



# A novel hybrid MCDM approach to evaluate universities based on student perspective

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## Abstract

University rankings are an essential source of comparisons between universities according to specific combinations of criteria. International or national rankings have an increasing impact on higher education institutions, stakeholders, and their environments. Thereby, on behalf of effective decision-making, university-ranking efforts should be a process involving some conflicting criteria and uncertainties in a more sensitive manner. This study presents a detailed university evaluation procedure under certain service criteria via multi-criteria decision-making (MCDM) methodologies and provides an appropriate clustering of universities according to teaching and research factors. A hierarchical cluster-based Interval Valued Neutrosophic Analytic Hierarchy Process (IVN-AHP) integrated VIKOR methodology that includes two stages, clustering and ranking, is proposed for the university evaluation problem. The hierarchical clustering method is performed using teaching and research factors in the first stage. The second stage addresses the determination weights of service criteria through IVN-AHP and the ranking of universities by using VIKOR according to service criteria under determined clusters. This study, in which the proposed methodology is applied to Turkish universities, is the most comprehensive in terms of the number of universities evaluated and participating students. Furthermore, the integration of IVN-AHP and VIKOR to solve MCDM problems is presented for the first time. This study differs from other studies in terms of novelties both methodological-based and application based. Moreover, categorizing universities with similar characteristics into groups using cluster analysis and ranking them with the MCDM methodology provide a more realistic and effective interpretation of the results.

**Keywords** University ranking problem · Neutrosophic numbers · AHP · VIKOR · Higher education · Turkey

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## Introduction

Higher education institutions are in competition to enhance regional growth and support global development strategies with the necessary highly qualified personnel and research (Al-Turki & Duffuaa, 2003; Ho et al., 2006). In such a competition among educational institutions, the awareness that is necessary to evaluate the quality of institutions effectively and objectively contributes to the increase in performance. Prospective students and their families consider university rankings to select a suitable university in terms of time, career prospects, and financial situations (Griffith & Rask, 2007). Moreover, scientists, with whom scientific cooperation can benefit from many university rankings when deciding on the university they will go to for research. Therefore, evaluating the organizational effectiveness of higher education institutions is becoming more important to governments, universities, researchers, and students. In the context of organizational effectiveness, determining the degree to which an organization reaches its objectives is complex. The number of resources to produce a unit of output is difficult to measure in universities with multiple inputs, outputs, and stakeholders (Ball & Halwachi, 1987). Fortunately, depending on developments in higher education, as long as the concepts of quality, efficiency, and accountability are more visible, performance evaluation processes can be managed more accurately in terms of teaching, research, and service quality indicators.

Higher education, especially in universities, involves many managerial and practical dimensions, such as human activities, limited resources, numerous actors, intense communication, etc., which need to be managed simultaneously. Due to the essentially conflicting criteria, the university ranking problem is a complex evaluation procedure that consists of more than one criterion by its nature (Azma, 2010). Therefore, multi-criteria decision-making (MCDM) approach, a branch of operations research and a systematic decision-making procedure on complex problems, can be considered an appropriate solution to handle the university ranking problem through evaluating multiple conflicting criteria. It is seen that some tangible quality criteria, which are measurable in units, are used in university performance improvement studies, such as teaching, research (Barnabè & Riccaboni, 2007; Wu et al., 2012), and international outlook (Aliyev et al., 2020). Since tangible quality indicators are not sufficient to evaluate universities in the context of organizational theory, service quality indicators should also be included to make a more comprehensive evaluation (Karadağ & Yücel, 2020). Service quality indicators that cannot be measured in units directly are called intangible criteria and are defined as stakeholders' satisfaction (students, researchers, lecturer, etc.). The service quality of universities should be improved to ensure the satisfaction of all stakeholders due to increasing competition in line with the increasing number of universities.

Due to the intangible nature of service quality indicators, the evaluation of these indicators depends directly on the perception of stakeholders. However, the expectations of stakeholders evolve according to the promised resources, their personal networks, and their status quo. Consequently, ranking universities that have different socioeconomic developments and provide disproportional opportunities according to perceived quality may present unfair results.

Researchers and theoreticians have focused on the university ranking problem and its extensions over the years. Using different optimization and sorting techniques for the university ranking problem is one of the most studied topics in the literature. Still, there are a limited number of studies on defining criteria and determining the weights of criteria. Therefore, this problem is discussed in this study.

Considering the above issues regarding the stakeholders' satisfaction and academic process improvement, this study presents a two-stage evaluation methodology for the university ranking problem. In the first stage, universities are clustered according to tangible factors, before ranking universities based on student satisfaction. These tangible factors, the foundation year, the number of academicians, the number of students per academician, the number of citations per academician, and the number of academic outputs per academician, are accessible before the choice of a university. Such factors are preferred because of their representation strength of the promised resources in higher education. In this way, it is ensured that universities with common characteristics are ranked according to the satisfaction of students who have similar expectations and prefer similar universities. Furthermore, thanks to clustering, the university ranking methodology can be applied in a more sensitive, realistic, and effective manner.

In the second, a hybrid MCDM model is employed to rank universities by considering the following service quality criteria: "learning experience", "campus life", "academic support", "management", "learning opportunities and resources", and "personal development and career support". In the MCDM methodology, the criteria are weighted by the Interval Valued Neutrosophic Analytic Hierarchy Process (IVN-AHP) based on student opinion; then, the universities are ranked using Višekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) based on student satisfaction. In this context, VIKOR is extended with IVN-AHP for the first time in the literature.

VIKOR, one of the MCDM methods, focuses on the selection of the most suitable one among a set of alternatives under conflicting criteria or the ranking of the alternatives (Büyüközkan & Ruan, 2008). VIKOR enables decision-makers to identify the compromise solution by evaluating conflicting criteria to reach a final decision. Compromising ranking determines a compromised solution, close to the ideal, that provides maximum 'group benefit' for the majority and minimum individual regrets (San Cristóbal, 2012). In this study, VIKOR is extended with IVN-AHP to obtain more systematic criteria weight determination and alternative evaluation.

To determine the relative importance of the criteria in the decision-making process, the criteria should be weighted according to the preferences of the decision-makers. Therefore, IVN-AHP is used to determine the weight of the criteria in this study. AHP is one of the MCDM methodologies based on a pairwise comparison of criteria and alternatives (Çavdur et al., 2018), enabling more appropriate decisions with a formal and systematic decision-making process. It has a structure that simplifies complex problems. Due to the nondeterministic environment, complexity and unreliable information arise when experts with different interests, loyalties, and cultures interact with a particular project or program to evaluate alternatives or criteria (Abdel-Basset et al., 2019). The method sometimes does not reflect the human way of thinking, even if it receives information from experts (Ayyildiz & Taskin Gumus, 2020). Therefore, IVN-AHP emerged by combining AHP with neutrosophic logic. Comparison values in IVN-AHP are used in a range of values, unlike AHP, where net values are used. Neutrosophic logic provides a more flexible tool for experts while expressing their opinions with inconsistent and incomplete information under uncertainty, especially when experts' opinions are taken with linguistic evaluations in decision-making problems (Gulum et al., 2021). Therefore, AHP is extended with a neutrosophic set, which was first proposed by (Smarandache, 1999).

This study has three main contributions to the literature from different aspects. (i) The first methodological contribution is, to the best of our knowledge, the use of the integrated application of IVN-AHP and VIKOR. (ii) The second methodological contribution is the consideration of both tangible and intangible factors for university ranking thanks to

performing clustering and MCDM consecutively. (iii) From the practical aspect, this study is the most comprehensive in terms of the number of evaluated universities and participating students. In this context, such a study that integrates a clustering method to the university ranking problem through MCDM emphasizes reflecting student requirements to universities in terms of universities assessment in a more sensitive manner and the importance of evaluation indicators determined by students with a procedure easy to understand and apply. Moreover, the neutrosophic set provides a representation of knowledge to cope with uncertainty and lack of information inherent in such problems that involve many students' opinions of different faculties in evaluating the indexes for university rankings.

The rest of the paper is structured as follows. Section “[Literature review](#)” presents a review of the literature on the university ranking problem. The proposed integrated methodology is given in section “[Proposed methodology](#)”. The application of the proposed methodology for Turkish universities is presented in section “[The application](#)”. In section “[Discussions and implications](#)”, the discussion and implications are provided. Finally, the conclusions are presented in section “[Conclusion](#)”.

## Literature review

The literature review focuses on two subjects; the first focus is studies related to a better understanding of the factors affecting the choice of a university, and the second one is studies related to the evaluation of higher education institutions according to different perspectives. Additionally, since this study integrates clustering and MCDM through a holistic framework methodology for the university ranking problem, studies related to clustering or classification of universities are also reviewed.

Factors affecting university choice have been an attractive topic for researchers, especially over the last two decades. Soutar and Turner (2002) applied conjoint analysis to examine important factors affecting the choice of a university in Australia. Briggs (2006) surveyed to detect the determinants of undergraduate education preferences and conducted a factor analysis to obtain more meaningful results and categorize the determinants of undergraduate education institution choice. Briggs and Wilson (2007) examined the factors that affect the choice of a university in Scotland, especially the 'Information Supplied by Universities' and 'Cost of the Package' factors. It was observed that these factors were ranked 10th and 20th among 22 factors considered in university choice. Simões and Soares (2010) conducted a quantitative analysis to determine the factors affecting students' decisions for university selection. They conducted a questionnaire survey on 1641 students who applied to the university for the first time. Sojkin et al. (2012) performed a survey with 1420 Polish students to determine the factors affecting university choice and examine how these factors differ according to personal information such as gender, age, and family income level.

Recently, parallel to the increase in competition among universities, studies related to their evaluation have gained increasing attention from different perspectives such as overall performance (Aliyev et al., 2020; Nazari-Shirkouhi et al., 2020; Wu et al., 2012; Zolfani & Ghadikolaei, 2013), research capacity (Duc et al., 2020; Su et al., 2020), innovation (Chen & Chen, 2010), a department of a university (Muhammad et al., 2021), sustainability (Arora et al., 2020; Puente et al., 2020), lean philosophy (Kazancoglu & Ozkan-Ozen, 2019; Klein et al., 2021), and student viewpoint (Castro-Lopez et al., 2021; Goyal et al., 2021; Kabak & Dağdeviren, 2014; Nanath et al., 2021; Nojavan et al., 2021).

One of the most common perspectives in ranking universities is the overall performance. Wu et al. (2012) applied a hybrid AHP-VIKOR method to rank 12 private universities in Taiwan according to their performance from academicians' viewpoint. They structured a 3-level criteria hierarchy based on the performance evaluation structure developed by the Taiwan Assessment and Evaluation Association. Zolfani and Ghadikolaei (2013) proposed a model in which balance score card (BSC) and MCDM techniques were used to evaluate performances of private universities in Iran. The Decision Making Trial and Evaluation Laboratory (DEMATEL) was used to reveal the relationships among the perspectives of BSC, the Analytic Network Process (ANP) was used to determine the importance of the criteria, and VIKOR was used to obtain the final ranking of the universities. On behalf of improving this methodology, both Özdemir and Tüysüz (2017) and Nazari-Shirkouhi et al. (2020) integrated fuzzy logic into BSC-MCDM to cope with the ambiguity of decision-makers. Aliyev et al. (2020) applied a Fuzzy AHP model to rank five universities in the United Kingdom regarding four criteria.

