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Scholarship recipient selection for higher education with AHP, SAW and TOPSIS

Okan Arslantaş[1], Mehmet Gümüş[2], Emir Hüseyin Özder[3*]

[1]Faculty of Engineering and Social Sciences, Sabancı University, Tuzla/İstanbul, Turkiye,
e-mail: okanarslantas@sabanciuniv.edu, ORCID No: http://orcid.org/0000-0002-5237-0105
[2]Rafet Kayış Faculty of Engineering, Alanya Alaaddin Keykubat University, Alanya/Antalya, Turkiye,
e-mail: mehmet.gumus@alanya.edu.tr, ORCID No: http://orcid.org/0000-0003-2588-0270
[3]Faculty of Engineering and Architecture, Ankara Science University, Çankaya/Ankara, Turkiye,
e-mail: emir.ozder@ankarabilim.edu.tr, ORCID No: http://orcid.org/0000-0002-1895-8060
*Corresponding Author

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Abstract

Higher education students need financial support from various sources to meet their needs throughout their education life. Besides non-profit organizations and governmental authorities, public charities provide scholarships to students with financial difficulties. These institutions give scholarships to a few students chosen from a pool of applicants based on various criteria. This study develops a model for selecting the most suitable higher-education students applying for a scholarship at a public charity organization. The organization takes applications on an annual basis. A total of eight selection criteria are determined based on literature review and expert opinions. Multi-criteria decision-making methods of AHP, SAW, and TOPSIS are employed to identify scholarship recipients. AHP is used to weigh the selection criteria. The ranking of applicants is achieved by SAW and TOPSIS. The opinions of the members of the organization's board of directors are used throughout the study. The proposed model provides a means for a time-efficient and more objective selection of scholarship recipients.

1. Introduction

Today, many students attend higher education, both undergraduate and graduate. These students experience problems in many ways. Financial difficulties are at the top of their problems. Students have nutrition, transportation, shelter, course materials, and social needs. It is often not possible for students to finance all these needs themselves. For this reason, undergraduate and graduate students apply for scholarships to various institutions and organizations to continue their education.

Many public and private institutions provide financial support to students in various ways. Students show great interest in these scholarships, which provide financial support for their student's academic life. These institutions, which cannot offer scholarship opportunities to all students who apply, try to decide on the most suitable ones by considering many criteria (Abalı et al. 2012).

Decision-making is the process of determining and selecting alternatives that will create the most appropriate solution in light of various factors and expectations of decision-makers. Decisions are typically made in an environment that combines knowledge, values, alternatives, and preferences. The compelling situation when deciding is the variety of criteria considered in evaluating alternatives. Multi-Criteria Decision Making (MCDM) methods are thus used to overcome such difficulties in the decision-making process. In this way, it becomes easier to solve complex decision-making problems (Aytaç & Gürsakal, 2015).

In this study, MCDM methods of Analytical Hierarchy Process (AHP), Simple Additive Weighting (SAW), and Technique For Order Preference By Similarity To An Ideal Solution (TOPSIS) are used to select scholarship recipients among a pool of applicants pursuing undergraduate studies. The AHP method is chosen due to its ability to weight criteria efficiently. SAW and TOPSIS are used in order to compare and rank the applicants, and to identify the scholarship awardees. TOPSIS method is selected because it is thought to be a complex but better performing method for complicated problems with high number of alternatives and criteria. On the other hand, SAW is typically considered as a simple method and has generally not been measured against TOPSIS. Due to that, and to generate a new perspective, this study compares SAW and TOPSIS methods with a case study.

Rest of the paper includes five sections. The next section is a literature review which examines the papers that include AHP, TOPSIS, and SAW methods, and also the articles relevant to higher-educations scholarships. Next, the third section explains the concept of scholarship in Turkey. The MCDM methods of AHP, TOPSIS, and SAW are explained with their mathematical representations in the fourth section. The fifth section includes a case study that applies these methods to a particular dataset, and the last section provides the conclusions.

2. Literature review

This paper contributes to the literature by applying AHP, TOPSIS, and SAW methods for scholarship selection and explains the higher-education scholarships selection process in Turkey. Moreover, it compares the SAW and TOPSIS methods using a real life case. The following subsections are used to detail the literature on the methods used and on the problem studied separately.

2.1. Literature review for the suggested methods

This section provides related literature on the MCDM methods, including AHP and TOPSIS. To start with, Yeh (2003) formulates the scholarship student selection process as a multiattribute decision-making problem and presents suitable compensatory methods for solving the problem. A new empirical validity procedure is developed to deal with the inconsistent ranking problem caused by different multi-attribute decision-making methods.
Özkan (2007) used the AHP, ELECTRE, and TOPSIS methods to determine the most suitable candidate for the job in "Investigation of Decision-Making Methods in Personnel Selection."

Ertuğrul and Karakaşoğlu (2009) evaluated the performance of commercial banks by using multi-criteria decision-making methods in their study. The criteria that are effective in performance evaluation are weighted with the AHP method, and a ranking is made in terms of the performances of the banks examined by the VIKOR method.
Ersöz et al. (2011) discussed the subject of course selection in undergraduate and graduate education. The criteria that were effective in the course selection process of the students were determined and weighted using the ANP method, and the weighted courses were arranged in the most appropriate way for the student with the Topsis method.

Kaya et al. (2011) evaluated the quality of life of the European Union and candidate countries for 2003, 2005, and 2007 with VIKOR, a multi-criteria decision-making method. Result of the study, our country, which is a candidate country for the European Union, seems to be in the last place in terms of quality of life for the three years of research.

