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# A methodology for personnel selection in business development: An interval type 2-based fuzzy DEMATEL-ANP approach

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A B S T R A C T

The employee selection procedure holds significant importance for every company or organization involved in current economic activities. It is vital to underscore staff selection since it plays a crucial role in determining a firm's success. When a corporation selects a suitable applicant for a position and initiates the recruiting process, it might mark a critical point for the firm and substantially impact its functioning. In the present study, I utilized the trapezoidal interval type-2 (IT2) fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) - Analytic Network Process (ANP) methodology to conduct person selection. Additionally, statistically significant values for both the primary and secondary criteria related to staff recruitment were determined. The employment of square comparison matrices is essential for implementing the DEMATEL-ANP approach. The number of subcriteria for this application is equal to that of the alternative. The approach was successfully executed without facing any obstacles. The aim of this research was to investigate the viability of employing IT2 Fuzzy Systems to handle and control uncertainty efficiently. In addition, the implementation of sensitivity analysis plays a vital role in the context of multicriteria decision-making (MCDM) techniques.

## 1. Introduction

A company's human resources (HR) division is among the most critical parts of a company. Issues that arise while trying to make judgments are something that personnel in the HR department must deal with on a regular basis. Because of the nature of their work, which requires them to communicate with a wide variety of people, it may be challenging for HR personnel to determine which course of action will be most effective in a specific circumstance.

Personnel selection refers to the systematic process of evaluating and choosing the most qualified candidates from a pool of applicants for a particular job position within an organization. The objective is to identify individuals with the necessary skills, knowledge, and abilities to perform their job duties efficiently and effectively, constituting a crucial stage in human resource management. Contemporary organizations face considerable challenges because of the escalating competition in the global market. The sustainability of enterprises in the future is primarily based on the input of their workforce. The success of an organization is heavily reliant on the performance of its employees or personnel, including their knowledge, capabilities, talents, and other abilities. According to Zhang and Liu [1], companies must prioritize their personnel selection process to sustain their market position.

In every scenario, the procedure entails recruiting individuals who satisfy the necessary parameters. The chosen individual should be capable of meeting the minimal requirements for all the predetermined characteristics. Regrettably, hiring all the people who apply

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for jobs is not always feasible. A selection should proceed with candidates who satisfy the requirements for the open post. This method of hiring new employees should be taken seriously since, if it is successful, both time and resources will be well spent. The personnel selection process is essential to management because the cost of acquiring unpleasant employees may be significant.

A competent HR department should manage employee selection to conduct unbiased evaluations of candidates and ensure that the most qualified individuals are recruited to fill available positions. However, most businesses fail to recognize the value of HR and do not have robust HR departments. These businesses, instead, pick their employees using more time-honored methods. Each of the three managers—the general manager, the department head, and the HR manager—conducts their assessments of the applicants and selects those who will move on [2].

Every person faces the necessity to deliberate and settle on a course of action at some point in their lives. Whether in their social, personal, or professional lives, people are regularly confronted with decision-making scenarios in which they must select one course of action from two or more alternatives. While evaluating potential employees, two aspects must be taken into consideration and cannot be ignored; the first is to consider which standards ought to be followed, and the second is to consider which approaches might be applied to compare the many alternatives.

In reality, selecting appropriate employees is extremely difficult, much like many other decision-making challenges. To solve decision-making issues that include the selection of several alternatives based on several criteria at once, a technique known as multicriteria decision-making (MCDM) has become popular. The evaluation of employees throughout the selection and recruiting process is an issue that may be handled by employing MCDM methods.

In type-1 fuzzy sets (FSs), the membership functions comprise two dimensions; however, in type-2 FSs, the membership functions comprise three dimensions. The new third dimension makes it possible to directly model uncertainties because it provides additional degrees of freedom that the dimension offers.

Personnel selection is a frequently studied issue in the context of MCDM methods. The overwhelming majority of real-world issues entail multiple criteria that must be considered when determining the optimal approach to addressing the problem. As a direct result, MCDM techniques for tackling complicated problems have been developed. Finding out what people's overall preferences are from the several possibilities provided is the purpose of the MCDM. Techniques from the MCDM can be utilized for grading prospective solutions, provided that the appropriate ones are selected first. The problem of person selection is one that a few authors have approached, and they have done so by employing a few MCDM methodologies. The personnel selection methodology that incorporates the fuzzy analytic hierarchy process (FAHP) was presented by Gungor et al. [3]. The FAHP determines the optimal personnel for assessing criteria with qualitative and quantitative characteristics. In 2010, Dagdeviren [4] presented a hybrid model that combines the Analytic Network Process (ANP) with a modified version of the Technique for Order Performance by Similarity to an Ideal Solution (TOPSIS) to address personnel selection. Dereli et al. [2] suggested a new framework for assessing employees. The researchers employed a hybrid method by integrating the preference ranking organization method for enrichment evaluation (PROMETHEE) and Mamdani methodologies to facilitate a multicriteria selection process. The personnel selection problem was addressed by Fathi et al. [5] by applying the fuzzy TOPSIS method, which relied on FSs. Zhang and Liu [1] presented a methodology for personnel selection that integrates intuitionistic fuzzy multicriteria group decision-making with gray relational analysis (GRA).

Kabak et al. [6] introduced a methodology for decision-making that utilizes a hybrid approach incorporating both qualitative and quantitative factors. This approach is based on fuzzy logic and multicriteria analysis. The researchers employed a hybrid methodology of Fuzzy Analytic Network Process (FANP), fuzzy Elimination and Choice Expression of Reality (ELECTRE), and fuzzy TOPSIS methods to introduce an MCDM approach to select snipers. Kabak [7] introduced a proficient model that relies on fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) and FANP to facilitate personnel selection. The model employed DEMATEL to address the interrelationships among the assessment criteria. Subsequently, the FANP was employed to determine the weights of individual criteria and assess candidates. Kose et al. [8] presented a hybrid technique based on gray theory to select snipers. Initially, the researchers utilized the gray analytic network process (GANP) methodology to find the selection criteria weights. Subsequently, the candidates were prioritized based on their gray possibility degrees.

Abdullah and Zulkifli [9] suggested the amalgamation of FAHP and interval type-2 (IT2) fuzzy DEMATEL, with a primary emphasis on utilizing IT2 trapezoidal fuzzy numbers for a specific case in the field of HR. To improve the precision of the personnel selection methodology, Alguliyev et al. [10] integrated a modified fuzzy VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and worst-case approaches. Chang [11] presented a model that utilizes fuzzy Delphi, ANP, and TOPSIS to choose the most suitable personnel effectively.

Tomar et al. [12] ranked suppliers in an Indian corporate setting based on their performance using the analytic hierarchy process (AHP) as their research methodology. Aghaee and Aghaee [13] presented a hybrid, structured methodology for selecting logistics personnel by incorporating MCDM techniques. The Delphi technique was initially used to select effective criteria. Then, they performed the fuzzy DEMATEL technique to define the direction and relationships between criteria and the FANP technique to select the optimal candidate. Bilgehan Erdem [14] sought to develop an FAHP technique for information technology (IT) personnel selection. Gul et al. [15] presented integrating computer simulation, MCDM techniques of IT2 FAHP, and ELECTRE for a university hospital's emergency department (ED) system. In addition, their integrated method can be utilized to determine the ED's performance and select the optimal scenario, considering different numbers of nurses and physicians for three shifts. Kundakci [16] proposed GRA to select employees for a technology company. Combining AHP and VIKOR, Salehi [17] presented a hybrid fuzzy MCDM technique for personnel selection.