Another common topic about university ranking is research capacity. Duc et al. (2020) proposed a new MCDM model that uses improved arithmetic operations of generalized fuzzy numbers. They applied this model to evaluate research capacity at Vietnam University. Su et al. (2020) proposed a model that uses MCDM and output-oriented nonradial super efficiency Data Envelopment Analysis (DEA) to evaluate the research efficiency of Chinese universities. There are few applications in the literature on university ranking problems based on the perspective of innovation. Chen and Chen (2010) emphasized that university innovation could not be measured only by academic research papers, but also other factors such as 'number of chair professors' and 'international academic interaction'. Therefore, the authors proposed a new MCDM model to evaluate universities' innovation performance. They formed a decision support system that combines DEMATEL to reveal the relationships between criteria, fuzzy ANP to determine the criteria weights, and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to rank the alternatives. Muhammad et al. (2021) proposed an MCDM model to evaluate the usability of academic websites of higher education institutions. They used fuzzy AHP to determine criteria weights and compare alternatives.

A brand new perspective is sustainability. Puente et al. (2020) proposed an integrated model for quality assessment and sustainability assessment for higher education institutions in Europe. A fuzzy DEMATEL model was used to reveal the relationships between criteria, a fuzzy ANP model was used to determine the weights of criteria, and finally, a Fuzzy Inference System was used to make final evaluations of higher education institutions. Arora et al. (2020) Arora et al. applied fuzzy AHP to prioritize sustainability drivers of higher education institutions and revealed that environmental practices and social responsibility are the most critical drivers. Likewise, another challenging topic is lean philosophy. Kazancoglu and Ozkan-Ozen (2019) proposed the fuzzy DEMATEL model to detect and rank important wastes in higher education institutions from the academic staff perspective. Klein et al. (2021) determined wastes in higher education institutions and applied AHP to prioritize them and concluded that the most important wastes are loss of knowledge and overprocessing.

Evaluating universities from students' viewpoints has been much sought after, especially in the last few years. Kabak and Dağdeviren (Kabak & Dağdeviren, 2014) applied a hybrid MCDM method to understand Industrial Engineering students' way of thinking in university choice. They used the ANP method to determine the weights of the criteria and the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to obtain the final ranking. Goyal et al. (2021) contributed to this topic by considering the

uncertainty of student judgments through Fuzzy AHP. Nanath et al. (2021) investigated differences in university choice factors pre and after the COVID-19 pandemic via one-way multivariate analysis of variance (MANOVA) and ranked universities via AHP. Nojavan et al. (2021) focused on academic units' performance from students' viewpoints in higher education. Hence, they proposed a model in which students' opinions were received by a fuzzy SERVQUAL questionnaire, the criteria weights were determined by Fuzzy AHP, the final ranking was obtained by Fuzzy TOPSIS, and the efficiency of the units were revealed by Fuzzy DEA. Introducing a new perspective, Castro-Lopez et al. (2021) proposed a hybrid AHP-Fuzzy Inference Systems method so that the reasons for university dropout and factors that affect the intention to remain in the university can be better understood.

As mentioned above, studies related to clustering or classification of universities for different purposes were also reviewed. For example, Valadkhani and Worthington (2006) clustered 36 universities in Austria according to research capacity per academic staff, Erdoğan and Esen (2016) clustered Turkish universities according to institutional size and performance by using hierarchical cluster analysis, Wang and Zha (2018) implemented three clustering methods to Chinese universities to cluster them according to systematic diversity, Perchinunno and Cazzolle (2020) applied clustering analysis to 780 international universities and revealed four groups according to sustainability, and etc.

A comprehensive literature review reveals that MCDM-based approaches are often used to solve university evaluation problems from different perspectives. Moreover, studies dealing with university evaluation from the student perspective do not include teaching and research factors. The evaluation of similar universities is not addressed in such studies, and the number of included universities has always been limited. Different MCDM methodologies are employed to handle the university ranking problem, especially for weighting criteria. In this study, the VIKOR methodology is extended with IVN-AHP to solve the university ranking problem.

This study considers both student satisfaction criteria and widespread teaching and research characteristics by focusing on these research gaps. Primarily, universities are clustered according to teaching and research characteristics, and then, universities are ranked within each cluster according to students' satisfaction. In this way, instead of ranking a large number of universities at once, it is possible to perform the proposed MCDM method to rank fewer universities within the clusters. A more sensitive, realistic, and effective evaluation of similar universities is obtained. A novel MCDM methodology that integrates IVN-AHP and VIKOR is presented for the first time in the decision-making literature. Furthermore, to the best of the authors' knowledge, it is the most comprehensive study in terms of the number of universities considered and the number of students who participated.

## Proposed methodology

The proposed methodology consists of two stages. At the first stage, universities are divided into different clusters via hierarchical clustering based on teaching and research characteristics. At the second stage, the predetermined criteria, which have been used to rank universities in a previous survey (Karadağ & Yücel, 2020), are weighted using the IVN-AHP methodology based on opinions taken from students from different universities. VIKOR is then employed to evaluate and rank the universities in each cluster using these weights. The methodology also has a subsidiary stage to compare cluster-based rankings

with holistic rankings. The proposed integrated methodology is illustrated in Fig. 1 and is theoretically detailed in the following subsections.

### Hierarchical clustering

Dividing data into meaningful or useful groups ensures that algorithms generate more significant outputs. Based on the groups, formed for understanding (objects share common characteristics) or utility (characterizing clusters in terms of cluster prototypes), the outputs better reflect the people’s ways of analyzing and describing the natural structure of the domain (Tan & Steinbach, 2006).

Cluster analysis (or clustering) is one of the most common ways to group objects based on several measurements made on each object individually. Within the frame of understanding the objects in the same groups, the key idea is to guarantee within-group similarity, and hence dissimilarity among the groups. For this purpose, there are two general types of clustering algorithms: hierarchical clustering and nonhierarchical clustering (Köhn & Hubert, 2015).

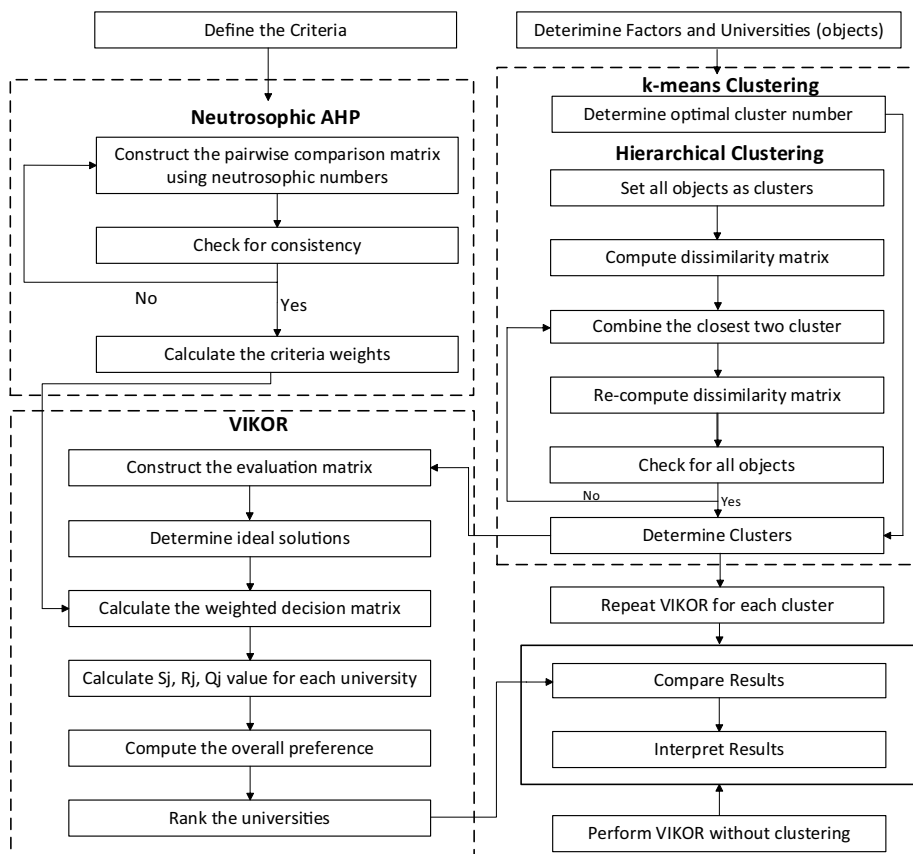


Fig. 1 The proposed methodology

Nonhierarchical algorithms produce nonoverlapping clusters, meaning an object belongs to one cluster. The algorithm requires a prespecified cluster number to assign an object to one of the clusters. However, hierarchical algorithms arrange the clusters into a natural hierarchy. This natural hierarchy produces a set of nested clusters in the form of a tree. Additionally, a prespecified cluster number is no need for hierarchical algorithms when useful in the absence of the information likely groups in the data.

In this study, to model each cluster separately rather than the entire heterogeneous dataset, a hierarchical clustering algorithm was used to group universities with similar teaching and research characteristics. Then, an individual comparison of each cluster is drawn through the proposed decision-making method.

The hierarchical clustering algorithm can be either agglomerative or divisive. The algorithm used in this study is agglomerative, which has widespread use, begins with  $n$  clusters (equal to the numbers of the object in the dataset) and continues progressively merging the two most similar (nearest) clusters until all objects belong to one cluster. The divisive clustering algorithm has an inverse logic with the agglomerative algorithm. A formal procedure for the hierarchical clustering is expressed in Algorithm 1 (González-Cabrera et al., 2021).

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**Algorithm. 1** Agglomerative hierarchical clustering algorithm.

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1. Set all objects in data as individual clusters.
2. Compute the dissimilarity between each possible cluster pair.

**Repeat**

3. Combine the closest (similar) two clusters to form one cluster.
4. Update the objects in data and count the combined objects as a single.
5. Re-compute dissimilarity between each new cluster pair using reduced data.

**Until** all objects are assigned to one cluster.

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Clusters have one or more objects. Hence, once the first iteration is applied and the nearest single objects are combined, the distance calculation between any two clusters (or a cluster and an object) is now needed to combine clusters. This distance calculation relies on the closeness of two clusters quantified by various linkage measures, such as minimum distance, average distance, centroid distance, and Ward's method. On the other hand, the dissimilarity between two objects  $i$  and  $j$  when evaluating linkage between clusters is measured by a distance metric such as Euclidean, Cosine, Pearson's correlation, and Minkowski.

