transfers but also provides mutual benefits for the public and private sectors.

"Entrepreneurial and Innovative University Index" has been published by TUBITAK since 2012 in order to encourage universities to entrepreneurship activities in Turkey. This index ranks universities under four dimensions, based on entrepreneurship and innovation performances. Four basic dimensions used in performance rankings are scientific and technological research competence, intellectual property pool, cooperation and interaction, and economic contribution and commercialization. This index report is expected to intensify competition in the field of entrepreneurship and innovation between universities and thus benefit the development of activities in this field.

In this study, 2018 performances of top 10 entrepreneurial and innovative universities in Turkey were ranked with MCDM methods. In this direction, the entrepreneurial and innovative university index criteria determined by TUBITAK were taken into account. Firstly, the objective weights of the criteria were determined by Entropy method. Then, the performances of the universities were measured with Edas and Topsis methods, which are from MCDM methods, and ranked and compared with TUBITAK results. Middle East Technical University ranks first in the performance evaluation ranking made according to Edas and Topsis methods. Istanbul Technical University ranks second for Edas and Topsis methods. Sabancı University ranks third for the Edas method and fourth for the Topsis method. When the overall ranking of all universities was examined, it was determined that their findings were quite similar to TUBITAK rankings.

When the findings of the studies in the literature conducted using different MCDM methods are examined, it is seen that, again, similar results were obtained with TUBITAK ranking results (Ömürbek and Karataş, 2018; Er and Yildiz 2018). Universities should support scientific studies, put emphasis on R&D activities, university-industry cooperation and patent studies in order to rise in performance rankings. The use of multiple methods within the scope of the study is important in terms of the comparison and consistency of the results. It is recommended to expand future studies to cover all universities in Turkey and to compare the results obtained by using different MCDM methods. In addition, the methods used in this study can be used to solve different decision-making problems.

Declaration of Conflicting Interests

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Statements of publication ethics

I hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Ethics Committee Approval Information

Since this study was carried out with open access data from the TUBITAK, the approval of the ethics commission was not applied.

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