Ali et al. [18] presented a personnel selection system utilizing the FAHP and Simple Additive Weighting (SAW) methods. They utilized the FAHP to determine the most qualified personnel based on qualitative and quantitative rating criteria. Ozdemir et al. [19] sought to identify personnel selection criteria and rank these criteria using Consistent Fuzzy Preference Relations (CFPR). Urosevic et al. [20] presented a method for selecting personnel for the position of sales manager in the tourism industry based on the stepwise weighted assessment ratio analysis (SWARA) and weighted aggregated sum product assessment (WASPAS) approaches. Celikbilek [21] presented an integrated gray AHP-multiobjective optimization method based on ratio analysis (MOORA) selection strategy. Efe and Kurt [22] proposed a novel, systematic method for selecting personnel. As an extension of the TOPSIS technique, they proposed a degree-based TOPSIS approach with IT2 trapezoidal fuzzy numbers for personnel selection. Ilce [23] intended to conduct trainee recruitment in a furniture factory using the FAHP technique, one of the MCDM techniques. Jasemi and Ahmadi [24] introduced a novel fuzzy ELECTRE technique classified as an MCDM technique for personnel selection.

Karabasevic et al. [25] suggested a method utilizing the evaluation based on the distance from average solution (EDAS) method to select experts in information technology business systems support (BSS). The SWARA technique was employed to ascertain the criteria weights, while the recently presented EDAS technique has been utilized to evaluate the ranking of the alternatives, specifically the candidates. Kazancoglu and Ozkan-Ozen [26] proposed a structural competency model that introduces novel criteria for personnel selection within the context of Industry 4.0 using fuzzy DEMATEL.

In a real-world personnel selection scenario, Nalbant and Ozdemir [27] used an MCDM technique known as fuzzy VIKOR to find the most qualified candidates for promotion. Demirci and Kilic [28] proposed a model that includes DEMATEL, ANP, and ELECTRE tools for personnel selection. Zulkifly et al. [29] aimed to assist customers in choosing suitable personal medical and health insurance by comparing four insurance companies based on four criteria. Therefore, they used the fuzzy TOPSIS approach to rank the insurance companies since it can address the uncertainty and subjectivity of the data.

Cebeci [30] developed a framework for choosing a lean six-sigma manager among candidates by employing the trapezoidal IT2 FAHP methodology. Kilic et al. [31] presented a comprehensive approach that utilizes the DEMATEL and ELECTRE techniques within an intuitive fuzzy (IF) framework for the purpose of personnel recruitment. The authors utilized a two-step approach in their methodology. Initially, they employed the IF-DEMATEL technique to derive the importance weights of the elicited criteria. Subsequently, they applied the IF-ELECTRE technique to rank the candidates.

The TOPSIS methodology's use in the personnel selection procedure was the subject of a study by Priyadharshini et al. [32]. The procedure involved evaluating and prioritizing two candidates based on distinct subcriteria. A hybrid gray MCDM model was proposed by Ulutas et al. [33] for personnel selection. The authors introduced a new method called Gray Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA-G) and employed it to evaluate the significance of the criteria. The gray operating competitiveness rating (OCRA-G) method was employed to find the ultimate ranking of the alternative candidates under consideration. Zulqarnain et al. [34] debated the TOPSIS approach and improved a model for the TOPSIS approach for medical staff selection.

Ozgormus et al. [35] proposed a comprehensive fuzzy quality function deployment (QFD) MCDM framework for addressing the issue of personnel selection. The DEMATEL method with a fuzzy approach was used to assign weights to social criteria. The authors utilized the fuzzy QFD technique to determine the weight of the technical requirements. This approach facilitated the assessment of the interdependence and significance of social and technical criteria. Subsequently, the fuzzy GRA technique is employed to rank the alternatives based on the criteria scores obtained in the preceding stage. Popović [36] employed the SWARA method to determine the criteria weights, whereas he applied the combined compromise solution (CoCoSo) technique for personnel selection ranking.

Danisan et al. [37] explained the issue of hiring someone to operate a machine with different special characteristics in the textile business. For preselection, they employed the weighted scoring (WS) approach. Furthermore, they applied the AHP approach to define critical criterion weights for the firm. In addition, they employed TOPSIS and the preference ranking organization method for enrichment evaluations (PROMETHEE) to select the best candidate from the pool. Dumnić et al. [38] performed personnel selection using the Choquet integral based on a fuzzy measure. Gottwald et al. [39] discussed the employee selection problem at the University of Pardubice. They applied the entropy method to evaluate the significance of the criteria and the ARAS technique to determine the preferences of the Ph.D. candidates. Nalbant [40] used CFPR-IT2 fuzzy TOPSIS to find the most qualified candidates for promotion.

Edinsel [41] aimed to identify the criteria for a sales manager and use MCDM methodologies for applying them. The criteria importance was determined through an intercriteria correlation based on a single-valued neutrosophic set (SVNS-CRITIC) method used for weighting eight criteria, and ratio analysis based on the single-valued neutrosophic sets (SVNS-MULTIMOORA) method was used for ranking the alternatives. Chuang & Chang [42] applied the hierarchical structure to an airline and assisted its managers in selecting flight attendants using AHP and TOPSIS. Jin [43] combined the FMEA and DEMATEL methodologies with the TOPSIS method to analyze the unpredictability of the virtual team member selection problem and determine the risk priority number (RPN) for the MCDM criteria. Kara et al. [44] employed multicriteria decision-making strategies for project manager selection problem applications. Seven criteria were determined based on a review of relevant literature and interviews with manufacturing executives. The criterion weights were determined using the fuzzy stepwise weight assessment ratio analysis (F-SWARA) method. Four candidates were evaluated using the OCRA-G to determine the most qualified. Khalil et al. [45] formulated a model for staff selection within the context of a fuzzy environment, employing the TOPSIS method. Yenilmezel & Ertugrul [46] employed the combined use of fuzzy pivot pairwise relative criteria importance assessment (PIPRECIA) and fuzzy complex proportional assessment (COPRAS) procedures, both of which are fuzzy MCDM methods, to enhance the effectiveness of the results.

The originality of the paper is that it proposes a trapezoidal IT2 fuzzy DEMATEL-ANP model to select the best personnel alternative. During the evaluation process, the IT2 fuzzy DANP approach introduced by Dincer et al. [47] was utilized to assign weights to the different dimensions and criteria taken into consideration. When the relevant published material was reviewed, it was discovered that the field of personnel selection makes relatively little use of the techniques that include type 2 fuzzy numbers. The studies that used T1 and T2 fuzzy numbers and MCDM approaches to solve the employee selection problems described in the literature were investigated and are shown in Table 1. The aim of the present study is to evaluate the possibility of using IT2 FSs to handle such uncertainty more comprehensively. No previous study has applied the IT2 fuzzy DANP technique alone to the context of the selection of individuals. In this investigation, I utilize the IT2 fuzzy DEMATEL-ANP approach, and the comparison matrices for this method must be square matrices. In the context of this application, the number of subcriteria is equivalent to that of the alternative. In this manner, I did not experience any difficulties in putting this strategy into practice. The application of this method was successfully executed due to the equivalence of the number of alternatives and subcriteria, thereby avoiding any complications.

The DANP technique is the outcome of combining two different methods, namely, DEMATEL and ANP. The primary goal of each of these decision-making approaches is to ascertain the relevance of several aspects relevant to the decision-making procedure. This approach enables the development of a better-equipped strategy to encompass all components of coping with cognitive ambiguity. With the assistance of this methodology, it is possible to determine the interdependencies between the main and subcriteria.