### Interval-valued neutrosophic analytical hierarchy process (IVN-AHP)

The neutrosophic logic was developed by Smarandache (1998) as a more generalized version of fuzzy sets to cope with indeterminacy and ambiguity more comprehensively by extending fuzzy logic with a novel function named "uncertainty" (Kahraman et al., 2020). Three functions are used to define a neutrosophic set  $\tilde{A}$  in the universe  $E$ . These functions are represented as  $T_A(x)$  for truth-membership function,  $I_A(x)$  for indeterminacy-membership function, and  $F_A(x)$  falsity membership function (Bolturk & Kahraman, 2018).



**Definition 1** A single-valued neutrosophic number (SVNN)  $\tilde{S}$  is defined as follows (Biswas et al., 2014; Bolturk & Kahraman, 2018):

$$\tilde{S} = \{x, (T_S(x), I_S(x), F_S(x)) >: x \in E, (T_S(x), I_S(x), F_S(x)) \in ]0, 1[^+\} \tag{1}$$

**Definition 2** An interval-valued neutrosophic number (IVNN)  $\tilde{A}$  is defined as follows:

$$\tilde{A} = \{x, [T_A^L(x), T_A^U(x)], [I_A^L(x), I_A^U(x)], [F_A^L(x), F_A^U(x)]; x \in E\} \tag{2}$$

Similar to SVNNs, the values of the functions must be between 0 and 1.

**Definition 3** IVNN  $\tilde{A}$  is deneutrosophicated by (Bolturk & Kahraman, 2018):

$$\mathfrak{D}(x) = \left( \frac{(T_A^L + T_A^U)}{2} + \left( 1 - \frac{(I_A^L + I_A^U)}{2} \right) (I_A^U) - \left( \frac{F_A^L + F_A^U}{2} \right) (1 - F_A^U) \right) \tag{3}$$

**Definition 4** Let  $\tilde{\alpha} = [T_a^L, T_a^U], [I_a^L, I_a^U], [F_a^L, F_a^U]$  and  $\tilde{\beta} = [T_\beta^L, T_\beta^U], [I_\beta^L, I_\beta^U], [F_\beta^L, F_\beta^U]$  be two IVNNs. Basic mathematical operations on  $\tilde{\alpha}$  and  $\tilde{\beta}$  are given as follows (Kahraman et al., 2020; Karaşan et al., 2020):

$$\tilde{\alpha} \oplus \tilde{\beta} = \left\langle [T_a^L + T_\beta^L - T_a^U T_\beta^L, T_a^U + T_\beta^U - T_a^U T_\beta^U], [I_a^L I_\beta^L, I_a^U I_\beta^U], [F_a^L F_\beta^L, F_a^U F_\beta^U] \right\rangle \tag{4}$$

$$\tilde{\alpha} \ominus \tilde{\beta} = \left\langle [T_a^L - F_\beta^U, T_a^U - F_\beta^L], [Max(I_a^L, I_\beta^L), Max(I_a^U, I_\beta^U)], [F_a^L - T_\beta^U, F_a^U - T_\beta^L] \right\rangle \tag{5}$$

$$\tilde{\alpha} \otimes \tilde{\beta} = \left\langle [T_a^L T_\beta^L, T_a^U T_\beta^U], [I_a^L + I_\beta^L - I_a^L I_\beta^L, I_a^U + I_\beta^U - I_a^U I_\beta^U], [F_a^L + F_\beta^L - F_a^L F_\beta^L, F_a^U + F_\beta^U - F_a^U F_\beta^U] \right\rangle \tag{6}$$

$$(\tilde{\alpha})^\lambda = \left\langle [(T_a^L)^\lambda, (T_a^U)^\lambda], [(I_a^L)^\lambda, (I_a^U)^\lambda], [1 - (1 - F_a^L)^\lambda, 1 - (1 - F_a^U)^\lambda] \right\rangle; \lambda \geq 0 \tag{7}$$

$$\lambda \tilde{\alpha} = \left\langle [1 - (1 - T_a^L)^\lambda, 1 - (1 - T_a^U)^\lambda], [(I_a^L)^\lambda, (I_a^U)^\lambda], [(F_a^L)^\lambda, (F_a^U)^\lambda] \right\rangle; \lambda \geq 0 \tag{8}$$

The AHP method, whose fundamentals were firstly proposed by Myers and Alpert (1968). Then Saaty systematized and developed based on the logic of structuring a problem in hierarchical structure (Thor et al., 2013). The AHP methodology sometimes fails to reflect opinions from decision-makers because of indeterminacy and ambiguity in information (Ayyildiz et al., 2020). IVN-AHP can be used to handle indeterminacy and ambiguity with three functions to effectively integrate human thought into the decision-making process. In this study, the students' satisfaction factors are weighted using the IVN-AHP methodology. The application steps of the methodology are given below.

- Step 1. The criteria and evaluation scale are determined.
- Step 2. Pairwise comparison matrix  $(\tilde{P})$  is constructed via linguistic terms. Then, the evaluation scale is used to convert the linguistic terms to the IVNN numbers as given in Eq. 9. Deneutrosophication is performed for the pairwise comparison matrix to analyze the consistency of the matrix.

$$\tilde{\tilde{P}}_c = \begin{bmatrix} [T_{11}^L, T_{11}^U], [I_{11}^L, I_{11}^U], [F_{11}^L, F_{11}^U] & \dots & [T_{1m}^L, T_{1m}^U], [I_{1m}^L, I_{1m}^U], [F_{1m}^L, F_{1m}^U] \\ \vdots & \ddots & \vdots \\ [T_{m1}^L, T_{m1}^U], [I_{m1}^L, I_{m1}^U], [F_{m1}^L, F_{m1}^U] & \dots & [T_{mm}^L, T_{mm}^U], [I_{mm}^L, I_{mm}^U], [F_{mm}^L, F_{mm}^U] \end{bmatrix} \quad (9)$$

$m$  is the number of criteria.

Step 3. The normalized importance weights of the criteria are calculated by the following steps.

Step 3.1. Sum the values in each column as in Eq. 10:

$$\tilde{S}_{ij} = \left\langle \left[ \sum_{k=1}^m T_{kj}^L, \sum_{k=1}^m T_{kj}^U \right], \left[ \sum_{k=1}^m I_{kj}^L, \sum_{k=1}^m I_{kj}^U \right], \left[ \sum_{k=1}^m F_{kj}^L, \sum_{k=1}^m F_{kj}^U \right] \right\rangle \quad (10)$$

Step 3.2. The upper limit value for each parameter is determined and each term is divided by its corresponding element to obtain  $\tilde{N}_{ij}$  values by Eq. 11:

$$\tilde{N}_{ij} = \left\langle \left[ \frac{T_{kj}^L}{\sum_{k=1}^m T_{kj}^L}, \frac{T_{kj}^U}{\sum_{k=1}^m T_{kj}^U} \right], \left[ \frac{I_{kj}^L}{\sum_{k=1}^m I_{kj}^L}, \frac{I_{kj}^U}{\sum_{k=1}^m I_{kj}^U} \right], \left[ \frac{F_{kj}^L}{\sum_{k=1}^m F_{kj}^L}, \frac{F_{kj}^U}{\sum_{k=1}^m F_{kj}^U} \right] \right\rangle \quad (11)$$

Then, the matrix is constructed:

$$\tilde{\tilde{P}} = \begin{bmatrix} \left\langle \left[ \frac{T_{11}^L}{\sum_{k=1}^m T_{kj}^L}, \frac{T_{11}^U}{\sum_{k=1}^m T_{kj}^U} \right], \left[ \frac{I_{11}^L}{\sum_{k=1}^m I_{kj}^L}, \frac{I_{11}^U}{\sum_{k=1}^m I_{kj}^U} \right], \left[ \frac{F_{11}^L}{\sum_{k=1}^m F_{kj}^L}, \frac{F_{11}^U}{\sum_{k=1}^m F_{kj}^U} \right] \right\rangle, \dots, \left\langle \left[ \frac{T_{1m}^L}{\sum_{k=1}^m T_{kj}^L}, \frac{T_{1m}^U}{\sum_{k=1}^m T_{kj}^U} \right], \left[ \frac{I_{1m}^L}{\sum_{k=1}^m I_{kj}^L}, \frac{I_{1m}^U}{\sum_{k=1}^m I_{kj}^U} \right], \left[ \frac{F_{1m}^L}{\sum_{k=1}^m F_{kj}^L}, \frac{F_{1m}^U}{\sum_{k=1}^m F_{kj}^U} \right] \right\rangle \\ \vdots \\ \left\langle \left[ \frac{T_{m1}^L}{\sum_{k=1}^m T_{kj}^L}, \frac{T_{m1}^U}{\sum_{k=1}^m T_{kj}^U} \right], \left[ \frac{I_{m1}^L}{\sum_{k=1}^m I_{kj}^L}, \frac{I_{m1}^U}{\sum_{k=1}^m I_{kj}^U} \right], \left[ \frac{F_{m1}^L}{\sum_{k=1}^m F_{kj}^L}, \frac{F_{m1}^U}{\sum_{k=1}^m F_{kj}^U} \right] \right\rangle, \dots, \left\langle \left[ \frac{T_{mm}^L}{\sum_{k=1}^m T_{kj}^L}, \frac{T_{mm}^U}{\sum_{k=1}^m T_{kj}^U} \right], \left[ \frac{I_{mm}^L}{\sum_{k=1}^m I_{kj}^L}, \frac{I_{mm}^U}{\sum_{k=1}^m I_{kj}^U} \right], \left[ \frac{F_{mm}^L}{\sum_{k=1}^m F_{kj}^L}, \frac{F_{mm}^U}{\sum_{k=1}^m F_{kj}^U} \right] \right\rangle \end{bmatrix} \quad (12)$$

Step 3.3. The arithmetic mean is determined for each row to obtain the neutrosophic importance weight vector 13:

$$\tilde{W}_j = \begin{pmatrix} \left[ \frac{\sum_{k=1}^m \frac{T_{lj}^L}{\sum_{k=1}^m T_{kj}^L}, \sum_{k=1}^m \frac{T_{lj}^U}{\sum_{k=1}^m T_{kj}^U} \right]}{m} \\ \left[ \frac{\sum_{k=1}^m \frac{I_{lj}^L}{\sum_{k=1}^m I_{kj}^L}, \sum_{k=1}^m \frac{I_{lj}^U}{\sum_{k=1}^m I_{kj}^U} \right]}{m} \\ \left[ \frac{\sum_{k=1}^m \frac{F_{lj}^L}{\sum_{k=1}^m F_{kj}^L}, \sum_{k=1}^m \frac{F_{lj}^U}{\sum_{k=1}^m F_{kj}^U} \right]}{m} \end{pmatrix}, \quad j = 1, 2, \dots, m \quad (13)$$

Step 4. The importance weight vector is denegutrosophicated to determine the final weight of the criteria.