In Christobal's (2011) study, the selection of investment projects for the Renewable Energy Plan to be implemented in Spain was carried out with the VIKOR method. The criteria were weighted with the AHP method, and the most suitable project was selected among the projects that were candidates for this plan with the VIKOR method.
Jati (2012) investigated webometrics rankings for world universities in his study. TOPSIS and VIKOR calculated webometrics rankings for world universities using two quantitative techniques. These calculations were made according to the website volume, visibility of the published information, rich content size, and information criteria. As a result of the study, webometric rankings of 20 universities worldwide were obtained using TOPSIS and VIKOR methods.

Mančev (2013) aims to analyze the quality of NIS university library services. In his study, the criteria for the time spent searching through the existing library databases and the size of the available library funds were evaluated to compare the quality of services. Then, NIS University libraries were ranked according to their service quality with the VIKOR method.

Ömürbek et al. (2014) used AHP, TOPSIS, and VIKOR methods to evaluate the performances of 10 ADIM universities in Anatolia, which were established in 1993. In evaluating the performances of the selected ADIM universities, 21 criteria were determined by taking the studies in the literature and expert opinion, and the weighting of these criteria was made with the AHP method. The weighted criteria were solved by TOPSIS and VIKOR methods. The study of two different methods shows that the university with the highest performance among ADIM universities is Süleyman Demirel University.

Kittur (2015) discussed SAW, WP, and PROMETHEE methods to evaluate the optimal electricity generation time intervals from different local energy resources. The weight of each attribute is decided by using the AHP method. According to SAW and WP, 5 a.m. is the optimal generation time, but it is 6 a.m. based on the PROMETHEE method.

Urfalıoğlu (2015) used the ELECTRE, TOPSIS, and PROMETHEE methods to compare Turkey's performance with the European Union member states. Pekkaya (2015) examined the parameters that affect the career choice of students studying at Bülent Ecevit University. He reduced the criteria to 6 main criteria, and the students evaluated the criteria in pairwise comparison with the help of a questionnaire. He weighted the criteria with AHP and determined the degree of importance of the effective criteria at the end of the study.

Ameri et al. (2018) used morphometric parameter analysis on the sub-watershed of the Ghaemshahr Basin. Based on the results, they implement SAW, VIKOR, TOPSIS, and CF methods to prioritize sub-watersheds. In another study, Widianta et al. (2018) compared TOPSIS, SAW, AHP, and PROMETHEE methods for employee placement. Writers assigned different weights to each method. They calculated the accuracy score of each method, which ranged between %50 and %95. However, the results are almost identical for the first ten alternatives.

Ibrahim and Surya (2019) also used the SAW method to find the best school in Jambi. They conclude that the SAW method is capable of selecting the best schools. In their paper, Al Amin et al. (2019) explained the strengths and weaknesses of each MCDM process. Furthermore, they showed the steps of AHP and TOPSIS with a case study.

2.2. Literature review for the methods for allocation of scholarship

Sulaiman and Mohamad (2006) developed a fuzzy logic model for students applying for the scholarship selection process. The selection is based on specific criteria determined by the sponsor. An example is given at the end of the paper to illustrate the model. The MATLAB fuzzy logic toolbox is used to calculate the output.
In his study, Hacıköylü (2006) used the AHP method, one of the multi-criteria decision-making methods, to select students studying at Anadolu University who will receive scholarships and food aid. In selecting students who will receive a scholarship and food aid, four main criteria were evaluated, and their weights were determined by the AHP method, and at the end of the study, the students who would receive scholarships and aid were compared according to the criteria weights.

Abalı et al. (2012). In the study titled Scholar Selection with Multi-Criteria Decision-Making Methods: Application in an Educational Institution, students who are eligible to receive scholarships with the AHP and TOPSIS methods were determined for the supporting scholarship to be given to the students studying at the Engineering Faculty of Kırırkkale University. The weight of the criteria to be evaluated in determining the students who will receive support scholarships was determined by AHP, and the most suitable candidate was selected with the TOPSIS method.

Wimatsari et al. (2013) use fuzzy Multi-Attribute Making Decision with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method for demonstrating the scholarship selection with cases in a University, Indonesia. Selection of recommended students with the highest level of eligibility for the scholarship based on the value preferences.

Pençe et al. (2017) use AHP and TOPSIS methods to determine the students studying at a Turkish University Faculty of Education and applying for a scholarship. Their study identifies the most suitable 27 candidates for the the scholarship. On a similar problem, Marbun et al. (2018), consider only four criteria for scholarship selection in Indonesia. They use SAW, WP, and TOPSIS methods on a case. applies them to a scholarship selection.

3. The concept of scholarship and scholarship applications in Turkey

3.1. The concept of scholarship

Scholarships are monthly payments made by government or private institutions for a certain period to support a student's education financially or to increase his/her knowledge and culture. Higher education students should have the financial means to meet their social, cultural, and physiological needs. Students obtain these financial opportunities by getting support from their families, by working in a job, or by getting financial aid from some institutions and organizations that support students' education.

Most university students continue their education in different cities. Thus, higher education students typically face accommodation, transportation, and nutrition expenses. For many students, it is impossible to meet these expenses only with the contribution of their families. In addition to working part-time jobs, these students apply for financial support from institutions and organizations that provide scholarships. Scholarships can be for undergraduate or graduate students, reimbursed or non-refundable, and may be offered by public or private institutions either domestically or internationally. Indeed, various institutions that provide scholarships significantly contribute to students' living a more comfortable education life.