This study makes a major contribution to the existing corpus of knowledge in various ways. Therefore, the most important thing that this study brings to the table regarding its contribution to the field is the provision of a sensitivity analysis. This analysis determines whether the weights assigned to the main and subcriteria are compatible. Thus, it can be inferred whether the weights

**Table 1**
MCDM's research field: Technologies.

| The issue resolved | Techniques | Fuzzy Type | Authors |
|---|---|---|---|
| Personnel selection | FAHP | Type-1 | Gungor et al. [3] |
| Personnel selection in manufacturing systems | ANP, TOPSIS | – | Dagdeviren [4] |
| Personnel selection | PROMETHEE | Type-1 | Dereli et al. [2] |
| Personnel selection | Fuzzy TOPSIS | Type-1 | Fathi et al. [5] |
| Personnel selection | Fuzzy GRA | Type-1 | Zhang and Liu [1] |
| Professional selection | FANP, Fuzzy TOPSIS, Fuzzy ELECTRE | Type-1 | Kabak et al. [6] |
| Personnel selection | Fuzzy DEMATEL, FANP | Type-1 | Kabak [7] |
| Sniper selection | Gray Analytic Network Process | – | Kose et al. [8] |
| Human resources management | FAHP, IT2 fuzzy DEMATEL | Type-2 | Abdullah, and Zulkifli [9] |
| Personnel selection | Fuzzy VIKOR | Type-1 | Alguliyev et al. [10] |
| Public relations personnel selection | Fuzzy Delphi method, ANP, TOPSIS | – | Chang [11] |
| Prioritizing the personnel in India | AHP | – | Tomar et al. [12] |
| Selection of logistics personnel | Delphi Method (DM), FDEMATEL, FANP | Type-1 | Aghaee and Aghaee [13] |
| Personnel selection | FAHP | Type-1 | Bilgehan Erdem [14] |
| Emergency Department Performance Evaluation | IT2FAHP, ELECTRE | Type-2 | Gul et al. [15] |
| Employee selection | GRA | – | Kundakci [16] |
| Personnel selection | FAHP and Fuzzy VIKOR | Type-1 | Salehi [17] |
| Personnel selection | FAHP, SAW | Type-1 | Ali et al. [18] |
| Personnel selection | CFPR | – | Ozdemir et al. [19] |
| Personnel selection in the tourism industry | SWARA, WASPS | – | Urosevic et al. [20] |
| Personnel selection | Gray AHP–MOORA | – | Celikbilek [21] |
| Personnel selection | Fuzzy TOPSIS | Type-2 | Efe and Kurt [22] |
| Staff selection | FAHP | Type-1 | Ilce [23] |
| Personnel selection | Fuzzy ELECTRE | Type-1 | Jasemi and Ahmadi [24] |
| Personnel selection | EDAS method, SWARA | – | Karabasevic et al. [25] |
| Personnel selection in Industry 4.0 environment | Fuzzy DEMATEL | Type-1 | Kazancoglu and Ozkan-Ozen [26] |
| Personnel selection | Fuzzy VIKOR | Type-1 | Nalbant and Ozdemir [27] |
| Multifactor personnel selection | Fuzzy TOPSIS | Type-1 | Aliyeva [48] |
| Personnel selection | DEMATEL, ANP, ELECTRE | – | Demirci and Kilic [28] |
| Selection of personal medical and health insurance company | Fuzzy TOPSIS | Type-1 | Zulkifly et al. [29] |
| Selecting Lean Six Sigma manager | AHP | Type 2 | Cebeci [30] |
| Personnel selection | IF-DEMATEL, IF-ELECTRE | Type-1 | Kilic et al. [31] |
| Employee selection | Fuzzy TOPSIS | Type-1 | Priyadharshini et al. [32] |
| Personnel selection | PIPRECIA-G, OCRA-G | – | Ulutas et al. [33] |
| Medical staff for the health department | TOPICS | – | Zulqarnain et al. [34] |
| Personnel selection | Fuzzy DEMATEL, fuzzy QFD, Fuzzy Gray Relationship Analysis | Type-1 | Ozgormus et al. [35] |
| Personnel selection | SWARA, CoCoSo | – | Popović [36] |
| Personnel selection | The Weighted Scoring (WS), AHP, TOPSIS, PROMETHEE | – | Denison et al. [37] |
| Personnel selection | Choquet integral | Type-1 | Dumnić et al. [38] |
| Best possible Ph.D. candidate for an educational institution | Entropy method, ARAS | – | Gottwald et al. [39] |
| Personnel selection and promotion | CFPR, Fuzzy TOPSIS | Type 2 | Nalbant [40] |
| Flight attendants' selection | AHP, TOPSIS | – | Chuang and Chang [42] |
| Sales manager selection | SVNS-CRITIC, SVNS-MULTIMOORA | – | Edinsel [41] |
| Virtual team member selection | Failure mode and effect analysis (FMEA), DEMATEL, TOPSIS | – | Jin [43] |
| Supply chain project manager selection | F-SWARA, OCRA-G | Type 1 | Kara et al. [44] |
| Staff selection | TOPICS | – | Khalil et al. [45] |
| Blue collar personnel selection | Fuzzy COPRAS Method, Fuzzy PIPRECIA | Type-1 | Yenilmezel & Ertuğrul [46] |

assigned to the criteria are congruent with the available alternatives.

The personnel selection process holds significant importance in the contemporary business landscape characterized by fast technology advancements, as it directly impacts the overall profitability of a firm. The methodology employed in this study within the fuzzy logic domain demonstrates a highly noteworthy approach. In the contemporary era characterized by the pervasive adoption of digital technology, the recruitment process has significant importance in facilitating the growth and advancement of enterprises. Personnel selection plays a crucial role in implementing digital transformation strategies, hence becoming an essential requirement for organizations engaged in business development in the digital age.

Table 1 shows the lack of research utilizing fuzzy type 2 in the field of personnel selection in business development. The aim of this study is to augment the current information on personnel selection in the field of business development. Hence, this study makes a valuable contribution to the existing body of literature. In the future, this work will contribute to the field of personnel selection in the context of business development. The purpose of using type-2 fuzzy sets is to represent and minimize the effects of uncertainty in rule-based systems based on fuzzy logic. Moreover, researchers commonly favor IT2 fuzzy sets over T2 fuzzy sets due to their simplicity and reduced computing load in comparison to traditional T2 fuzzy sets. For this reason, IT2 FSs are employed in this investigation. These remarks are important to clarify how this work moves the field forward. A square matrix is needed by the method used in this study to create a normalized direct relation matrix using the DANP approach for pairwise comparison matrices of subcriteria alternatives. The DANP technique requires the use of an identity matrix and a square matrix in the pairwise comparison matrix for alternatives and subcriteria. The quantity of subcriteria must correspond to the quantity of alternatives. In practical terms, if the number of subcriteria