**VIKOR**

The VIKOR method was first presented by Opricovic (1998) for multi-criteria optimization of complex systems. VIKOR is a method that allows determining a consensual ranking and achieving a compromise solution according to the specified criteria. In the method, alternatives are evaluated according to criteria and a ranking is obtained by calculating proximity values to the ideal alternative (Tayyar & Arslan, 2013). The steps of VIKOR are given below:

Step 1. The decision matrix is established to evaluate alternatives. Let  $x_{ij}$  is the value of alternative  $i$  with respect to criterion  $j$ .

Step 2. The best  $x_j^+$  and the worst  $x_j^-$  value for each criterion is determined as follows:

$$x_j^+ = \max_i (x_{ij}); x_j^- = \min_i (x_{ij}) \quad \text{for benefit criteria} \quad (14)$$

$$x_j^+ = \min_i (x_{ij}); \quad x_j^- = \min_i (x_{ij}) \quad \text{for cost criteria} \quad (15)$$

Step 3.  $S_i$  and  $R_i$  are calculated using Eqs. 16 and 17, respectively.

$$S_i = \sum_{j=1}^m w_j (x_j^+ - x_{ij}) / (x_j^+ - x_j^-) \quad (16)$$

$$R_i = \max_j [w_j (x_j^+ - x_{ij}) / (x_j^+ - x_j^-)] \quad (17)$$

where  $w_j$  is the weight of criterion  $j$  determined by IVN-AHP.

Step 4.  $Q_i$  is computed:

$$Q_i = v \frac{(S_i - S^+)}{(S^- - S^+)} + (1 - v) \frac{(R_i - R^+)}{(R^- - R^+)} \quad (18)$$

where  $S^+ = \min_i S_i; S^- = \max_i S_i$  and  $R^+ = \min_i R_i; R^- = \max_i R_i$ .  $v$  and  $(1 - v)$  represent the weight of strategy of maximum group utility and individual regret, respectively.

Step 5. Alternatives are sorted by the values  $S_i, R_i$  and  $Q_i$  in descending order.

Step 6. A compromise solution for the given set of criteria, the alternative ( $a'$ ) which is ranked the best by the measure the minimum  $Q_i$  is proposed if the following two conditions are satisfied (Tzeng et al., 2005):

C1: "Acceptable advantage":  $Q(a'') - Q(a') \geq D(Q)$  where ( $a''$ ) is the second alternative in the ranking list by  $Q_i$  and  $D(Q) = 1/(K - 1)$ ;  $K$  represents the number of alternatives.

C2: "Acceptable stability in decision-making": Alternative ( $a'$ ) has to be best ranked by  $S$  or/and  $R$ .

If both conditions are satisfied, the alternative in the first rank is determined as the best alternative. If one of the conditions is not satisfied, then a set of compromise solutions is proposed (San Cristóbal, 2011):

- If C2 is not satisfied, Alternative ( $a'$ ) and Alternative ( $a''$ );
- If C1 is not satisfied, Alternative ( $a'$ ), Alternative ( $a''$ ) ... Alternative ( $Z$ ) is determined by the relation  $Q(Z) - Q(a') < D(Q)$  for maximum  $Z$ .

## The application

In 2020, 74 foundation and 129 state universities existed in Turkey. In the last decade, the number of students has increased more than twice in state universities and more than three times in foundation universities (YÖK, 2021c). Although there is an existing methodology for ranking universities in some countries, there is no such ranking system at the national level in Turkey. Furthermore, studies on university preference and classification for Turkey are quite few, and these studies are considered insufficient in terms of both scope and content. Kabak and Dağdeviren (Kabak & Dağdeviren, 2014) analyzed the factors for university selection and ranked universities in Turkey while only covering 15 universities and took the opinions of 50 students who are all engineering students. On the other hand, Erdoğan and Esen (2016) clustered Turkish universities according to different points of view. In the study by Erdoğan and Esen (2016), different weaknesses are faced in different clustering applications. For example, while universities were clustered according to their ranking scores, only 50 universities could be covered due to a lack of data; as for clustering in accordance with teaching performance, there was only one factor considered. Alternatively, global ranking systems mostly depend on academic research parameters (URAP Research Laboratory, 2021) and fail to satisfy being multidirectional. As distinct from the existing literature, this study provides the handling of both global and local characteristics of universities by clustering them according to academic and teaching characteristics and ranking them within the clusters considering student perspectives. The study has two main stages: (i) dividing universities into different groups and (ii) ranking them in each group separately. One hundred and ninety-one universities are clustered based on the teaching and research characteristics of universities. Clustering before ranking (i) ensures the impartial ranking of universities by only comparing universities that have students with similar expectations; (ii) can lead to getting smaller, more meaningful rankings instead of a multitude ranking which is difficult to interpret; (iii) prevents moving

away from the reality of the ideal alternative that is needed for VIKOR by avoiding ranking many alternatives. Following the clustering, the universities are ranked through the proposed MCDM method for each cluster. The data reflecting the academic achievements of universities are collected from the official data of the Turkish Council of Higher Education (YÖK, 2021c) and SciVal tool provided by Elsevier (SciVal, 2021). The data that quantify students' satisfaction are collected from the report of Turkish Universities Satisfaction Research (Karadağ & Yücel, 2020) by UniAr (Karadağ & Yücel, 2021).

### Clustering of Universities

As stated in the introduction, the foundation year is used to observe whether a longer service time of a university can lead to greater student satisfaction. The number of academicians of a university might be a kind of evidence for abundant sources that can be used for a wide range of demands. The number of academic outputs per academician is another factor in clustering universities. Here, academic output refers to the total number of articles, reviews, conference papers, books, and book chapters indexed in Scopus database. The other factors are considered signs of the academic outlook quality. Besides, these factors, which form the basis of our study for the clustering of universities, are factors that have been used frequently in previous studies to classify universities. Table 1 presents some examples of these studies that use these factors and their derivatives.

The factors are continuous and numerical variables. To ensure an equal contribution by the factors to the membership in a cluster, each factor is scaled according to Eq. 19 that normalizes the original values within the interval of [0,1].

$$x_{norm}^p = \frac{x^p - x_{min}^p}{x_{max}^p - x_{min}^p} \tag{19}$$

where  $x_{norm}^p$  is a normalized value, and  $x_{max}^p$  and  $x_{min}^p$  are the extreme points of the  $p$ th factor  $x^p$ .

191 universities are divided based on the five normalized factors through agglomerative hierarchical clustering. For the best division, the most appropriate alternatives of

**Table 1** Summary of related literature on similar factors in university clustering

| Factor   | Related sources   |
|--|---|
| The number of academicians                     | Abbott and Doucouliagos (2003), Aliyev et al. (2020), Erdoğmuş and Esen (2016), Su et al. (2020), Valadkhani and Worthington (2006), Wang and Zha (2018)  |
| The number of students per academician         | Abbott and Doucouliagos (2003), Aliyev et al. (2020), Erdoğmuş and Esen (2016), Su et al. (2020), Wang and Zha (2018), Wu et al. (2012)   |
| The number of academic outputs per academician | Abbott and Doucouliagos (2003), Alaşehir et al. (2014), Çakır et al. (2015), Chen and Chen (2010), Erdoğmuş and Esen (2016), Nazari-Shirkouhi et al. (2020), Porter, (1990), Valadkhani and Worthington (2006), Wang and Zha (2018), Wu et al. (2012) |
| The number of citations per academician        | Alaşehir et al. (2014), Aliyev et al. (2020), Çakır et al. (2015), Su et al. (2020)   |
| Foundation year                                | Erdoğmuş and Esen (2016), Soutar and Turner (2002)  |

hyperparameters are determined by testing all possible combinations of the number of clusters, distance metric, and linkage measures between clusters. The quality of clusters obtained for the combinations are compared over the mean silhouette score. The Silhouette score (Layton et al., 2013), which bases on the distance of an object to others in the same cluster and the distance of the object to objects in the nearest cluster, is a measure of cluster density.

The best combination of the hyperparameters for agglomerative clustering is determined according to 336 different combinations consisting of cluster numbers from 3 to 10; average, centroid, complete, median, single, Ward and Mcquaitty linkages and Euclidean, Manhattan, maximum, Pearson, Spearman and canberra distance metrics. Accordingly, the optimal hierarchical clustering hyperparameter set with the highest silhouette score 0.5071, as shown in Fig. 2, for the separation of the universities discussed in the study is as follows: 3 clusters, Euclidean distance and average linkage.

By the average linkage, the closeness between two clusters is defined as the average distance. The method averages the distances between each object in the first cluster and all objects in the second cluster (Yim & Ramdeen, 2015). Finally, the clusters that need to be combined are the two with the smallest average linkage distance calculated as in Eq. 20.

$$D(C_A, C_B) = \frac{1}{kl} \sum_{i=1}^k \sum_{j=1}^l \|\bar{x}_i - \bar{y}_j\| \tag{20}$$

where  $\bar{x}_i$  is a features vector for  $i$ th object of cluster  $C_A$  and  $\bar{y}_j$  is a features vector for  $j$ th object of cluster  $C_B$ .  $k$  and  $l$  show cardinalities of the clusters  $C_A$  and  $C_B$ , respectively.  $D(C_A, C_B)$  shows the average distance between clusters  $C_A$  and  $C_B$  that are candidates to be combined one.

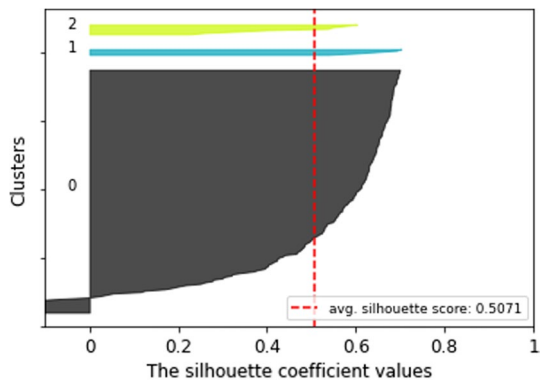
The Euclidean distance  $d_{ij}$  between two objects presented as vectors with  $p$  elements that stand for the decision variables is calculated using Eq. 21.

$$d_{ij} = \sqrt{(x_{i1} - x_{j1})^2 + \dots + (x_{ik} - x_{jk})^2 + \dots + (x_{ip} - x_{jp})^2} \tag{21}$$

where  $x_{ik}$  and  $x_{jk}$  are the observed values corresponding to the  $k$ th decision variable of object  $i$  and object  $j$ , respectively.

The clusters and universities involved in the clusters are listed in Table 2. The universities are represented by abbreviations in their official web addresses (i.e., the web address of Acibadem Mehmet Ali Aydinlar University is [www.acibadem.edu.tr](http://www.acibadem.edu.tr)).