3.2. Higher-education Scholarships in Turkey

Many institutions, municipalities, universities, and organizations, including the Credit and Hostels Institution in Turkey, provide financial aid to undergraduate and graduate students with low income and high success status under scholarships.
Scholarships and aids given to university students in Turkey are generally described as follows.

1- Scholarships from the Higher Education Credit and Hostels Institution,
2- Ministry of National Education scholarships,
3- Scholarships that universities give,
4- Scholarships given by institutions such as municipalities and various associations and foundations,
5- Scholarships that individuals give.

The majority of students in Turkey seek financial support for their university education. A survey study conducted in 2001 with 5154 higher education students studying at 52 universities highlighted this. Survey results revealed that 54.4% of university students received education loans, 47.8% received contribution loans, 16.5% received scholarships from public institutions, 6.6% received scholarships from various non-governmental organizations, and individuals gave 3.3% of their scholarships. (Hacıköylü, 2006).

4. MCDM methods of AHP, TOPSIS and SAW

Decision-making includes identifying and selecting alternatives to achieve the best solution based on various factors and decision-makers expectations. The multi-criteria decision-making process in this study includes AHP and TOPSIS, which are explained in the following sections.

4.1. Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP), developed by Thomas Saaty in the 1970s, is a Multi-Attribute Decision-Making method that enables complex decision problems to be dealt with in a hierarchical structure. In AHP, the decision maker can include his objective and subjective thoughts in the decision process. This will enable the decision maker to recognize their decision-making mechanisms by considering the observations in different psychological and sociological situations. This feature is an important feature that distinguishes AHP from other multi-qualified decision-making methods. Another feature of the method that distinguishes it from other multi-qualified decision-making methods is that it is the most widely used method in many areas, from political to individual decisions.
The Analytical Hierarchy Process includes the major following steps.

1. Defining the problem and identifying the information needed,
2. Establishing a decision hierarchy with the primary goal at the top, the criteria in between, and the alternatives at the bottom,
3. Creation of pairwise comparison matrices,
4. Determination of priorities for each level by using pairwise comparisons.

Step 1: With a detailed approach, the first step for finding criteria weights with AHP consists of creating an initial pairwise comparison matrix by assigning each comparison criterion to a 1-9 scale. 1-9 scale assignments made based on Table 1 and creating the initial pairwise comparison matrix formula shown in equation (1).

$$A = [a_{11} \cdots a_{1n} \vdots \ddots \vdots a_{m1} \cdots a_{mn}] \quad (1)$$

Table 1. Pairwise comparison values (Saaty, 1977)

1	**3**	**5**	**7**	**9**	**2, 4, 6, 8**
Equally Important	Moderately Important	Strongly Important	Very Strongly Important	Absolutely Important	Intermediate Values

Where A represents the initial pairwise comparison matrix, a_{ij} shows the importance of criteria i to criteria j.
Step 2: Initial pairwise comparison matrix normalized by following equation (2):

$$N_{ij} = \frac{a_{ij}}{\sum_i^n a_{ij}} \quad \text{where} \quad a_{ji} = \frac{1}{a_{ij}} \tag{2}$$

N_{ij} shows the normalized matrix, a_{ij} shows the importance of criteria i to criteria j
Step 3: With using normalized decision matrix, criteria weights determined by using the following formula (3):

$$W_i = \frac{\sum_j^n N_{ij}}{n} \tag{3}$$

W_i represents the criteria weight, N_{ij} is normalized matrix value and n is number of criteria.

Step 4: To examine the consistency of the criteria weights, the Consistency Indicator (CI) and Consistency Ratio (CR) was calculated according to formula (4) and (5).

$$CI = (\lambda_{max} - n) / (n - 1) \tag{4}$$

"n" represents the number of criteria and "λ_{max}" represents the principal eigenvalue

$$CR = CI / RI \tag{5}$$

"CL" is the consistency indicator and "RI" is the Random Index that calculates the mean consistency indices of specific numbers of random number pairwise comparison matrices. "RI" can be determined from Table 2.

Table 2. Random Index Table (Saaty, 1980)

Number of elements	**3**	**4**	**5**	**6**	**7**	**8**
R.I.	**0.52**	**0.89**	**1.11**	**1.25**	**1.35**	**1.40**

4.2. TOPSIS

The TOPSIS method, developed by Hwang and Yoon (1981), is based on ranking the alternatives in a decision-making problem according to specific criteria. The method relies on the chosen alternative being the closest to the ideal solution and the farthest from the negative ideal solution.
The first step in the TOPSIS method is to create a decision matrix with m alternatives evaluated according to n criteria. The alternatives are recorded from top to bottom, and the characteristics of that alternative according to the relevant criteria are written in front of each alternative. The general representation of this matrix is shown equation (6):

$$D = [x_{11} \cdots x_{1n} \vdots \ddots \vdots x_{m1} \cdots x_{mn}] \tag{6}$$

Here x_{ij} represents the performance measure of alternative *i* according to criteria *j*.
Further steps of the method are listed as follows:

Step 1: Normalize the decision matrix by taking the square root of the sum of squares of the criteria values. This process is structured as follows equation (7):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^m x_{kj}^2}} \tag{7}$$

r_{ij} represents the normalized matrix and x_{ij} is the criteria value.