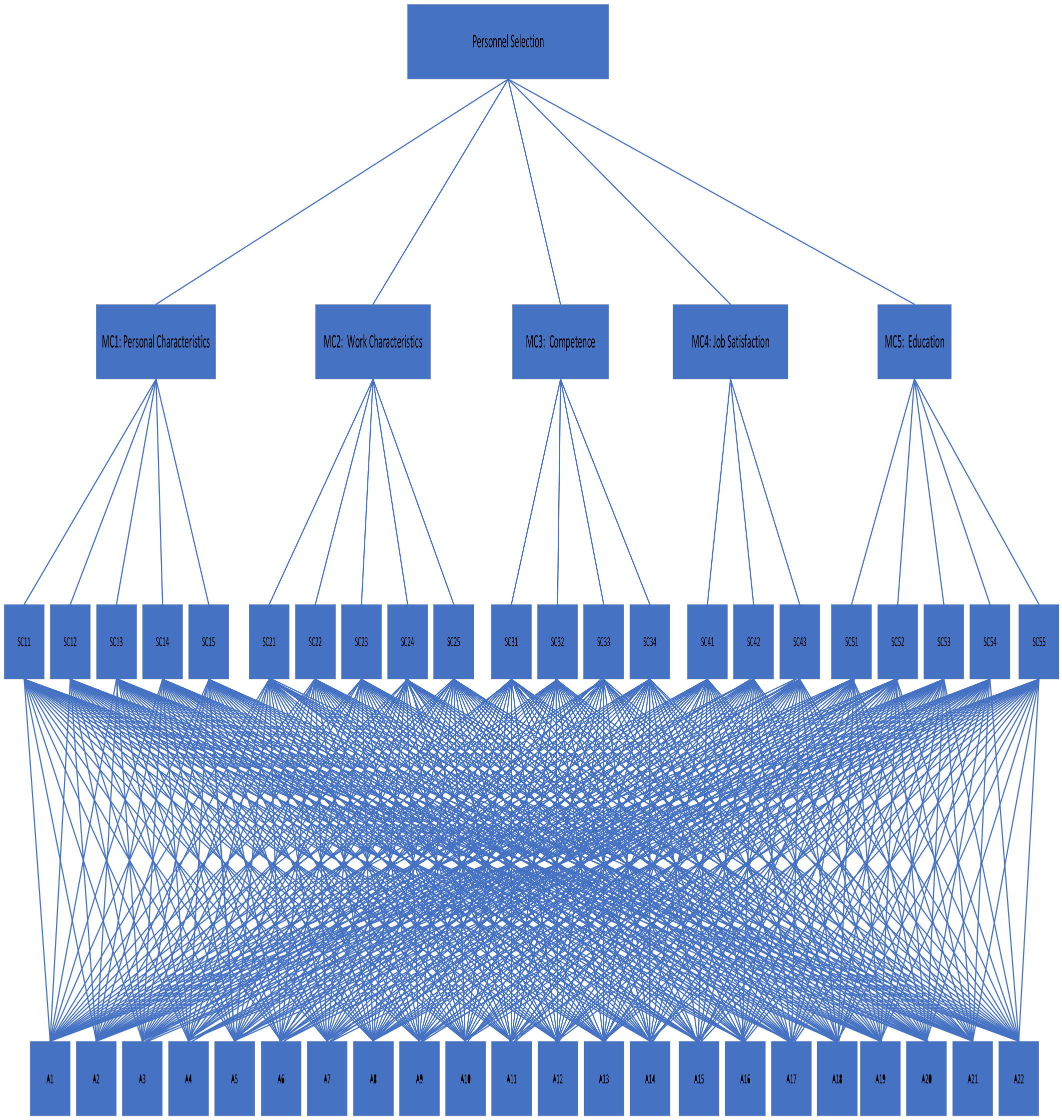


**Fig. 1.** A hierarchical framework for choosing employees.

and alternatives are not equal, issues are likely to arise. No problems were encountered while applying the method because both variables are equivalent in this study. Additionally, the literature review revealed a scarcity of MCDM research that utilizes sensitivity analysis, which is used to evaluate the impact of several elements on the result of a decision or project. However, conducting sensitivity analysis is crucial within the realm of decision-making. Sensitivity analysis is also applied in this study, and the results demonstrate a notable level of uniformity across all scenarios examined in this study.

In this article, the IT2 fuzzy DANP technique is performed to tackle the problem of personnel selection using the MCDM process. The following outlines how the paper is structured: The IT2 Fuzzy DANP Methodology, the computational findings, a comparison of the outcomes, and sensitivity analysis are all presented in Section 2. The limitations of the study and aspects of the methodology are discussed in Section 3. The suggestions for future works are examined in the conclusion section.

## 2. APPLICATION/RESEARCH technique

Here, I discuss the order of the various aspects of the employee selection problem. In addition, the criteria for evaluation, as well as the size of the personnel, are established in this section. After that, a concise description of the IT2 fuzzy DANP approach follows with the model proposal. In the second part of this section, the proposed technique is put into practice, after which the results of the analysis are presented. The evaluation of the results are presented in the next and final part of this section. The final element of this portion consists of examining sensitivity.

During this research, a business in Istanbul, Turkey, is selected as the focus for investigating the staff selection problem. It has been decided that one of the company's engineers will be given the opportunity to advance to the role of chief engineer. Three of the most prominent officials in the business take part in the evaluation process, and together, they decide on five primary criteria, twenty-two secondary criteria, and twenty-two alternatives.

The arrows in Fig. 1 illustrate the problem's hierarchy. Personal characteristics criteria (MC1) include the following subcriteria: leading spirit (SC11), positivism (SC12), enterprising (SC13), creativity (SC14), and reliability (SC15). Work characteristics criteria (MC2) include the following subcriteria: team worker (SC21), analytical thinking (SC22), the ability to persuade (SC23), self-disciplined (SC24), and solution-oriented (SC25). The following subcriteria are included in competence (MC3): productivity (SC31), moderate effectiveness (SC32), minimal competence (SC33), and inefficiency (SC34). Job satisfaction (MC4) includes the following subcriteria: salary (SC41), promotion (SC42), and work safety (SC43). Education (MC5) includes the following subcriteria: occupational experience (SC51), educational status (SC52), field information (SC53), knowledge of a foreign language (SC54), and informatics proficiency (SC55). Personnel alternatives were identified from A1 to A22. The objective of employing type-2 FSs is to model and reduce the consequences of uncertainty in fuzzy logic rule-based systems. Moreover, IT2 FSs are widely preferred T2 FSs owing to their uncomplicated nature and decreased computational burden compared to conventional T2 FSs. Because of this, IT2 FSs were utilized in this study.

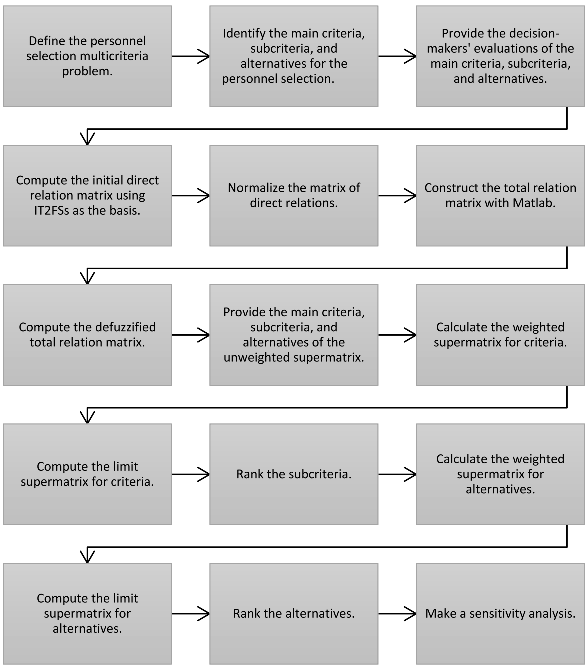


**Fig. 2.** The IT2 DEMATEL-ANP approach.

### 2.1. IT2 fuzzy DANP methodology

A trapezoidal IT2 fuzzy DANP multicriteria decision procedure is created to improve the evaluation of personnel (see Fig. 2). The IT2 fuzzy DANP technique proposed by Dincer et al. [47] is applied to this problem.

The IT2 fuzzy DANP method was applied to the problem of personnel selection. The matter of the recruitment of specialists in the field of business development, considering various factors, is now being examined. The establishment of primary factors, secondary considerations, and other possibilities for personnel selection is undertaken. The presentation showcases the assessments made by decision-makers on the main criteria, subcriteria, and alternatives. The computation of the first direct relationship matrix is performed using interval type-2 fuzzy sets (IT2FSs). Then, the matrix representing direct connections is standardized, and the generation of the whole relationship matrix is achieved through the utilization of the MATLAB program. Subsequently, the defuzzified total relationship matrix is calculated. After that, the computation of the major criteria, subcriteria, and alternatives inside the unweighted supermatrix is executed, and the computation of the weighted supermatrix for the criteria is conducted. Subsequently, the limit supermatrix is calculated based on the provided criteria.

Moreover, the process of determining the ranking of subcriteria has been successfully accomplished, and the computation of the weighted supermatrix for the alternatives is conducted. Then, the determination of the limit supermatrix is carried out for the various alternatives. Finally, the IT2 fuzzy DANP approach was utilized to choose the most appropriate alternative. In the last stage, a sensitivity analysis is performed. The trapezoidal IT2 fuzzy DANP approach allows for determining both the optimal criteria and the optimal alternative. During the use of the approach, the step involving the comparison of subcriteria with alternatives necessitates the use of a square matrix.

Given that the research consisted of 22 criteria and 22 alternatives, no issues were encountered in this study. Furthermore, a sensitivity analysis was conducted throughout the concluding phase. The aim of this investigation was to assess the accuracy of the approach across four cases.

The application procedures for this method are as follows:

The MCDM problem was defined initially. The main criteria, subcriteria, and alternatives were then identified. It was decided who would oversee making the decisions, and input was solicited. Three decision-makers (experts) who work in the industry as professionals throughout the world have been selected to offer linguistic assessments of the causes and options. Table 2 displays the language phrases and interval fuzzy numbers used to choose the primary criteria, subcriteria, and alternatives. In the beginning, a direct relation matrix was constructed by translating words into fuzzy integers.