**Fig. 2** The silhouette plot for the optimal hierarchical agglomerative clustering

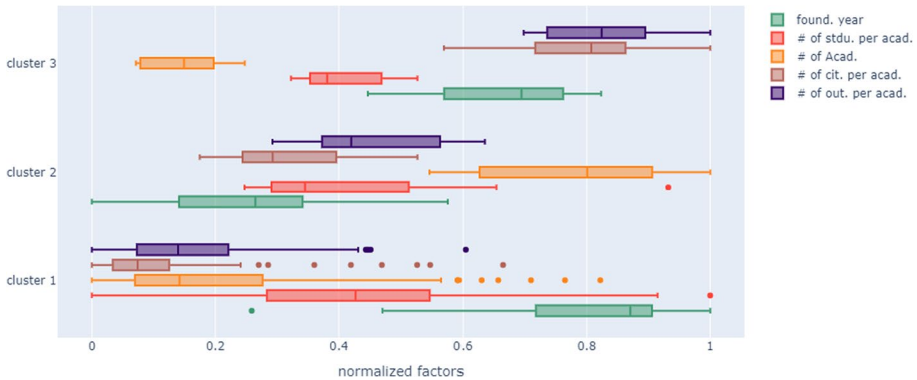


The basic variation among the clusters can be seen in Fig. 3. The figure illustrates the spread of the factors according to the clusters.

According to Fig. 3, Cluster-1 consists of both state and foundation universities with a relatively low number of academicians. The universities in this cluster have lower outputs per academician, although some outliers exist. The universities in Cluster-1 probably fail to recruit a qualified and sufficient number of academics. Cluster-2 corresponds to well-established universities with a higher population of both academicians and students. The universities in Cluster-2 have a longer service-time (note that the smaller normalized factor value for the foundation year is the longer service-time). Cluster-3 and Cluster-1 are similar in terms of factors except for the citations per academician and output per academician. The universities gathered in Cluster-3 have the highest values of these normalized factors. In this regard, the universities in this cluster care about the success of academicians without concern for the number of academicians. Having a small number of successful academicians leads to the cluster having a high number of academic outputs per academician.

**Table 2** The results of the clustering of universities

|           |            |              |           |           |            |                                |          |
|-----------|------------|--------------|-----------|-----------|------------|--------------------------------|----------|
| Cluster-1 |            |              |           |           |            |                                |          |
| 29mayis   | artvin     | biruni       | fbu       | iku       | ksbu       | ogu                            | thk      |
| acibadem  | asbu       | bitliseren   | firat     | inonu     | ksu        | ohu                            | ticaret  |
| adiyaman  | atilim     | bozok        | gantep    | isikun    | ktu        | okan                           | toros    |
| adu       | atu        | btu          | gedik     | isparta   | ktun       | omu                            | trabzon  |
| afsu      | avrasya    | cag          | gelisim   | istanbul  | sirnak     | osmaniye                       | trakya   |
| agri      | aybu       | cankaya      | gi        | iste      | maltepe    | tedu                           | ufuk     |
| agu       | aydin      | comu         | gidatarim | istinye   | marmara    | ozal                           | uludag   |
| ahbv      | ayvansaray | cu           | giresun   | iyte      | mcbu       | ozyegin                        | umeli    |
| ahep      | bakircay   | cumhuriyet   | gop       | izu       | medeniyet  | pau                            | usak     |
| ahievran  | balikesir  | subu         | gsu       | kafkas    | medipol    | pirireis                       | uskudar  |
| akdeniz   | bandirma   | deu          | gtu       | kapadokya | mef        | sakarya                        | yalova   |
| akev      | bartin     | dicle        | gumushane | karabuk   | mehmetakif | samsun                         | yasar    |
| aksaray   | baskent    | dogus        | hakkari   | karatay   | mersin     | sanko                          | yeditepe |
| aku       | batman     | dumlupinar   | halic     | karatekin | mgu        | sbu                            | tau      |
| alanya    | bau        | duzce        | harran    | kastamonu | mku        | sdu                            | yildiz   |
| alparslan | bayburt    | ebyu         | hitit     | kayseri   | msgsu      | selcuk                         | sinop    |
| altinbas  | beun       | erbakan      | hku       | kent      | mu         | siirt                          | yyu      |
| amasya    | beykent    | erciyes      | ibu       | khas      | munzur     | yuksekihtisasuni-<br>versitesi |          |
| anadolu   | beykoz     | erdogan      | idu       | kilis     | nevsehir   | lokmanhekim                    |          |
| antalya   | bezmialem  | erzurum      | ieu       | kku       | nisantasi  | demiroglu.bilim                |          |
| ardahan   | bilecik    | esenyurt     | igdir     | klu       | nku        | tarsus                         |          |
| arel      | bilgi      | eskisehir    | ihu       | kmu       | nny        | yeniyuzyil                     |          |
| artuklu   | bingol     | fatihisultan | ikc       | kocaeli   | odu        | ostimteknik                    |          |
| Cluster-2 |            |              |           |           |            |                                |          |
| ankara    | atauni     | ege          | gazi      | hacettepe | istanbul   | itu                            |          |
| Cluster-3 |            |              |           |           |            |                                |          |
| bilkent   | boun       | etu          | ku        | sabanci   |            |                                |          |



**Fig. 3** The spread of each factor by clusters

### Determination of the criteria weights

The proposed IVN-AHP VIKOR model was performed for Turkish universities. The criteria used for the ranking were adapted from the report of Turkish Universities Satisfaction Research (Karadağ & Yücel, 2020). The literature proves that these criteria are frequently used, as shown in Table 3.

In this study, the effects of the criteria discussed on total satisfaction might differ when evaluating universities from the student’s point of view. Therefore, this study determines the weights of each criterion using the MCDM approach. Thus, it is aimed at obtaining more meaningful results by prioritizing the criteria while evaluating universities. In this respect, the study differs from articles oriented to university ranking based on student satisfaction in the literature. In addition, both the criterion weights and university evaluations were determined using MCDM approaches. In this study, for the first time in the literature, the VIKOR method is extended to the IVN-AHP method to solve complex decision-making problems. In this context, this study offers innovations in both theory and application.

The criteria are evaluated by 50 students from 13 different universities in Turkey to construct the pairwise comparison matrix. The students are asked to express their opinions to prioritize the criteria through a questionnaire. The students evaluate the criteria by using the linguistic variables given in Table 4. The interval-valued neutrosophic scale corresponding to the linguistic variables shown in Table 4 is used for this evaluation.

Pairwise comparison matrices for the criteria are constructed for each student. For example, the pairwise comparison matrix created by student-2 is given in Table 5.

First, the pairwise comparison matrices are tested for consistency, and the matrices found to be consistent are used to determine the criteria weights. At this point, 30 of 50 responses are determined to be consistent. After that, the calculations of IVN-AHP methodology are performed to determine the weights of the criteria considering each student. Then, the criteria weights determined based on the opinions of 30 different students are aggregated, and then the weights for each criterion are calculated as in Table 6. All students are accepted with an equal coefficient in the aggregation process.



**Table 3** Summary of literature on the criteria for university selection from students' perspective

| Criteria                                | References   |
|---|--|
| Learning experience                     | Briggs (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Nojavan et al. (2021), Simões and Soares (2010), Sojkin et al. (2012), Soutar and Turner (2002) |
| Campus life                             | Briggs, (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Simões and Soares (2010), Sojkin et al. (2012), Soutar and Turner (2002)                       |
| Academic support                        | Briggs, (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nojavan et al. (2021)  |
| Management                              | Briggs and Wilson (2007), Goyal et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012)   |
| Learning opportunities and resources    | Briggs, (2006), Briggs and Wilson (2007), Goyal et al. (2021), Kabak and Dağdeviren (2014), Muhammad et al. (2021), Nanath et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012)  |
| Personal development and career support | Briggs (2006), Briggs and Wilson (2007), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012), Soutar and Turner (2002)   |

**Table 4** Definition and IVN scales of the linguistic variables

| Linguistic variables      |     | $T^L$ | $T^U$ | $I^L$ | $I^U$ | $F^L$ | $F^U$ |
|---------------------------|-----|-------|-------|-------|-------|-------|-------|
| Absolutely more important | AMI | 0.9   | 0.95  | 0     | 0.05  | 0.05  | 0.15  |
| Strongly more important   | SMI | 0.8   | 0.9   | 0.05  | 0.1   | 0.1   | 0.2   |
| More important            | MI  | 0.7   | 0.8   | 0.15  | 0.25  | 0.2   | 0.3   |
| Weakly more important     | WMI | 0.6   | 0.7   | 0.25  | 0.35  | 0.3   | 0.4   |
| Equal importance          | EI  | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   |
| Weakly less important     | WLI | 0.4   | 0.5   | 0.55  | 0.65  | 0.5   | 0.6   |
| Less important            | LI  | 0.3   | 0.4   | 0.65  | 0.75  | 0.6   | 0.7   |
| Strongly less important   | SLI | 0.2   | 0.3   | 0.75  | 0.85  | 0.7   | 0.8   |
| Absolutely less important | ALI | 0.1   | 0.2   | 0.9   | 0.95  | 0.8   | 0.9   |

**Table 5** Pairwise comparison of the main criteria by student 2

|    | C1  | C2  | C3  | C4  | C5  | C6  |
|----|-----|-----|-----|-----|-----|-----|
| C1 | EI  | LI  | WLI | SMI | WLI | WMI |
| C2 | WMI | EI  | MI  | AMI | MI  | SMI |
| C3 | WMI | LI  | EI  | WMI | EI  | WMI |
| C4 | SLI | ALI | WLI | EI  | WLI | WMI |
| C5 | WMI | LI  | EI  | WMI | EI  | MI  |
| C6 | WLI | SLI | WLI | WLI | LI  | EI  |

**Table 6** Aggregated weights of criteria

| Criteria                                | Weight |
|---|--------|
| Learning experience                     | 0.1755 |
| Campus and campus life                  | 0.1528 |
| Academic support and interest           | 0.1671 |
| Management and operations               | 0.1631 |
| Learning opportunities and resources    | 0.1698 |
| Personal development and career support | 0.1717 |

## Ranking Universities with VIKOR

After the determination of the criteria weights, the opinions of the students for the evaluation of universities are provided from Turkish University Satisfaction Research (Karadağ & Yücel, 2020). In this framework, 39,386 undergraduate students' opinions are received from 191 different universities. While 125 state universities and 66 foundation universities are included, only two universities from Turkey could not be covered by this study due to their insufficient number of students.

In the report, student selection is conducted according to the quota sampling, and at least 75 students' opinions are taken from each university. According to quota sampling, different disciplinary students are reached. The most participating faculties are the Faculty of Engineering and Architecture with 17.8%, the Faculty of Economics and Administrative Sciences with 14.8%, and the Faculty of Science and Literature with 14.4%. In the questionnaire, participants are asked to evaluate the university at which they are studying according to six criteria on a Likert scale of 0–100 points. Thus, university evaluation matrices for each cluster are constructed for each criterion. The data used in this study are compiled from the UNIAR yearly report for 2020 (Karadağ & Yücel, 2020).