Step 2: Build the weighted normalized matrix.

$$V = [w_{11}r_{11} \cdots w_{1n}r_{1n} \vdots \ddots \vdots w_{m1}r_{m1} \cdots w_{mn}r_{mn}] \quad (8)$$

Where V represents the weighted normalized matrix, r_{mn} represents the normalized matrix and w_{mn} shows the criteria weights.
Step 3: Identify the ideal and negative ideal solutions. The ideal solution is denoted as A^*, the negative ideal solution as A^-, and the alternatives (solutions) are defined as follows:

$$A^* = \{(max_i v_{ij}\, j\epsilon J), (min_i v_{ij} j\epsilon J|), i = 1,2,3 \ldots m\} = \{V_1^*, V_2^*, V_3^*, \ldots V_n^*\}$$
$$A^- = \{(min_i v_{ij}\, j\epsilon J), (min_i v_{ij} j\epsilon J|), i = 1,2,3 \ldots m\} = \{V_{1-}^*, V_{2-}^*, V_{3-}^*, \ldots V_{n-}^*\}$$
$$J = \{j = 1,2,3 \ldots . n \text{ and } j \text{ related to utility criteria}\}$$
$$J| = \{j = 1,2,3 \ldots n \text{ and } j \text{ related to cost } (lost) \text{ criterion}\}$$

Step 4: Calculate the distance to the maximum ideal point (9).

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v*_j)^2}; \qquad i = 1,2,3, \ldots, m \quad (9)$$

S_i^* represents the distance to the maximum ideal point, v_{ij} shows weighted alternatives and $v*_j$ is the maximum ideal point.

Step 5: Calculate the distance to the minimum ideal point (10).

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j-})^2}; \qquad i = 1,2,3, \ldots, m \quad (10)$$

S_i^- is the distance to the minimum ideal point, v_{ij} shows weighted alternatives and v_{j-} is the minimum ideal point.
Step 6: Calculate the relative closeness to the ideal solution (11).

$$C_i^* = \frac{S_{i-}}{S_{i^*} + S_{i-}}; 1 \geq C_i \geq 0 \text{ and } i = 1,2,3, \ldots, m \quad (11)$$

C_i^* shows relative closeness to the ideal solution, S_{i^*} and S_{i-} are distances to ideal maximum and minimum points, respectively.
Step 7: Rank the alternatives according to the obtained C_i^* values

4.3. SAW
Simple Additive Weighting is a commonly used method among the Multi-Criteria Decision Models. It is also known as the weighted sum method. Let i and j be the alternatives and selection criteria index, respectively. i = 1, 2, …, M and j = 1, 2, …, N. Then the SAW method consists of three steps.
Step 1: Normalization of initial matrix based on the efficiency index R_{ij} (12).

$$R_{ij} = \frac{X_{ij}}{\sum_i^M Xij} \quad (12)$$

R_{ij} is the normalized value of the j th criterion, M is the number of the criteria, and X_{ij} is the initial value. R_{ij} formula changes depending on the type of the criteria as follows:

If the criteria are classified as a benefit, R_{ij} is maximized based on this formula (13):

$$R_{ij} = \frac{X_{ij}}{X_{ij}^{Max}} \quad (13)$$

If the criteria are classified as a cost, R_{ij} is minimized based on this formula:

$$R_{ij} = \frac{X_{ij}^{Min}}{X_{ij}} \quad (14)$$

Step 2: Calculate the normalized weights for each criteria (15).

$$w_j = \text{The weight obtained from AHP} \quad (15)$$

Note that w_j is the weight of criteria j. Although different methods may be used to obtain weights, this paper uses the previously calculated weights in the AHP method.

Step 3: Calculate the total preference value for each alternative and rank the alternatives (16).

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$$V_i = \sum_{j=1}^{N} R_{ij} \times w_j \quad (16)$$

V_i is the final preference value of the ith alternative. Alternatives are then ranked based on their V_i score and sorted in descending order. The alternative that has the highest preference score is the best alternative.

5. Case Study

The discussed MCDM methods are applied in a public charity organization that awards scholarships to several university students nationwide every year. Many students need this scholarship application to the regional branches of the organization at the beginning of each year. In most cases, awards are entitled to receive the scholarship until the year they graduate as long as they are academically successful. Scholarship recipients are typically selected by the members of the administrative board of the branch, taking into account the applicants' information and subjective scoring and evaluation of each student.

Currently, the evaluation is made by considering many criteria and alternatives. Therefore, there is a high probability that the board of directors members makes mistakes in selecting the appropriate students when making the assessment. In addition, evaluating and scoring each student one by one causes an excessive waste of time.

In this study, eligibility ranking was made by establishing a model using AHP, TOPSIS, and SAW methods to identify the students most suitable for the scholarship. Application is carried out at a branch that wanted to select 23 scholarship students out of 335 applicants.

In the first stage of the study, through interviews with the members of the branch board of directors, the criteria for selecting scholarship awardees were determined. In the second stage, the weights of the criteria were determined by the AHP method. In the last stage, the TOPSIS and SAW methods were used to rank the applicants according to their eligibility levels, and the ones entitled to receive the scholarship were determined.