Additionally, the decision-maker ratings were averaged to create the initial direct connection matrix. The weights of the primary criteria and subcriteria were calculated using the DANP technique and based on IT2 FSs. The first direct relationship matrices were then normalized. Total relation matrices were created by building the identity matrix and using MATRIX LABORATORY (MATLAB) to determine the variations between the identity matrix and the normalized matrix for each item of a trapezoidal fuzzy number. The defuzzified total relation matrix was created with the defuzzification approach for T2 FSs that Kahraman et al. [49] suggested. The defuzzified matrix's rows were added to create a supermatrix without weights, which was then used to create the new matrix. The transposed values of the new matrix served as its defining feature. The unweighted values of the subcriteria were determined similarly.

Finding the weighted supermatrix involved the multiplication of the main criteria and subcriteria matrices after the initial unweighted supermatrix had been weighted. The process of stabilizing the weighted supermatrix involved elevating it to a high-power k, resulting in a limited supermatrix that exhibits long-term stability. Determining global weights for criteria was conducted by considering both primary and secondary criteria. At this juncture of the procedure, the limit supermatrix about subcriteria is derived. The subcriteria ranking is determined through the utilization of the matrix. Subsequently, the DANP methodology was employed, utilizing IT2 FSs to find the weights of the alternatives. Subsequently, the matrices depicting direct relationships were subjected to normalization. The generation of total relation matrices was accomplished by constructing an identity matrix and subsequent calculation of differences between the identity matrix and the normalized matrix for each item of a trapezoidal fuzzy number utilizing MATLAB. The study conducted by Dincer et al. [47] revealed that the IT2 DANP method necessitates using a square matrix to construct the total influence matrix, owing to utilizing a unit matrix. Upon analyzing the study, it was observed that the situation was determined using a formula. Thus, the square matrix is scrutinized at this juncture to determine whether the alternatives and subcriteria exhibit equivalence. The computations were deemed unproblematic, as the quantity of subcriteria examined in my investigation was equivalent to the quantity of alternatives under consideration. As a result, I could independently employ the IT2 DANP technique. Then, the defuzzification method was employed to generate the defuzzified total relation matrix. The resultant supermatrix was obtained by aggregating the rows of the defuzzified matrix without considering any weights. The transposed values of the new matrix were observed. The unweighted values of the alternatives were computed comparably. The unweighted supermatrix was weighted by

**Table 2**
Criteria and dimensions based on linguistic assessments and IT2 fuzzy numbers [49].

| Linguistic Expressions | Trapezoidal IT2 fuzzy numbers |
|---|---|
| Strong (AS) | (7,8,9,9; 1,1) (7.2,8.2,8.8,9; 0.8,0.8) |
| Very Strong (VS) | (5,6,8,9; 1,1) (5.2,6.2,7.8,8.8; 0.8,0.8) |
| Fairly Strong (FS) | (3,4,6,7; 1,1) (3.2,4.2,5.8,6.8; 0.8,0.8) |
| Slightly Strong (SS) | (1,2,4,5; 1,1) (1.2,2.2,3.8,4.8; 0.8,0.8) |
| Exactly Equal (E) | (1,1,1,1; 1,1) (1,1,1,1; 1,1) |

multiplying the criteria and alternative matrices to obtain the weighted supermatrix.

Moreover, weighted supermatrices were restricted by limited supermatrices. Finally, the alternative ranking was determined by the limit supermatrix, and the best alternative was selected. The final step was performing a sensitivity analysis. Sensitivity analysis is a common practice in evaluating the resilience and longevity of a specific solution.

This research used a method known as trapezoidal IT2 fuzzy DEMATEL-ANP, a kind of current MCDM, to rank the various alternatives based on certain criteria. Linguistic factors are used to assess both the effectiveness of the alternatives and the significance of the criterion. In most cases, scales ranging from 1 to 9 have been utilized to evaluate the various alternatives regarding their efficiency and criteria. Table 2 provides the conversion of the language variables into their corresponding numerical values. The individuals in charge of making the decisions were tasked with assessing each criterion concerning each alternative using a range of language expressions in Table 2.

### 2.2. Results

The decision-makers' linguistic evaluations of the main criteria, subcriteria, and alternatives are shown in Appendices A, B and C. E1, E2, and E3 denote expert 1, expert 2, and expert 3, respectively. Table 3 presents the primary direct relationship matrix for the various aspects of personnel selection. The matrix of dimensions that have been normalized is presented in Appendix D. The creation of an identity matrix and the computation of the differences between the identity matrix and the normalized matrix for each component of a trapezoidal fuzzy number are the two steps involved in the generation of total influence matrices. The computation of transposed matrices is necessary to compute the complete influence matrix for every trapezoidal fuzzy number. The total relationship matrix for the main criteria was computed using MATLAB and is shown in Appendix E. Kahraman et al. [49] introduced the defuzzification technique to obtain the defuzzified total relation matrix for T2 FSs. The defuzzified total relation matrix is shown in Appendix F. The process of creating a supermatrix without weights involves the summation of rows in the defuzzified matrix to form the new matrix. The transposed values distinguish the new matrix in Appendix G. Similarly, the unweighted subcriteria values were computed. Additionally, a defuzzified total relation matrix and an unweighted supermatrix were derived for the subcriteria. The process of weighting the unweighted supermatrix involves the multiplication of both the main criteria and subcriteria matrices. The stability of the weighted supermatrix can be achieved by iteratively raising it to a large exponent k, resulting in a stable supermatrix that exhibits long-term stability. Subsequently, the limit matrix was derived, exhibiting the localized relative weights assigned to each constituent element within the supermatrix alongside the normalized fuzzy matrices. The weighted supermatrix for subcriteria is shown in Appendix H. The stability of the weighted supermatrix is achieved by elevating it to a sufficiently large exponent k, resulting in a stable supermatrix that endures over an extended period. The limit supermatrix about subcriteria is presented in Appendix I. The matrix of limits exhibits the relative weights of each constituent element within the supermatrix in a local context. The limit supermatrix for alternatives is displayed in Appendix J.

### 2.3. Evaluation

The local weights of the subcriteria and alternatives were obtained. Finally, this technique employing the IT2 fuzzy scales chose the best outcome as "A4″ in Table 4. Other alternatives are ranked as A9, A2, A1, A21, A12, A11, A14, A17, A19, A10, A15, A6, A5, A8, A13, A16, A20, A7, A18, A3, and A22. Moreover, this method employing the IT2 fuzzy numbers has chosen the best criteria as "SC43″

**Table 3**
Initial direct-relation matrix for the main criteria.

| | MC1 | MC2 | MC3 |
|---|---|---|---|
| **MC1** | (1,1,1,1; 1,1)<br>(1,1,1,1; 1,1) | (1.44,2,2.88,3.27; 1,1)<br>(1.57,2.1,2.8,3.2; 0.8,0.8) | (1,1.26,1.59,1.71; 1,1)<br>(1.06,1.13,1.56,1.69; 0.8,0.8) |
| **MC2** | (0.31,0.35,0.5,0.69; 1,1)<br>(0.31,0.36,0.48,0.64; 0.8,0.8) | (1,1,1,1; 1,1)<br>(1,1,1,1; 1,1) | (1,1.59,2.52,2.92; 1,1)<br>(1.13,1.69,2.44,2.85; 0.8,0.8) |
| **MC3** | (0.58,0.63,0.79,1; 1,1)<br>(0.59,0.64,0.77,0.94; 0.8,0.8) | (0.34,0.4,0.63,1; 1,1)<br>(0.35,0.41,0.59,0.89; 0.8,0.8) | (1,1,1,1; 1,1)<br>(1,1,1,1; 1,1) |
| **MC4** | (0.31,0.35,0.5,0.69; 1,1)<br>(0.31,0.36,0.48,0.64; 0.8,0.8) | (0.16,0.19,0.31,0.48; 1,1)<br>(0.17,0.2,0.3,0.43; 0.8,0.8) | (0.2,0.25,0.5,1; 1,1)<br>(0.21,0.26,0.45,0.83; 0.8,0.8) |
| **MC5** | (0.34,0.4,0.63,1; 1,1)<br>(0.35,0.41,0.59,0.89; 0.8,0.8) | (0.58,0.63,0.79,1; 1,1)<br>(0.59,0.64,0.77,0.94; 0.8,0.8) | (0.58,0.63,0.79,1; 1,1)<br>(0.59,0.64,0.77,0.94; 0.8,0.8) |
| | **MC4** | **MC5** | |
| **MC1** | (1.44,2,2.88,3.27; 1,1)<br>(1.57,2.1,2.8,3.2; 0.86,0.86) | (1,1.59,2.52,2.92; 1,1)<br>(1.13,1.69,2.44,2.85; 0.86,0.86) | |
| **MC2** | (2.08,3.17,5.24,6.26; 1,1)<br>(2.31,3.39,5.04,6.05; 0.8,0.8) | (1,1.26,1.59,1.71; 1,1)<br>(1.06,1.3,1.56,1.69; 0.93,0.93) | |
| **MC3** | (1,2,4,5; 1,1)<br>(1.2,2.2,3.8,4.8; 0.8,0.8) | (1,1.26,1.59,1.71; 1,1)<br>(1.06,1.3,1.56,1.69; 0.93,0.93) | |
| **MC4** | (1,1,1,1; 1,1)<br>(1,1,1,1; 1,1) | (0.34,0.4,0.63,1; 1,1)<br>(0.35,0.41,0.59,0.89; 0.86,0.86) | |
| **MC5** | (1,1.59,2.52,2.92; 1,1)<br>(1.13,1.69,2.44,2.85; 0.86,0.86) | (1,1,1,1; 1,1)<br>(1,1,1,1; 1,1) | |