The universities are evaluated according to predetermined criteria for each cluster. Therefore, the VIKOR methodology is applied to rank universities for each cluster in Turkey. For this purpose, evaluation matrices are constructed for each cluster by categorizing the evaluations according to the obtained clusters. Firstly, the best and worst values of each criterion are determined for each cluster as given in Table 7. Therefore, the ideal solutions for each cluster are determined.

$S_j$ ,  $R_j$  and  $Q_j$  are calculated using the weights obtained from IVN-AHP, and the ideal solutions given in Table 7 for each university and their rankings in their clusters are determined in this way. The  $S$ ,  $R$ , and  $Q$  values of universities and their rankings according to these values are given in Tables 8, 9, 10 for Cluster-1, Cluster-2, and Cluster-3, respectively.

“ozyegin” is determined as the best university according to  $Q_i$  scores. Both conditions are satisfied for Cluster-1. The ranks of other universities are given in Table 8 as the  $Q$  index for Cluster 1.

Again, two conditions are satisfied for Cluster 2. Therefore, “ege” is determined as the best university for Cluster 2. The ranks of other universities are given in Table 9 as the  $Q$  index for Cluster 2.

“sabanciu” is determined as the best university according to  $Q_i$  scores. “sabanciu” satisfies the condition C2 (Acceptable stability in decision-making), because it is determined as

**Table 7** The ideal solutions for each cluster

| Cluster   |         | C1 | C2 | C3 | C4 | C5 | C6 |
|-----------|---------|----|----|----|----|----|----|
| Cluster-1 | $x_j^+$ | 89 | 91 | 88 | 90 | 91 | 93 |
|           | $x_j^-$ | 30 | 34 | 36 | 34 | 35 | 35 |
| Cluster-2 | $x_j^+$ | 85 | 87 | 84 | 83 | 91 | 89 |
|           | $x_j^-$ | 58 | 62 | 63 | 61 | 75 | 70 |
| Cluster-3 | $x_j^+$ | 91 | 92 | 91 | 91 | 94 | 91 |
|           | $x_j^-$ | 68 | 72 | 69 | 58 | 71 | 69 |
| General   | $x_j^+$ | 91 | 92 | 91 | 91 | 94 | 93 |
|           | $x_j^-$ | 30 | 34 | 36 | 34 | 35 | 35 |

the best alternative for both S and Q. However, the condition C1 (Acceptable advantage) is not satisfied for “sabanciu”. Since the condition C1 is not fulfilled for the “sabanciu”, inequality of  $Q(a'') - Q(a') \geq D(Q)$  should be checked to find the compromise solution. Accordingly, the difference between “sabanciu” and “bilkent” is less than 0.2. For this reason, “sabanciu” and “bilkent” should be considered as compromise for the best university alternatives. If only one university is selected, “sabanciu”, and if two universities are selected, “sabanciu” and “bilkent” should be determined as the best university together for Cluster 3. The ranks of other universities are given in Table 10 as the Q index.

### Discussions and implications

The weights of six university service quality criteria are obtained using IVN-AHP methodology and then applied to the VIKOR model to determine the ranking index of the 191 universities in Turkey based on their clusters. Before applying the proposed MCDM methodology, clustering is performed for those universities.

The clustering method reveals that the universities are divided into 3 clusters. The result of the clustering is given in Table 2. Cluster-1, Cluster-2, and Cluster-3 include 178, 8, and 5 universities, respectively.

University Ranking by Academic Performance (URAP) has prepared a report taking the ranking values of 11 organizations that rank the leading universities worldwide. According to this report, 5 Turkish Universities (“itu”, “hacettepe”, “metu”, “istanbul”, “ankara”) are existing in all of these rankings, 3 universities (“bilkent”, “boun”, “ege”) are in ten lists, 1 university (“ku”) is in nine lists and 2 universities (“sabanciu”, “atatürk”) are in eight lists. As for the results of the proposed clustering method, the universities that exist in all 11 organizations’ lists of leading universities (“itu”, “hacettepe”, “metu”, “istanbul”, “ankara”) are in the same cluster, namely Cluster-2. Besides, “ege,” which belongs to 10 of the 11 lists, is also in Cluster-2. The remaining universities of Turkey that frequently existed in the leading universities lists appear in Cluster-3. Considering comparisons about university rankings, the result of the clustering method can be validated in this context.

The rankings of the universities in each cluster determined as a result of the proposed MCDM method are examined. According to Table 8, “ozyegin”, “agu”, and “acibadem” are ranked as the first, second, and third, respectively, in the same cluster. Although “ozyegin” and “acibadem” are foundation universities, and “agu” is a state university supported



Table 8 (continued)

| Uni             | Qi | Si    | Ri | Uni         | Qi  | Si    | Ri  |
|-----------------|----|-------|----|-------------|-----|-------|-----|
| isikun          | 28 | 0.222 | 29 | kastamonu   | 117 | 0.637 | 116 |
| 29mayis         | 29 | 0.223 | 30 | aku         | 118 | 0.638 | 121 |
| erciyes         | 30 | 0.227 | 20 | kmu         | 119 | 0.641 | 117 |
| karatay         | 31 | 0.227 | 37 | artuklu     | 120 | 0.641 | 118 |
| marmara         | 32 | 0.236 | 39 | isparta     | 121 | 0.660 | 119 |
| omu             | 33 | 0.238 | 45 | istinye     | 122 | 0.662 | 109 |
| demiroglu.bilim | 34 | 0.240 | 25 | samsun      | 123 | 0.667 | 126 |
| sdü             | 35 | 0.242 | 43 | klu         | 124 | 0.671 | 120 |
| balikesir       | 36 | 0.243 | 46 | lokmanhekim | 125 | 0.672 | 125 |
| tau             | 37 | 0.247 | 31 | ahbv        | 126 | 0.675 | 128 |
| ihu             | 38 | 0.254 | 40 | gedik       | 127 | 0.678 | 127 |
| hku             | 39 | 0.257 | 36 | nevsehir    | 128 | 0.680 | 124 |
| odu             | 40 | 0.263 | 42 | sinop       | 129 | 0.687 | 132 |
| aybu            | 41 | 0.264 | 34 | amasya      | 130 | 0.700 | 138 |
| mehmetakif      | 42 | 0.269 | 38 | ayvansaray  | 131 | 0.708 | 137 |
| trakya          | 43 | 0.270 | 44 | osmaniye    | 132 | 0.714 | 139 |
| ikk             | 44 | 0.270 | 41 | subu        | 133 | 0.722 | 144 |
| selcuk          | 45 | 0.271 | 47 | agri        | 134 | 0.723 | 131 |
| uludag          | 46 | 0.282 | 48 | beun        | 135 | 0.725 | 129 |
| fatih Sultan    | 47 | 0.282 | 35 | bilecik     | 136 | 0.735 | 140 |
| mcbu            | 48 | 0.285 | 56 | ostimteknik | 137 | 0.735 | 147 |
| ogu             | 49 | 0.308 | 55 | trabzon     | 138 | 0.740 | 130 |
| yüü             | 50 | 0.314 | 58 | eskisehir   | 139 | 0.740 | 133 |
| antalya         | 51 | 0.318 | 66 | gi          | 140 | 0.743 | 134 |
| yeditepe        | 52 | 0.318 | 49 | ozal        | 141 | 0.745 | 142 |

Table 8 (continued)

| Uni       | Qi | Si    | Ri | Uni   | Qi | Si    | Ri  |       |     |       |     |       |
|-----------|----|-------|----|-------|----|-------|-----|-------|-----|-------|-----|-------|
| sanko     | 53 | 0.323 | 33 | 0.224 | 71 | 0.083 | 142 | 0.746 | 141 | 0.700 | 135 | 0.138 |
| okan      | 54 | 0.327 | 54 | 0.286 | 56 | 0.074 | 143 | 0.746 | 136 | 0.674 | 140 | 0.142 |
| ticaret   | 55 | 0.332 | 68 | 0.329 | 51 | 0.068 | 144 | 0.756 | 135 | 0.674 | 152 | 0.146 |
| medipol   | 56 | 0.334 | 60 | 0.306 | 54 | 0.073 | 145 | 0.765 | 146 | 0.712 | 140 | 0.142 |
| baskent   | 57 | 0.337 | 67 | 0.321 | 53 | 0.071 | 146 | 0.767 | 150 | 0.733 | 137 | 0.139 |
| biruni    | 58 | 0.341 | 53 | 0.284 | 62 | 0.079 | 147 | 0.774 | 149 | 0.729 | 140 | 0.142 |
| gantep    | 59 | 0.344 | 64 | 0.316 | 57 | 0.074 | 148 | 0.782 | 145 | 0.711 | 153 | 0.148 |
| inonu     | 60 | 0.349 | 52 | 0.283 | 70 | 0.082 | 149 | 0.790 | 152 | 0.740 | 150 | 0.146 |
| atilim    | 61 | 0.350 | 57 | 0.301 | 62 | 0.079 | 150 | 0.792 | 143 | 0.708 | 159 | 0.152 |
| pau       | 62 | 0.356 | 50 | 0.279 | 72 | 0.084 | 151 | 0.796 | 156 | 0.767 | 143 | 0.143 |
| istanbulc | 63 | 0.356 | 59 | 0.304 | 68 | 0.080 | 152 | 0.801 | 148 | 0.724 | 161 | 0.152 |
| harran    | 64 | 0.357 | 72 | 0.340 | 57 | 0.074 | 153 | 0.804 | 158 | 0.768 | 148 | 0.145 |
| beykoz    | 65 | 0.359 | 61 | 0.308 | 68 | 0.080 | 154 | 0.808 | 153 | 0.759 | 153 | 0.148 |
| medeniyet | 66 | 0.359 | 65 | 0.318 | 62 | 0.079 | 155 | 0.809 | 161 | 0.779 | 148 | 0.145 |
| izu       | 67 | 0.361 | 51 | 0.280 | 75 | 0.086 | 156 | 0.813 | 159 | 0.769 | 153 | 0.148 |
| nku       | 68 | 0.370 | 69 | 0.332 | 67 | 0.080 | 157 | 0.814 | 157 | 0.768 | 157 | 0.149 |
| hitit     | 69 | 0.375 | 76 | 0.358 | 59 | 0.077 | 158 | 0.814 | 154 | 0.767 | 158 | 0.149 |
| altinbas  | 70 | 0.381 | 77 | 0.359 | 62 | 0.079 | 159 | 0.815 | 163 | 0.792 | 147 | 0.145 |
| giresun   | 71 | 0.382 | 80 | 0.371 | 61 | 0.077 | 160 | 0.832 | 162 | 0.783 | 159 | 0.152 |
| nny       | 72 | 0.386 | 79 | 0.369 | 62 | 0.079 | 161 | 0.832 | 155 | 0.767 | 162 | 0.155 |
| adu       | 73 | 0.387 | 81 | 0.383 | 59 | 0.077 | 162 | 0.834 | 165 | 0.808 | 153 | 0.148 |
| ihtisas   | 74 | 0.388 | 70 | 0.336 | 73 | 0.085 | 163 | 0.842 | 151 | 0.734 | 172 | 0.163 |
| bau       | 75 | 0.393 | 63 | 0.311 | 80 | 0.091 | 164 | 0.853 | 160 | 0.770 | 169 | 0.161 |
| bandirma  | 76 | 0.403 | 78 | 0.360 | 74 | 0.086 | 165 | 0.862 | 164 | 0.793 | 166 | 0.160 |
| kapadokya | 77 | 0.408 | 75 | 0.353 | 78 | 0.089 | 166 | 0.869 | 166 | 0.823 | 164 | 0.157 |