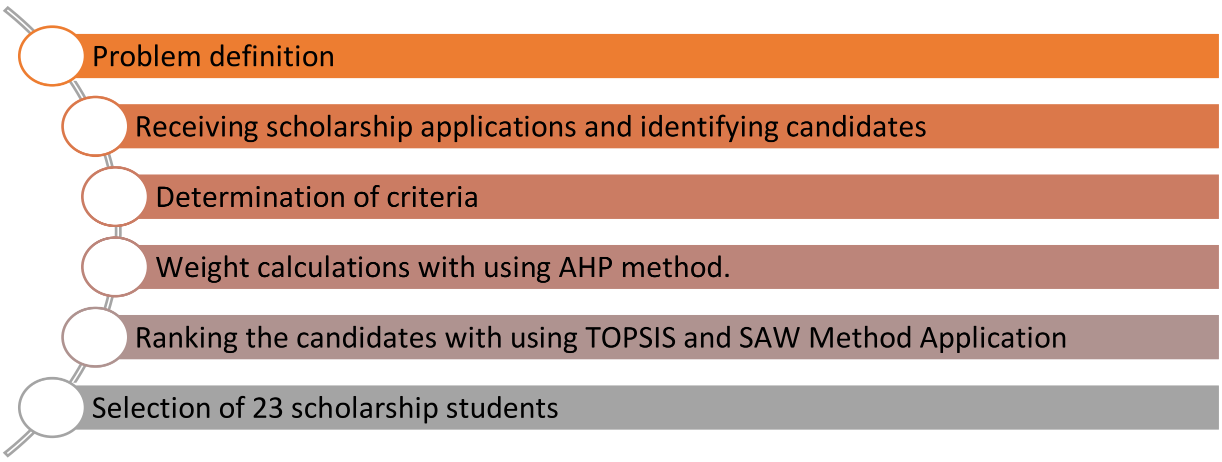

Figure 1. Application steps

5.1. Selection Criteria

While determining the criteria, a literature review was done for the important criteria in the scholarship process. Moreover, the scholarship application forms of the scholarship institutions were examined. A criteria table was created with the information obtained from the research. While examining the studies in the literature has been focused on the criteria determined during the selection, especially in the scholarship selection studies. The mentioned criteria are shown in Table 3.

Table 3. Selected studies

Authors	Selection Criteria
Wimatsari et al. (2013)	Economic capacity of parents GPA Student's status Proof for Bills and Payments
Abalı et al. (2012)	Number of dependent children in the family Total monthly income of the family Parent status Total number of properties owned by the family Student's working status
Sulaiman and Mohamad, (2006)	Academic Qualification Relevancy of area of study Performance in Interview
Yeh, (2003)	Community services Sports/Hobbies Work expenerice Energy Communication skills Attitude to business Maturity Leadership

The opinions of the association's board of directors were then consulted to finalize the list of criteria they want to use awarding scholarships. The final criteria determined in line with their opinions are Grade point average (GPA), Total monthly income of the family (MI), student's class (SC), The student's family (parent) status (SPS), Number of people in the family (NPF), Number of students in the family (NSF), student's department (SD) and student's monthly income (SMI). We note that SPS and SD are subjective, and the rest are objective criteria. SPS and SD are subjective criteria because the status and social environment of the family and the quality of the department the student studies can be evaluated differently from person to person in terms of whether it is good or bad. In the evaluation phase of the alternatives, the students' data were used directly for the objective criteria, and the values were assigned by the board of directors using the "1-9 scale" and "1-5 scale" for the subjective criteria.

The so-called expert board consists of 9 people and each member has more than 20 years of experience in the field. The members of this board met 4 times in total, at the request and hosting of the institution that will provide the scholarship, to determine the criteria and to give the necessary ideas. In determining the criteria and comparing them with each other, each expert makes his/her own assessment. Finally, those assessments are combined by averaging the experts' individual evaluation scores.

Among the objective criteria, GPA is necessary to examine a student's course success. Since the 1st year students do not have a GPA yet, their high school graduation score was used instead. The student's GPA was converted to a percentage (i.e., out of 100) and used as an objective criterion. MI shows the total monthly income of the people working in the student's family, and SC shows the class the student is currently enrolled. NPF and NSF indicate the number of people and the number of students living in the applicant's family household, respectively. SMI shows the student's monthly income earned either by working in a job or getting a scholarship elsewhere.

SPS is a subjective criterion that shows the status of the student's parents. Its values are assigned by the board of directors using a 1-9 scale as follows: 1 if the mother and father are together; 3 if the parents are divorced; 5 if the mother is alive and the father is deceased; 6 if the mother is deceased and the father is alive; 9 if the mother and father are deceased.

SD is also a subjective criterion that shows the major the student is studying. Since some of the benefactors who donated scholarships to the association wanted to give scholarships to students studying in specific departments,

the department the students studied was considered as a criterion. Its values are assigned as per major by the board of directors using a 1-5 scale as follows: 5 for medicine; 4 for dentistry; 3 for engineering, architecture, physiotherapy and rehabilitation, nursing, and education; 2 for the other 4-year majors; 1 for two-year courses.
In addition to the selection criteria described above, the organization's board members also conduct interviews with applicants before finalizing the list of awardees. As those members judge the interview results according to their experience and expectations, they are not included in this study.

5.2. Determining the Weights of the Criteria with AHP

While determining the criteria weights, the opinions of experts were consulted. The importance values of the criteria were determined according to the board of directors' members using the survey method for the criteria weights. By using these values, a pairwise comparison matrix was obtained. The criteria weights were reached using the pairwise comparison matrix and the AHP method. The pairwise comparison matrix shows the importance of the criteria relative to each other. Using this matrix, the processing steps of the AHP method were started. The pairwise comparison matrix is shown in Table 4.