**Table 4**
Ranking results with IT2 DANP methodology.

| Alternatives | Weights | Normalized values | Ranking |
|---|---|---|---|
| A1 | 0.0000000000851 | 4.771526997 | 4 |
| A2 | 0.0000000000861 | 4.826197903 | 3 |
| A3 | 0.0000000000741 | 4.156522358 | 21 |
| A4 | 0.0000000000900 | 5.044269915 | 1 |
| A5 | 0.0000000000798 | 4.474567249 | 14 |
| A6 | 0.0000000000799 | 4.481578511 | 13 |
| A7 | 0.0000000000764 | 4.284512751 | 19 |
| A8 | 0.0000000000789 | 4.425877549 | 15 |
| A9 | 0.0000000000881 | 4.938493892 | 2 |
| A10 | 0.0000000000817 | 4.578093555 | 11 |
| A11 | 0.0000000000834 | 4.67688773 | 7 |
| A12 | 0.0000000000838 | 4.695075733 | 6 |
| A13 | 0.0000000000784 | 4.393883205 | 16 |
| A14 | 0.0000000000828 | 4.644192871 | 8 |
| A15 | 0.0000000000814 | 4.561218885 | 12 |
| A16 | 0.0000000000782 | 4.384418819 | 17 |
| A17 | 0.0000000000826 | 4.628791939 | 9 |
| A18 | 0.0000000000756 | 4.235576697 | 20 |
| A19 | 0.0000000000820 | 4.5954304 | 10 |
| A20 | 0.0000000000767 | 4.302474684 | 18 |
| A21 | 0.0000000000848 | 4.753067742 | 5 |
| A22 | 0.0000000000740 | 4.147340616 | 22 |

in Table 5. The ranking of the others is SC51, SC41, SC42, SC52, SC55, SC53, SC54, SC31, SC15, SC24, SC25, SC13, SC14, SC23, SC22, SC11, SC32, SC21, SC12, SC33, and SC34.

### 2.4. *Sensitivity analysis*

Personnel selection is a critical organizational issue due to the potential advantages gained from making appropriate personnel choices and the equally negative consequences that can result from incorrect selections; as a result, it is a challenging problem to address. The phenomenon can be attributed to the potential loss of benefits that may arise from erroneous decisions about personnel selection, thereby underscoring the importance of making accurate choices in this regard. There exists a possibility that the company may encounter significant challenges in the future due to decisions made regarding the recruitment of employees that may not be entirely suitable.

The final phase of the model entails performing a sensitivity analysis to evaluate the criteria weights for consistency. Sensitivity analysis is employed to modify criteria weights, and the results displayed are illustrated in Table 7 via comparative IT2-based fuzzy decision-making models. The sensitivity analysis technique is frequently employed to assess the robustness and durability of a

**Table 5**
Ranking results of criteria with IT2 DANP methodology.

| Criteria | | Weights | Normalized values | Ranking |
|---|---|---|---|---|
| SC11 | Leading Spirit | 0.000129859 | 1.297 | 17 |
| SC12 | Positivism | 0.000085494 | 0.854 | 20 |
| SC13 | Enterprising | 0.000153174 | 1.53 | 13 |
| SC14 | Creativity | 0.000135937 | 1.357 | 14 |
| SC15 | Reliability | 0.000271525 | 2.711 | 10 |
| SC21 | Teamwork | 0.000121537 | 1.214 | 19 |
| SC22 | Analytical Thinking | 0.000130938 | 1.308 | 16 |
| SC23 | Ability of Persuasion | 0.000134414 | 1.342 | 15 |
| SC24 | Self-Disciplined | 0.000189449 | 1.892 | 11 |
| SC25 | Solution-Oriented | 0.00018581 | 1.855 | 12 |
| SC31 | Productivity | 0.00032218 | 3.217 | 9 |
| SC32 | Moderate Effectiveness | 0.000125832 | 1.257 | 18 |
| SC33 | Minimal Competence | 0.000075363 | 0.753 | 21 |
| SC34 | Inefficiency | 0.000059991 | 0.599 | 22 |
| SC41 | Salary | 0.00101945 | 10.18 | 3 |
| SC42 | Promotion | 0.001018119 | 10.17 | 4 |
| SC43 | Work Safety | 0.001651132 | 16.49 | 1 |
| SC51 | Occupational Experience | 0.001416681 | 14.15 | 2 |
| SC52 | Educational Status | 0.000836713 | 8.355 | 5 |
| SC53 | Field Information | 0.000613301 | 6.124 | 7 |
| SC54 | Knowledge of a Foreign Language | 0.000542478 | 5.417 | 8 |
| SC55 | Informatics Proficiency | 0.000794676 | 7.936 | 6 |

**Table 6**
Weights assigned to experts during sensitivity analysis.

| | Expert1 | Expert2 | Expert3 |
|---|---|---|---|
| **Case 1** | 0.3 | 0.3 | 0.3 |
| **Case 2** | 0.4 | 0.3 | 0.3 |
| **Case 3** | 0.3 | 0.4 | 0.3 |
| **Case 4** | 0.3 | 0.3 | 0.4 |

**Table 7**
Sensitivity analysis for personnel.

| Alternatives | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| A1 | 4 | 4 | 4 | 4 |
| A2 | 3 | 3 | 3 | 3 |
| A3 | 21 | 21 | 22 | 21 |
| A4 | 1 | 1 | 1 | 1 |
| A5 | 14 | 14 | 13 | 14 |
| A6 | 13 | 13 | 14 | 13 |
| A7 | 19 | 19 | 19 | 19 |
| A8 | 15 | 15 | 15 | 15 |
| A9 | 2 | 2 | 2 | 2 |
| A10 | 11 | 10 | 11 | 11 |
| A11 | 7 | 7 | 7 | 6 |
| A12 | 6 | 6 | 6 | 7 |
| A13 | 16 | 16 | 17 | 17 |
| A14 | 8 | 8 | 8 | 8 |
| A15 | 12 | 12 | 12 | 12 |
| A16 | 17 | 17 | 16 | 16 |
| A17 | 9 | 9 | 9 | 9 |
| A18 | 20 | 20 | 20 | 20 |
| A19 | 10 | 11 | 10 | 10 |
| A20 | 18 | 18 | 18 | 18 |
| A21 | 5 | 5 | 5 | 5 |
| A22 | 22 | 22 | 21 | 22 |

particular solution. The abovementioned task is accomplished by closely monitoring the factors' parameters and ranking changes.

Table 6 displays the weights assigned by the experts during the sensitivity analysis. The study involved conducting the process four times, with each expert being assigned equal weight in each iteration. Subsequently, the weights assigned to each expert varied independently, with the highest weight assigned to each expert. The results of four additional scenarios and cases are presented in Table 7. The alternative ranking exhibits a high degree of consistency across all instances. The instances serve as evidence of the efficacy of the IT2 fuzzy DANP approach in facilitating a streamlined assessment procedure.