Table 8 (continued)

| Uni        | Qi | Si    | Ri | Uni   | Qi  | Si    | Ri  |       |     |       |     |       |
|------------|----|-------|----|-------|-----|-------|-----|-------|-----|-------|-----|-------|
| sakarya    | 78 | 0.409 | 62 | 0.310 | 85  | 0.096 | 167 | 0.875 | 169 | 0.848 | 162 | 0.155 |
| deu        | 79 | 0.417 | 73 | 0.342 | 82  | 0.093 | 168 | 0.880 | 168 | 0.840 | 165 | 0.158 |
| karabuk    | 80 | 0.430 | 86 | 0.399 | 77  | 0.088 | 169 | 0.900 | 171 | 0.859 | 169 | 0.161 |
| bartin     | 81 | 0.435 | 82 | 0.386 | 81  | 0.092 | 170 | 0.900 | 172 | 0.862 | 168 | 0.160 |
| erbakan    | 82 | 0.437 | 85 | 0.397 | 79  | 0.090 | 171 | 0.901 | 170 | 0.848 | 171 | 0.163 |
| dicle      | 83 | 0.442 | 91 | 0.429 | 76  | 0.087 | 172 | 0.902 | 174 | 0.868 | 166 | 0.160 |
| ksbu       | 84 | 0.458 | 89 | 0.421 | 82  | 0.093 | 173 | 0.917 | 167 | 0.838 | 176 | 0.170 |
| msgsu      | 85 | 0.476 | 83 | 0.387 | 94  | 0.105 | 174 | 0.921 | 173 | 0.863 | 173 | 0.167 |
| asbu       | 86 | 0.478 | 71 | 0.339 | 101 | 0.114 | 175 | 0.934 | 176 | 0.888 | 173 | 0.167 |
| erzurum    | 87 | 0.487 | 84 | 0.393 | 97  | 0.107 | 176 | 0.940 | 175 | 0.883 | 175 | 0.170 |
| cumhuriyet | 88 | 0.488 | 92 | 0.443 | 86  | 0.099 | 177 | 0.988 | 177 | 0.938 | 178 | 0.176 |
| duzce      | 89 | 0.494 | 94 | 0.445 | 87  | 0.101 | 178 | 0.988 | 178 | 0.961 | 177 | 0.172 |

**Table 9** Rankings for Cluster-2

| Uni       |   | Qi    |   | Si    |   | Ri    |
|-----------|---|-------|---|-------|---|-------|
| ege       | 1 | 0.030 | 2 | 0.072 | 1 | 0.033 |
| hacettepe | 2 | 0.179 | 3 | 0.176 | 2 | 0.052 |
| itu       | 3 | 0.205 | 1 | 0.033 | 4 | 0.091 |
| gazi      | 4 | 0.280 | 5 | 0.247 | 3 | 0.065 |
| istanbul  | 5 | 0.381 | 6 | 0.260 | 4 | 0.091 |
| metu      | 6 | 0.568 | 4 | 0.208 | 7 | 0.156 |
| ankara    | 7 | 0.737 | 7 | 0.455 | 6 | 0.150 |
| atauni    | 8 | 1.000 | 8 | 0.676 | 8 | 0.176 |

**Table 10** Rankings for Cluster-3

| Uni      |   | Qi    |   | Si    |   | Ri    |
|----------|---|-------|---|-------|---|-------|
| sabanciu | 1 | 0.034 | 1 | 0.031 | 2 | 0.046 |
| bilkent  | 2 | 0.037 | 2 | 0.107 | 1 | 0.031 |
| boun     | 3 | 0.164 | 4 | 0.191 | 3 | 0.069 |
| ku       | 4 | 0.193 | 3 | 0.145 | 4 | 0.092 |
| etu      | 5 | 1.000 | 5 | 1.061 | 5 | 0.252 |

by the foundation, the common feature of these three universities is that the amount of expenditure per student is more than 20,000 Turkish Lira (YÖK, 2021b). In the same cluster, "akev", "hakkari" and "bitliseren" universities are ranked as the last three universities. A possible explanation for this might be that they are located in cities far from the metropolitans and have not developed industrial areas. The fact that the program occupancy rates of these universities are 64%, 81%, and 67% also confirms their place in the ranking.

As for Cluster-2, all universities except "atauni" are located in the three biggest cities of Turkey in terms of industry and population. The reason "atauni" placed last in the ranking may arise from the location of the university, a relatively underdeveloped city in a remote area. It is not surprising that "atauni" gets the lowest evaluations of the criteria "Personal Development and Career Support" and "Learning Opportunities and Resources" considering the location of the university. On the other hand, universities that are in the first three places, "ege", "hacettepe", and "itu", are outstanding in terms of overall program occupancy rate. While "ege" surpasses other universities in Cluster-2 in especially the "Management and Operations" and "Academic Support and Interest" criteria, "hacettepe" never comes first in accordance to any criteria yet comes really close to the best values in each criterion. The fact that "metu", one of the best universities in Turkey, is ranked sixth in this cluster shows that student satisfaction is relatively low.

When examining Cluster-3, "sabanciu" can be seen in the first place. The fact that "sabanciu" has a 98% overall program occupancy rate even though it is a foundation university corroborates this result. Furthermore, the number of students from the university of "sabanciu" participating in Technocity or Technology Transfer Office (TTO) projects and industrial projects is more than twice times higher as the universities within the same cluster. For "bilkent", which is in the second place, it can be concluded that it offers a vibrant social environment for students, as it has the second highest number of sports facilities and the highest number of student societies. Additionally, "bilkent" is the second-highest in its



cluster in terms of the number of faculty members, while it ranks first on foreign academic staff. The fact that the university of "etu" has the lowest number of faculty members, foreign academic staff, sports facilities, and student societies compared to other universities in Cluster 2, justifies the rank of last place in accordance to the satisfaction of students (YÖK, 2021a).

## General ranking

Finally, considering the nonclustering case, all universities are evaluated using the VIKOR method and ranked. In this scenario, all 191 universities are evaluated together via VIKOR. The comparison of the general ranking and cluster-based ranking is given in Table 11. The universities in Cluster-2 and Cluster-3 are highlighted with red and green, respectively.

The positions of the universities in the overall rankings are not always consistent with their positions in the cluster-based rankings, as expected. While "sabanciu" is determined as the best university in its cluster (Cluster-3), it ranks second in overall ranking. Conversely, "bilkent" ranks second in its cluster-based ranking and first in the overall ranking. The negative ideal alternative for Cluster-3 is represented by the values of  $S^- = 1.061$  and  $R^- = 0.252$ , which has coincided with the "etu" university. Although there is no significant difference between them, "sabanciu" is farther from the negative ideal alternative ( $Q_{\text{sabanciu}} = 0.034$ ,  $Q_{\text{bilkent}} = 0.037$ ) in its cluster. In the overall ranking, the negative ideal alternative is represented with the values of  $S^- = 0.961$  and  $R^- = 0.176$ . The negative ideal alternative that does not correspond to the existing universities is very similar to the "hakkari" and "akev" universities. This time, "sabanciu" is closer to the negative ideal with  $Q_{\text{sabanciu}} = 0.019$  compared to "bilkent" with  $Q_{\text{bilkent}} = 0.016$ .

In other words, the distance from the negative ideal alternative "sabanciu", which is determined as the best university in cluster 3, is even more affected than "bilkent", which is determined as the second-best university in the cluster. This situation stems from the difference between the R values of the two universities. For this reason, the rankings have changed for the non-clustering case.

## Sensitivity analysis

A sensitivity analysis is conducted to show the reliability, robustness, and applicability of the proposed methodology due to changes in the parameter values. The threshold value ( $v$ ) used in VIKOR is changed to perform sensitivity analysis. The analysis is performed for Cluster-2. In each scenario, the threshold value is increased by 0.1 starting from 0.1 and till 0.9 and the  $Q_i$  score of each university is recalculated. The changes in the  $Q_i$  scores according to different threshold values are shown in Fig. 4.

Then final rankings of universities are determined according to updated scores and shown in Fig. 5 for different threshold values.

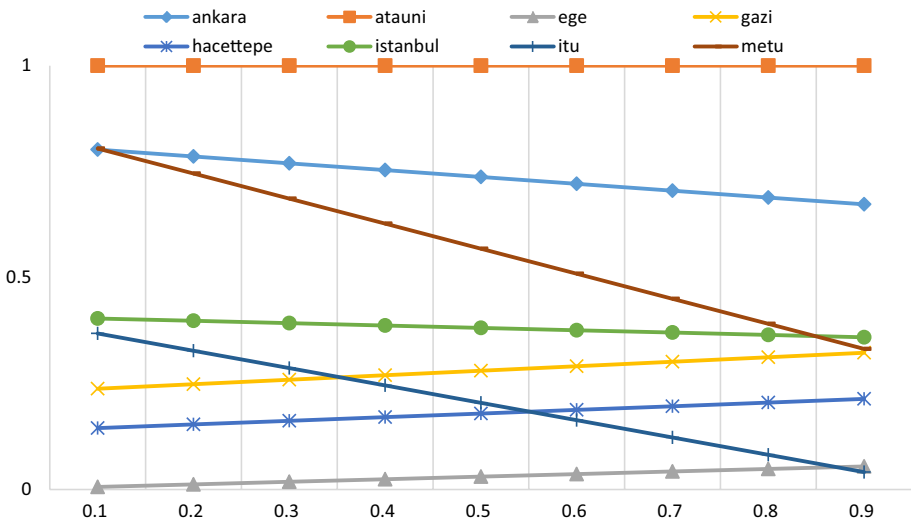
The effect of threshold value on university ranking is analyzed via sensitivity analysis. The reason for the changes in the ranking is that the universities have  $S_i$  (the weighted total regret) and  $R_i$  (the weighted maximum regret) values. As shown in Fig. 5, "ege" which is the best university in the current situation, is determined as the best university for all threshold values except 0.9. This means "ege" can be evaluated as student-friendly university. The ranking of "itu", which currently takes the fourth place, increases while the threshold value increases; so it becomes the second-best university for 0.9. The reason for this is that "itu" has bad value for  $S_i$  (the weighted total regret). As the threshold value