Table 4. Binary comparison matrix for criteria

Criteria	GPA	MI	SC	SPS	NPF	NSF	SD	SMI
GPA	1.00	1.50	1.70	5.00	2.50	2.00	3.35	1.50
MI	0.67	1.00	1.15	3.50	1.75	1.50	2.30	1.00
SC	0.59	0.87	1.00	3.00	1.50	1.20	2.00	0.80
SPS	0.20	0.29	0.33	1.00	0.50	0.40	0.65	0.28
NPF	0.40	0.57	0.67	2.00	1.00	0.80	1.35	0.58
NSF	0.50	0.67	0.83	2.50	1.25	1.00	1.65	0.70
SD	0.30	0.43	0.50	1.54	0.74	0.61	1.00	0.40
SMI	0.67	1.00	1.25	3.57	1.72	1.43	2.50	1.00
TOTAL	4.32	6.33	7.43	22.11	10.96	8.93	14.80	6.26

The normalized decision matrix is then created, and the priority vectors are found. All elements in the pairwise comparison matrix is divided by the sum of the column they are in, and a normalized decision matrix is created with the resulting values. Priority vectors are obtained by averaging the rows of this matrix (5).

Table 5. Normalized decision matrix of criteria

Criteria	GPA	MI	SC	SPS	NPF	NSF	SD	SMI	Priority Vector
GPA	0.231	0.237	0.229	0.226	0.228	0.224	0.226	0.240	0.230
MI	0.154	0.158	0.155	0.158	0.160	0.168	0.155	0.160	0.158
SC	0.136	0.137	0.135	0.136	0.137	0.134	0.135	0.128	0.135
SPS	0.046	0.045	0.045	0.045	0.046	0.045	0.044	0.045	0.045
NPF	0.093	0.090	0.090	0.090	0.091	0.090	0.091	0.093	0.091
NSF	0.116	0.105	0.112	0.113	0.114	0.112	0.111	0.112	0.112
SD	0.069	0.069	0.067	0.070	0.068	0.068	0.068	0.064	0.068
SMI	0.154	0.158	0.168	0.162	0.157	0.160	0.169	0.160	0.161

The consistency of the pairwise comparison matrix created in line with the opinions of the board of directors is examined. The following formulas are used to examine consistency (17) (18):

$$Indıcator\ of\ Consistency\ (CL)\ = (\lambda_{max} - n)\ \div\ (n-1) \tag{17}$$

$$Consistency\ Ratio\ (CR) = CL \div RI \tag{18}$$

“RI” represents the Randomness Indicator Value, and “n” is the number of benchmarks compared. The consistency ratio is calculated for the pairwise comparison matrix. To reach the λmax value, first matrix multiplication is made between the pairwise comparison matrix and the priority vector values. The λmax value is obtained by dividing the elements of this matrix into the priority vector matrix elements in order and taking the average. The λmax value obtained as a result of these processes is 8.00198. So, CL is calculated as (19):

$$CL = (\lambda_{max} - n) \div (n-1) = 0.000283 \tag{19}$$

The RI value for n equals 8, is obtained as 1.41 from the random indicators.CR was founded as (20)

$$Consistency\ Ratio\ (CR) = CL \div RI = 0.000201 \tag{20}$$

Since the Consistency Ratio is less than 0.10, the pairwise comparison matrix is consistent. When the weights of the criteria are examined, it can be said that the most important criterion is the GPA criterion with a weight of 0.230, and the criterion with the lowest weight is the SPS criterion with a weight of 0.045.

5.3. Application of TOPSIS

This study used the actual data of 335 university students who applied for scholarships. The codes S1 - S335 were used instead of the students' names. Using the application data of the students, the suitability-level ranking was made with the help of the TOPSIS method. The decision matrix prepared based on the applications is given in Table 6.

Table 6. Decision matrix for alternatives

Students	Criteria							
	GPA	MI	SC	SPS	NPF	NSF	SD	SMI
S1	57.3	1530	1	1	3	1	1	500
S2	79.93	1200	1	1	4	2	2	0
S3	53.8	1800	4	1	4	2	3	0
S4	96	0	2	5	4	2	5	0
S5	68	4200	1	1	5	3	3	0
S6	68.73	3700	3	1	4	2	2	0
S7	91.6	0	2	1	4	2	4	0
S8	64.06	1500	4	1	4	2	2	500
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
S335	60.00	6700	1	1	4	1	3	0

The decision matrix is then normalized, and the results are given in Table 7.

Table 7. Normalized decision matrix for alternatives

Students	Criteria							
	GPA	MI	SC	SPS	NPF	NSF	SD	SMI
S1	0.0443	0.0299	0.0203	0.0287	0.0319	0.0208	0.0167	0.0773
S2	0.0618	0.0235	0.0203	0.0287	0.0426	0.0416	0.0334	0
S3	0.0416	0.0352	0.0812	0.0287	0.0426	0.0416	0.0501	0
S4	0.0742	0	0.0406	0.1433	0.0426	0.0416	0.0835	0
S5	0.0526	0.0822	0.0203	0.0287	0.0532	0.0624	0.0501	0
S6	0.0531	0.0724	0.0609	0.0287	0.0426	0.0416	0.0334	0
S7	0.0708	0	0.0406	0.0287	0.0426	0.0416	0.0668	0
S8	0.0495	0.0294	0.0812	0.0287	0.0426	0.0416	0.0334	0.0773
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
S335	0.05	0.1311	0.0203	0.0287	0.0426	0.0208	0.0501	0

The weighted decision matrix is then obtained by multiplying the criteria weights obtained using the AHP method and the normalized decision matrix elements. The weighted normalized decision matrix obtained is shown in Table 8.