## 3. Discussion and limitations

It is difficult to find studies that investigate how the interval type 2 DANP technique can be used with trapezoidal fuzzy numbers in the social work field. As a result of the present research, the existing body of literature will be improved, and the research gap discovered will be filled. Within the context of business and management, the implementation of decision-making processes carries with it a large amount of weight and significance. Within the framework of the digital era, decision-making methods are used to aid in the progression of business operations to advance those activities. The capability of fuzzy MCDM techniques to find the best choice in the context of personnel selection is one of the many ways these methods contribute significantly to improving business procedures.

Type-2 fuzzy systems accomplish the primary goals of modeling uncertainty and minimizing its impact in fuzzy logic rule-based systems. Furthermore, researchers often prefer IT2 fuzzy systems over traditional T2 fuzzy systems because they are easier to compute and require less effort. Therefore, IT2 FSs were chosen for this study. Analysis of the relevant published information reveals that the area of population selection makes limited use of methods incorporating type 2 fuzzy numbers. The investigations focus on the research that employed T1 and T2 fuzzy numbers as well as MCDM methodologies to address the personnel selection challenges outlined in the published literature. The purpose of this study was to investigate the feasibility of utilizing IT2 FSs to manage such uncertainty in a more all-encompassing manner. Furthermore, no study has used the IT2 fuzzy DANP technique alone in the context of personnel selection. However, certain studies have implemented it as a hybrid approach. To make a normalized direct relation matrix using the DANP method for pairwise comparison matrices of subcriteria alternatives, a square matrix must be provided as an input. To complete the pairwise comparison matrix for alternatives and subcriteria, the DANP method necessitates the utilization of an identity matrix in addition to a square matrix. Ensuring an equivalent number of subcriteria and alternatives is of utmost importance; in everyday parlance, this means that problems are more likely to occur if the number of subcriteria and alternatives is not the same. Because both variables in this investigation were equivalent, there were no issues that arose throughout the process of using the approach.

The IT2 DANP approach, utilized in the process of business development, specifies both criteria and alternatives. Furthermore, the approach involves selecting the most suitable alternative. The use of this strategy allows for the determination of which criteria are significant for the growth of businesses in this era of digital technology. Most research on person selection aims to identify the option that yields the best outcome. In contrast, the findings of this research reveal both the best criteria and the best alternative for personnel selection in the context of business development.

By employing this methodology for people selection within the field of business growth, it becomes feasible to proficiently ascertain and pick the most advantageous criteria and alternatives. The identification of the most crucial criteria may be achieved through the utilization of this methodology. Upon examination of the literature, it becomes evident that research is scarce, including sensitivity analysis. The sensitivity analysis conducted in this work serves as a paradigm for forthcoming research endeavors. The sensitivity demonstrated in this investigation exhibits a considerable level of precision.

The process of personnel selection holds significant importance for organizations due to the potential advantages that can be gained from making appropriate personnel choices as well as the equally costly consequences that can result from making incorrect selections. As a result, addressing it presents a significant obstacle. The loss of benefits may result from erroneous personnel selection decisions, underscoring the criticality of exercising accuracy in this regard. Future substantial challenges may befall the organization because of employment decisions concerning personnel who may not be entirely suitable. The final step of the procedure involves conducting a sensitivity analysis to evaluate the consistency of the criterion weights. As an approach to evaluating the durability and resiliency of a particular solution, sensitivity analysis is frequently employed by researchers. Every instance of the alternate ranking consistently demonstrates a substantial degree of consistency. The events prove that the IT2 fuzzy DANP method is efficacious in streamlining the assessment procedure. The study also underlines the need to perform sensitivity analysis after adopting decision-making procedures for company growth. Selecting the wrong individual in areas such as staff selection, promotion selection, manager selection, and team leader selection may result in significant financial loss for the organization. As a result, sensitivity analysis was successfully used in the study.

The limitation of the model developed in this study is the requirement of a square matrix to construct a normalized direct relation matrix using the DANP technique for pairwise comparison matrices of subcriteria alternatives. The DANP technique is employed in the pairwise comparison matrix, including alternatives and subcriteria, because the approach necessitates the employment of an identity matrix and a square matrix. The number of subcriteria must match the number of alternatives. Instances in which the subcriteria and the alternative do not possess equal values impose constraints on the model.

Future research attempts that use fuzzy logic methodology have the potential to give a workable resolution to an existing constraint of the DANP approach, which currently demands a square matrix and may be a step in the right direction. In addition, it is possible to design software capable of effectively overcoming the constraints linked to this method. The utilization of complex software might significantly improve the resolution of challenges associated with the selection of human resources in business and management.

## 4. Conclusion

Staff selection is a strategic option that is critically important in various industries, including the technology field. The PS process ultimately determines the input quality of the human resources, and because of this, it involves a certain element of uncertainty concerning the performances and weights. Throughout this investigation, the PS problem has been examined as a fuzzy MCDM problem. During the decision-making procedure, decision-makers must deal with ambiguity. The assessment method is improved by applying fuzzy logic to each of the strategies to make it more accurate and adaptive for personnel overseeing decisions. The decision phase decided to use FSs in its portrayal of uncertainty in several different areas. This decision led to the use of FSs in the process of simplifying the complicated structure of the decision phase. In other words, it is possible that using one's inherent language inclinations might be of significant value when coping with challenging circumstances.

The aim of this study was to evaluate personnel selection systems using an IT2-based fuzzy technique. By analyzing the literature on similar research, this framework identified five distinct main criteria and twenty-two distinct criteria. In this problem, the objective is to pick the most appropriate solution for the personnel from the twenty-two alternatives. The problem was solved using the IT2 fuzzy DANP technique. Based on the findings of the IT2 fuzzy DANP approach, it is decided that "SC43" (work safety), "SC51" (occupational experience), "SC41" (salary), and "SC42" (promotion) are the most crucial factors. The ranking of the others is "SC52" (educational status), "SC55" (informatics proficiency), "SC53" (field information), "SC54" (knowledge of a foreign language), "SC31" (productivity), "SC15" (reliability), "SC24" (self-disciplined), "SC25" (solution-oriented), "SC13" (enterprising), "SC14" (creativity), "SC23" (ability of persuasion), "SC22" (analytical thinking), "SC11" (leading spirit), "SC32" (moderate effectiveness), "SC21" (teamworker), and "SC12" (positivism). On the other hand, it is determined that "SC33" (minimal competence) and "SC34" (inefficiency) are the least significant. According to this method's ranking outcomes, A4 is the best alternative. Other alternatives are ranked as A9, A2, A1, A21, A12, A11, A14, A17, A19, A10, A15, A6, A5, A8, A13, A16, A20, A7, A18, A3, and A22. Through the utilization of this approach for personnel selection in the realm of business development, it becomes possible to effectively identify and choose both the best criteria and alternatives. It is feasible to determine which criteria are the most essential by utilizing this approach. During the sensitivity analysis, the expert-assigned weights are visible. The study encompassed the replication of the experimental protocol on four separate cases, with careful consideration devoted to providing an equitable focus on each specialist at every iteration. Subsequently, the weights assigned to each expert were changed individually, with the highest weight assigned to each expert. In this study, the ramifications of four interrelated events and circumstances were examined. The alternate rating demonstrated a significant level of consistency across all occurrences. Upon examination of all four cases, it is evident that the outcomes of the alternative rankings exhibit a high degree of similarity across all four cases. This observation indicates that the value of consistency is rather high. The presented instances provide empirical support for the effectiveness of the IT2 fuzzy DANP technique in enhancing the efficiency of the assessment process.