**Table 11** In-cluster and general ranking of universities

| GR | Uni              | CR | GR        | Uni           | CR       | GR  | Uni         | CR  | GR  | Uni         | CR  |
|----|------------------|----|-----------|---------------|----------|-----|-------------|-----|-----|-------------|-----|
| 1  | <b>bilkent</b>   | 2  | 49        | mehmetakif    | 42       | 97  | ksbu        | 84  | 145 | osmaniye    | 132 |
| 2  | <b>sabanci</b>   | 1  | 50        | aybu          | 41       | 98  | msgsu       | 85  | 146 | agri        | 134 |
| 3  | ozyegin          | 1  | 51        | selcuk        | 45       | 99  | asbu        | 86  | 147 | beun        | 135 |
| 4  | agu              | 2  | 52        | trakya        | 43       | 100 | erzurum     | 87  | 148 | subu        | 133 |
| 5  | acibadem         | 3  | 53        | ikc           | 44       | 101 | cumhuriyet  | 88  | 149 | bilecik     | 136 |
| 6  | mef              | 4  | 54        | odu           | 40       | 102 | duzce       | 89  | 150 | ostimteknik | 137 |
| 7  | <b>boun</b>      | 3  | 55        | fatihsultan   | 47       | 103 | firat       | 90  | 151 | eskisehir   | 138 |
| 8  | gtu              | 5  | 56        | mcbu          | 48       | 104 | ufuk        | 92  | 152 | trabzon     | 139 |
| 9  | <b>ku</b>        | 4  | 57        | uludag        | 46       | 105 | bakircay    | 91  | 153 | gi          | 140 |
| 10 | pirireis         | 6  | 58        | ogu           | 49       | 106 | kent        | 94  | 154 | ozal        | 141 |
| 11 | iyte             | 7  | 59        | <i>metu</i>   | 6        | 107 | beykent     | 96  | 155 | siirt       | 142 |
| 12 | bilgi            | 8  | 60        | yyu           | 50       | 108 | gop         | 93  | 156 | alanya      | 143 |
| 13 | <i>ege</i>       | 1  | 61        | antalya       | 51       | 109 | uskudar     | 95  | 157 | bozok       | 144 |
| 14 | akdeniz          | 11 | 62        | yeditepe      | 52       | 110 | afsu        | 98  | 158 | aydin       | 145 |
| 15 | khas             | 10 | 63        | sanko         | 53       | 111 | ahievran    | 97  | 159 | ahep        | 146 |
| 16 | mu               | 13 | 64        | okan          | 54       | 112 | erdogan     | 99  | 160 | ebyu        | 147 |
| 17 | bezmialem        | 12 | 65        | baskent       | 57       | 113 | tarsus      | 100 | 161 | ardahan     | 148 |
| 18 | ieu              | 9  | 66        | medipol       | 56       | 114 | nisantasi   | 102 | 162 | artvin      | 149 |
| 19 | maltepe          | 15 | 67        | ticaret       | 55       | 115 | cag         | 101 | 163 | gidatarim   | 150 |
| 20 | yildiz           | 14 | 68        | <i>ankara</i> | 7        | 116 | anadolu     | 104 | 164 | aksaray     | 151 |
| 21 | yasar            | 16 | 69        | inonu         | 60       | 117 | mku         | 103 | 165 | alparslan   | 152 |
| 22 | gsu              | 17 | 70        | gantep        | 59       | 118 | usak        | 105 | 166 | gumushane   | 153 |
| 23 | <i>hacettepe</i> | 2  | 71        | biruni        | 58       | 119 | dumlupinar  | 106 | 167 | arel        | 154 |
| 24 | ktun             | 18 | 72        | istanbulc     | 63       | 120 | ibu         | 108 | 168 | halic       | 155 |
| 25 | <i>itu</i>       | 3  | 73        | pau           | 62       | 121 | atu         | 107 | 169 | adiyaman    | 156 |
| 26 | iku              | 19 | 74        | izu           | 67       | 122 | cankaya     | 110 | 170 | yalova      | 158 |
| 27 | tedu             | 20 | 75        | beykoz        | 65       | 123 | btu         | 109 | 171 | bingol      | 157 |
| 28 | <i>gazi</i>      | 4  | 76        | atillim       | 61       | 124 | kku         | 111 | 172 | thk         | 159 |
| 29 | ktu              | 21 | 77        | harran        | 64       | 125 | ohu         | 112 | 173 | fbu         | 162 |
| 30 | comu             | 22 | 78        | nku           | 68       | 126 | kafkas      | 113 | 174 | idu         | 160 |
| 31 | kocaeli          | 25 | 79        | medeniyet     | 66       | 127 | ksu         | 114 | 175 | karatekin   | 161 |
| 32 | iste             | 24 | 80        | hitit         | 69       | 128 | avrasya     | 115 | 176 | mgu         | 163 |
| 33 | mersin           | 27 | 81        | adu           | 73       | 129 | kmu         | 119 | 177 | dogus       | 164 |
| 34 | isikun           | 28 | 82        | altinbas      | 70       | 130 | aku         | 118 | 178 | umeli       | 165 |
| 35 | 29mayis          | 29 | 83        | giresun       | 71       | 131 | artuklu     | 120 | 179 | batman      | 166 |
| 36 | erciyes          | 30 | 84        | nny           | 72       | 132 | toros       | 116 | 180 | kayseri     | 167 |
| 37 | cu               | 23 | 85        | yuksekihtisas | 74       | 133 | kastamonu   | 117 | 181 | kilis       | 168 |
| 38 | sbu              | 26 | 86        | bau           | 75       | 134 | isparta     | 121 | 182 | yeniyuzuil  | 170 |
| 39 | <i>istanbul</i>  | 5  | 87        | bandirma      | 76       | 135 | istinye     | 122 | 183 | igdir       | 171 |
| 40 | omu              | 33 | 88        | kapadokya     | 77       | 136 | klu         | 124 | 184 | sirnak      | 169 |
| 41 | sdu              | 35 | 89        | sakarya       | 78       | 137 | samsun      | 123 | 185 | munzur      | 172 |
| 42 | demiroglu.bilim  | 34 | 90        | deu           | 79       | 138 | lokmanhekim | 125 | 186 | gelisim     | 173 |
| 43 | karatay          | 31 | 91        | bartin        | 81       | 139 | ahbv        | 126 | 187 | bayburt     | 174 |
| 44 | marmara          | 32 | 92        | erbakan       | 82       | 140 | nevsehir    | 128 | 188 | esenyurt    | 175 |
| 45 | ihu              | 38 | 93        | karabuk       | 80       | 141 | gedik       | 127 | 189 | bitliseren  | 176 |
| 46 | balikesir        | 36 | <b>94</b> | <b>etu</b>    | <b>5</b> | 142 | sinop       | 129 | 190 | akev        | 178 |
| 47 | hku              | 39 | 95        | <i>atauni</i> | 8        | 143 | amasya      | 130 | 191 | hakkari     | 177 |
| 48 | tau              | 37 | 96        | dicle         | 83       | 144 | ayvansaray  | 131 |     |             |     |

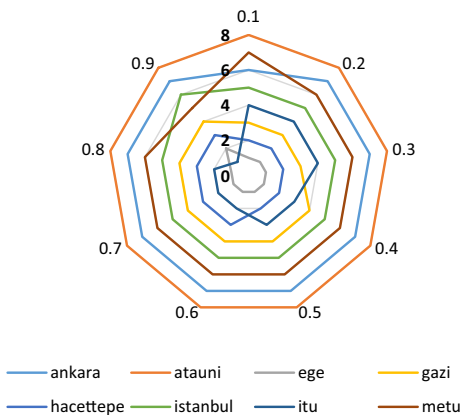
**Table 11** (continued)

CR cluster ranking; GR general ranking; Universities in italics are in Cluster-2, and universities in bold are in Cluster-3



**Fig. 4** The changes in the  $Q_i$  scores

**Fig. 5** The ranking of alternatives according to different threshold values



increases, the effect of the  $S_i$  decreases. “atauni” is determined as the worst university in Cluster-2 for all scenarios.

**Conclusion**

The competition between universities is getting challenging with the increasing number of institutions. Therefore, universities should improve themselves in areas such as research and education and even make improvements by taking student satisfaction into

account. In this study, a novel framework is established to address university ranking. In this framework, the clustering of universities according to teaching and research characteristics is performed in the first stage, and ranking universities according to student satisfaction, in-cluster and general, is obtained in the second stage. Six factors representing the characteristics of universities in the teaching and research areas were used in the clustering analysis: "foundation year", "the number of academicians", "the number of students per academician", "the number of citations per academician", and "the number of outputs per academician". In the second stage, to prioritize the evaluation criteria which are "learning experience", "campus life", "academic support and interest", "management", "learning opportunities and resources", and "personal development and career support", IVN-AHP is used. The results of IVN-AHP are used in the VIKOR method as criteria weights to reveal the ranking.

The contributions of this study to the literature can be summarized as follows: (1) A novel clustering-based MCDM methodology is presented to handle MCDM problems with more alternatives; (2) Both global and local characteristics of universities are handled together; (3) The factors related to university segmentation are determined by literature review; (4) The most important criteria regarding university ranking by student satisfaction are determined by IVN-AHP; (5) The university ranking problem is modeled as an MCDM problem; (6) A brief literature review on university ranking problem is presented; (7) The universities from Turkey are clustered by hierarchical clustering; (8) Universities are evaluated and ranked through VIKOR; (9) To the best of our knowledge, this paper presents IVN-AHP integrated VIKOR methodology for the first time; (10) A real case application for evaluating universities in Turkey is presented to show the applicability of the proposed methodology.

The results show that there is no significant difference between the weights of the criteria that affect students' perceptions of university satisfaction, while "learning experience" is the most important criterion, followed by "personal development and career support" and "learning opportunities and resources". In other respects, the fact that foundation universities take most of the first places is a valuable insight for authorized institutions such as The Council of Higher Education (YÖK). Moreover, the results of this study have guiding features for universities in Turkey, as they show their position in terms of student satisfaction.

The proposed hybrid methodology can be used to solve complex decision-making problems. The quality of services in different public or private institutions can be evaluated using the proposed MCDM approach. The proposed methodology can also be applied to different types of educational institution, such as primary school, high school. This study can be expanded by interviewing more experts or the number of factors and/or criteria can be increased.

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**Data Availability** Not applicable.

**Code Availability** Not applicable.

## Declarations

**Conflict of interest** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

**Ethical Approval** Ethics committee approval is not required.

**Consent to Participate** Not applicable.

**Consent to Publish** The authors confirm that the final version of the manuscript has been reviewed, approved and consented for publication by all authors.

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