Table 8. Weighted normalized decision matrix for alternatives

Students	Criteria							
	GPA	MI	SC	SPS	NPF	NSF	SD	SMI
S1	0.0102	0.0047	0.0027	0.0013	0.0029	0.0023	0.0011	0.0124
S2	0.0142	0.0037	0.0027	0.0013	0.0039	0.0047	0.0023	0.0000
S3	0.0096	0.0056	0.0109	0.0013	0.0039	0.0047	0.0034	0.0000
S4	0.0171	0.0000	0.0055	0.0065	0.0039	0.0047	0.0057	0.0000
S5	0.0121	0.0130	0.0027	0.0013	0.0048	0.0070	0.0034	0.0000
S6	0.0122	0.0115	0.0082	0.0013	0.0039	0.0047	0.0023	0.0000
S7	0.0163	0.0000	0.0055	0.0013	0.0039	0.0047	0.0045	0.0000
S8	0.0114	0.0047	0.0109	0.0013	0.0039	0.0047	0.0023	0.0124
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
S335	0.0107	0.0208	0.0027	0.0013	0.0039	0.0023	0.0034	0

Ideal and negative ideal solutions are then identified. In Table 9, an explanation has been made about whether each criterion is a benefit or a cost.

Table 9. Benefit – Cost criteria

Criteria	Status	Benefit - Cost Reasoning
GPA	Benefit	A high GPA score means a high level of success which is desired by the organization.
MI	Cost	Higher monthly income of the students' family indicates lesser need for scholarship.
SC	Cost	Organization intends to give scholarships to selected students until they graduate and hence aims for providing scholarships for a long time in order to contribute more to their needs. As the class of the students increases, the duration of benefiting from the scholarship will decrease.
SPS	Benefit	Applicants are scored by the board of directors considering their family status. Students with high scores have an advantage in assessment
NPF	Benefit	Higher number of people in the student's family cause lesser share of the family income per individual, which increases the student's need for scholarship.
NSF	Benefit	A high number of students in the family causes the family's income spared for education to be shared more, thus increasing the student's need for scholarship.
SD	Benefit	The majors of students are scored by the administrative board. Students with high scores have an advantage in assessment.
SMI	Cost	If the students earn income by working or by receiving a scholarship from another institution shows that they need the organization's scholarship less.

The A^+ and A^- values obtained by using the weighted decision matrix are given in Table 10.

Table 10. A^- and A^+ Values

	GPA	MI	SC	SPS	NPF	NSF	SD	SMI
IDEAL SOLUTION (A^+)	0.0175	0.0000	0.0027	0.0078	0.0136	0.0186	0.0057	0.0000
NEGATIVE IDEAL SOLUTION (A^+)	0.0029	0.0589	0.0109	0.0013	0.0010	0.0023	0.0011	0.0627

The distances of alternatives (students) to ideal and negative ideal solutions are then calculated for each alternative. The distance to the ideal point (S_i^+) and the negative ideal point (S_i^-) for the alternatives are shown in Table 11. The relative closeness (C_i^*) to the ideal solution are the calculated and depicted in Table 11.

Table 11. S_i^- , S_i^+ and C_i^* values of alternatives

Students	S_i^+	S_i^-	C_i^*
S1	0.0259241	0.07474	0.7425
S2	0.0191551	0.08479	0.8157
S3	0.0222993	0.08270	0.7876
S4	0.0172743	0.08772	0.8355
S5	0.0213852	0.07894	0.7868
S6	0.0230591	0.07932	0.7748
S7	0.0184663	0.08740	0.8256
S8	0.02496	0.07456	0.7492
.	.	.	.
.	.	.	.
.	.	.	.
S335	0.02974	0.07434	0.7142

Ranking of the alternatives for awarding a scholarship is then made by ordering the C_i^* values from highest to lowest. The results are given in Table 11.

5.4. Application of SAW

Similar to the TOPSIS method, the decision matrix for alternatives (Table 6) and the cost-benefit criteria (Table 9) are also used for the SAW method. As the weights come from the AHP method, we next show the calculations for the R_{ij}'s and V_i's. To start with, the normalized matrix created based on the R_{ij} values of each alternative is given in Table 12.

Table 12. Normalized Matrix base on R_{ij}

Students	Criteria							
	GPA	**MI**	**SC**	**SPS**	**NPF**	**NSF**	**SD**	**SMI**
S1	0.58	0.00006	1	0.17	0.21	0.13	0.2	0.0002
S2	0.81	0.00008	1	0.17	0.29	0.25	0.6	1
S3	0.55	0.00005	0.25	0.17	0.29	0.25	0.6	1
S4	0.98	1	0.5	0.83	0.29	0.25	1	1
S5	0.69	0.00002	1	0.17	0.36	0.38	0.6	1
S6	0.7	0.00002	0.33	0.17	0.29	0.25	0.4	1
S7	0.93	1	0.5	0.17	0.29	0.25	0.8	1
S8	0.65	0.00006	0.25	0.17	0.29	0.25	0.4	0.0002
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
S335	0.61	0.00001	1	0.17	0.29	0.13	0.6	1

To obtain the weighted normalized decision matrix, the Rij's are then multiplied by the criteria weights which were obtained by the AHP method, and the results are given in Table 13.

Table 13. Weighted Normalized Decision Matrix

Students	Criteria							
	GPA	**MI**	**SC**	**SPS**	**NPF**	**NSF**	**SD**	**SMI**

S1	0.134073	0.000010	0.134729	0.007511	0.019490	0.013992	0.013538	0.000032
S2	0.187023	0.000013	0.134729	0.007511	0.025987	0.027984	0.027075	0.160979
S3	0.125883	0.000009	0.033682	0.007511	0.025987	0.027984	0.040613	0.160979
S4	0.224625	0.158498	0.067364	0.037556	0.025987	0.027984	0.067688	0.160979
S5	0.159109	0.000004	0.134729	0.007511	0.032484	0.041977	0.040613	0.160979
S6	0.160817	0.000004	0.044910	0.007511	0.025987	0.027984	0.027075	0.160979
S7	0.214329	0.158498	0.067364	0.007511	0.025987	0.027984	0.054150	0.160979
S8 . . . . **S335**	0.149890 . . . . 0.14390	0.00001 . . . . 0.00002	0.033682 . . . . 0.134729	0.007511 . . . . 0.007511	0.02587 . . . . 0.025987	0.027984 . . . . 0.013992	0.02707 . . . . 0.040613	0.0000320 . . . . 0.1609790

Then sum all the values in the row is the V_i score for given alternative. Ranking of the alternatives are performed based on the V_i values (from the highest to the lowest) as given in Table 13.

5.5. Ranking with TOPSIS and SAW

Ranking of the alternatives based on TOSIS and SAW are given in a single table for comparison purposes. Those ranking are provided in Table 14.

Table 14. Rank of each alternative

	Ranking with TOPSIS		Ranking with SAW	
Rank	**Student #**	**TOPSIS Value**	**Student #**	**SAW Value**
1	82	0.89528	4	0.77068
2	194	0.88406	320	0.75363
3	31	0.86657	277	0.73748
4	248	0.85742	298	0.73298
5	251	0.85662	7	0.71680
6	244	0.85441	82	0.70074
7	168	0.85076	100	0.69369
8	245	0.84646	329	0.66060
9	217	0.84528	306	0.66000
10	277	0.84357	264	0.65286
11	298	0.84084	16	0.65028
12	103	0.83965	257	0.65001
13	9	0.83775	106	0.63450
14	126	0.83727	301	0.63437
15	83	0.83710	299	0.62319
16	4	0.83548	163	0.61754
17	100	0.83461	155	0.60463
18	90	0.83416	208	0.60357
19	55	0.83415	103	0.60218
20	320	0.83394	249	0.60012

21	87	0.83187	44	0.59934
22	16	0.83093	31	0.59333
23	82	0.89528	260	0.59060
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
335	215	0.44908	133	0.25829

When the ranking results are, TOPSIS finds that the most suitable student to receive the scholarship is student # 82 with a Ci* value of 0.89528, and the least suitable one is student # S215 with a Ci* value of 0.44908. As for SAW, the best candidate is student # 4, with a Vi value of 0.77068, and the worst candidate on the list is student # 133, with a Vi value of 0.25829.

Note that the ranking list purposely includes the first 23 as the maximum number of scholarships planned to be granted. The first 23 candidates in SAW and TOPSIS rankings have 12 common candidates: students # 4, 16, 31, 82, 100, 103, 194, 208, 257, 277, 298, and 320. This makes a 52.17% commonality in the results of two different methods when the first 23 candidates are considered.

6. Conclusions

This study used MCDM methods to select scholarship students for a public charity organization that provides scholarships to higher education students for financial support and aims to reach eligible students. While the organization's directors select the most suitable students among the applicants, they examine the application information for each student individually. As a result of this examination, subjective evaluation by the board of directors members determined that the students be awarded scholarships. This decision-making process includes many objective and subjective parameters and poses a problem to which MCDM methods can be applied.

MCDM methods evaluate many criteria and parameters together. It enables sorting and selection by evaluating the alternatives considered. This study proposed a model that included AHP, TOPSIS, and SAW methods to select the most suitable students for scholarships among university students who apply for a scholarship.

The study started by determining the criteria to be considered in the granting process. Studies in the literature that included scholarship criteria were examined. After taking the opinions of the board of directors, eight criteria were determined. Firstly, the opinions of the board of directors were taken to determine the weights of the criteria. Then, the weights of the criteria were calculated using the AHP method. From the results obtained, it was determined that the most important criterion was the grade point average, with a weight of 0.230, and the least important criterion was the status of the student's parents, with a weight of 0.047. After that, the TOPSIS and SAW methods were applied separately using the data of 335 students, and the students were ranked according to their suitability. These rankings identify the 23 students to whom the branch can grant scholarships.

Ten students in the first 23 students obtained in SAW and TOPSIS rankings are the same, which makes around a 43 % commonality in the two separate lists. Although not low, this percentage would naturally be preferred to be higher. It is important to note that the calculation of the normalization matrix is different in SAW and TOPSIS. Moreover, SAW does not consider the closeness to the ideal solution, whereas TOPSIS does. Hence, the intuition suggests that TOPSIS is a preferred method over SAW. Nevertheless, it is better if the first 23 in both lists (i.e., 36 students, as ten are common) are all invited for an interview.

The proposed models provide benefits and convenience to the organization's directors while choosing the scholarship recipients. The high number of applications made to the organization and the evaluation process made by the board of directors by examining the students is inefficient and open to mistakes. With the proposed model, the time allocated by the branch directors for evaluation is expected to be considerably shortened. In addition, since the proposed selection is made through a scientific method, it is anticipated that it will contribute significantly to the transparency of the selection process.

Contribution of Researchers

Okan Arslantaş carried out model calibrations and data analysis. Mehmet Gümüş and Emir Hüseyin Özder reviewed the literature and contributed to the interpretation of model results.

Conflicts of Interest

The authors declared that there is no conflict of interest.

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