There exist a limited number of techniques employing type 2 fuzzy logic within this domain. The present research endeavor can potentially enhance the existing body of knowledge in this domain. One of the most significant discoveries as a direct result of this body of work was that a square matrix is needed to create a normalized direct relation matrix, using the DANP approach for pairwise comparison matrices for alternatives that fall under subcriteria, which was one of the most important discoveries. This finding is one of the most important contributions to this body of study, which has created many different things. The FANP method was utilized to find a solution to this issue as a direct consequence of this situation. In addition, sensitivity analysis is employed to determine whether experts' priorities are compatible with one another. The literature indicates that studies conducting sensitivity analysis are not prevalent. A proficient sensitivity analysis was conducted in this study, and the results indicate that utilizing the IT2 fuzzy DEMATEL-ANP approach exhibits high sensitivity across various case scenarios when addressing the problem at hand. In various instances, the outcomes exhibit a high degree of proximity. In each instance, the utilization of alternative ordering yielded highly similar results.

The use of the trapezoidal IT2 fuzzy DEMATEL-ANP methodology for personnel selection is an area rarely explored in the current literature. To my knowledge, no available literature has used IT2 fuzzy DANP in isolation for personnel selection purposes. Therefore, the literature has used the integrated techniques of IT2 DANP. In this study, the IT2 fuzzy DANP methodology is used, which requires the use of square matrices for comparison matrices. Within the framework of this study, it is observed that the number of subcriteria is equal to the number of alternatives. As a result, no problems were encountered. In addition, it shows that the application of sensitivity analysis is insufficient in this area. The previous examples provide evidence of the effectiveness of the IT2 fuzzy DANP methodology in accelerating an efficient evaluation process. The sensitivity analysis results show a remarkable degree of consistency across all scenarios.

In terms of conducting more research, the issue may be examined utilizing various MCDM approaches, and the assessment procedures of various personnel selection problems would benefit from a wider variety of solution comparisons. Both aspects of the research could be improved with more application. Both considerations are essential to keep in mind. Furthermore, creating intelligent software capable of automatically calculating responses is possible. This software will be developed in the future. Additional multi-criteria approaches, such as PROMETHEE and integrated fuzzy methods employing IT2 fuzzy FSs, have been suggested for use in future research by the authors to justify the complexity of the staff selection problem. These techniques are recommended in future research because they help justify the difficulty of the staff selection problem. It is strongly suggested that these additional multicriteria procedures be utilized and assessed in parallel.

The consequences for future research are as follows: It is anticipated that future research in the field of personnel selection for company growth will incorporate the integrated utilization of the DANP strategy. Future research projects that use the combined fuzzy logic method in later investigations might be able to find a workable solution to the problem with the current DANP strategy, which needs a square matrix. There is an expectation that in the future, corporations may develop software to assist in the execution of decision-making procedures. Furthermore, the constraints connected with the built-in software may be efficiently resolved. The utilization of sophisticated software has significant promise for enhancing efficacy in regard to tackling human resource selection difficulties within business and management domains. By utilizing this software, individuals will possess the capacity to proficiently choose the most advantageous option for personnel selection. The present approach exhibits the capacity to be employed across diverse domains within the framework of forthcoming scholarly investigations. To address this issue, prospective research endeavors might employ diverse fuzzy logic methodologies derived from distinct theoretical frameworks. By employing this methodology for people selection within the context of corporate development, it becomes feasible to proficiently ascertain and pick the most advantageous criteria and alternatives. After conducting a comprehensive review of the existing scholarly literature, it is apparent that there is a notable dearth of studies in this field, particularly regarding sensitivity analysis. The sensitivity analysis conducted in this study will serve as an example for future research attempts. Furthermore, our primary objective for forthcoming research endeavors is to make a scholarly contribution by utilizing fuzzy MCDM methods in conjunction with the DANP.

## 5. Ethics declarations

Informed consent was not needed for this study because this study did not involve experiments on participants and patients.

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### Data availability statement

Data tables are included in the appendix.

### CRediT authorship contribution statement

**Kemal Gokhan Nalbant:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Linguistic evaluations of decision-makers for the main criteria

| | MC1 | | | MC2 | | | MC3 | | | MC4 | | | MC5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **MC1** | E | E | E | SS | E | FS | E | SS | E | FS | SS | E | E | SS | SS |
| **MC2** | 1/SS | E | 1/FS | E | E | E | E | SS | SS | SS | FS | FS | E | E | SS |
| **MC3** | E | 1/SS | E | E | 1/SS | 1/SS | E | E | E | SS | SS | SS | E | SS | E |
| **MC4** | 1/FS | 1/SS | E | 1/SS | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS | E | E | E | 1/SS | 1/SS | E |
| **MC5** | E | 1/SS | 1/SS | E | E | 1/SS | E | 1/SS | E | SS | SS | E | E | E | E |

## Appendix B. Linguistic evaluations of decision-makers for the subcriteria

| | SC11 | | | SC12 | | | SC13 | | | SC14 | | | SC15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **SC11** | E | E | E | E | E | SS | E | E | SS | FS | SS | E | E | E | SS |
| **SC12** | E | E | 1/SS | E | E | E | FS | SS | E | SS | SS | E | FS | SS | FS |
| **SC13** | E | E | 1/SS | 1/FS | 1/SS | E | E | E | E | 1/SS | E | 1/SS | E | SS | E |
| **SC14** | 1/FS | 1/SS | E | 1/SS | 1/SS | E | SS | E | SS | E | E | E | FS | SS | E |
| **SC15** | E | E | 1/SS | 1/FS | 1/SS | 1/FS | E | 1/SS | E | 1/FS | 1/SS | E | E | E | E |
| **SC21** | E | 1/SS | E | E | E | 1/SS | E | SS | E | 1/SS | 1/SS | E | E | E | E |
| **SC22** | E | 1/SS | 1/FS | 1/SS | 1/SS | 1/SS | SS | E | E | E | 1/SS | 1/SS | E | SS | SS |
| **SC23** | E | 1/SS | E | E | 1/SS | 1/SS | E | E | E | 1/SS | 1/SS | 1/SS | E | SS | SS |
| **SC24** | 1/SS | E | E | 1/SS | 1/SS | E | E | E | SS | E | 1/SS | 1/SS | E | E | SS |
| **SC25** | E | E | 1/SS | 1/SS | E | 1/FS | E | SS | E | 1/FS | E | 1/SS | SS | E | SS |
| **SC31** | E | E | 1/SS | 1/FS | E | 1/SS | E | 1/SS | E | E | E | E | SS | SS | E |
| **SC32** | SS | SS | SS | SS | SS | SS | SS | SS | FS | SS | FS | SS | FS | SS | SS |
| **SC33** | VS | VS | VS | FS | FS | VS | VS | VS | VS | VS | FS | VS | VS | VS | VS |
| **SC34** | AS | AS | AS | VS | AS | AS | AS | AS | AS | AS | VS | AS | AS | AS | AS |
| **SC41** | 1/FS | 1/FS | 1/FS | 1/VS | 1/VS | 1/FS | 1/SS | 1/FS | 1/SS | 1/VS | 1/FS | 1/VS | 1/SS | 1/SS | 1/SS |
| **SC42** | 1/FS | 1/VS | 1/FS | 1/FS | 1/VS | 1/FS | 1/FS | 1/FS | 1/SS | 1/VS | 1/FS | 1/VS | 1/SS | 1/SS | 1/SS |
| **SC43** | 1/VS | 1/VS | 1/VS | 1/VS | 1/VS | 1/VS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS |
| **SC51** | 1/AS | 1/VS | 1/AS | 1/AS | 1/AS | 1/AS | 1/AS | 1/VS | 1/AS | 1/AS | 1/AS | 1/AS | 1/VS | 1/VS | 1/AS |
| **SC52** | 1/SS | 1/SS | E | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS | E | E | E | 1/SS | 1/SS | 1/SS | E |
| **SC53** | 1/FS | 1/FS | 1/SS | 1/VS | 1/VS | 1/FS | 1/SS | E | 1/SS | E | 1/SS | E | 1/SS | E | 1/SS |
| **SC54** | 1/SS | 1/FS | 1/SS | 1/VS | 1/AS | 1/VS | 1/SS | 1/FS | E | 1/SS | 1/SS | 1/FS | SS | SS | FS |
| **SC55** | 1/VS | 1/VS | 1/FS | 1/AS | 1/AS | 1/VS | 1/VS | 1/FS | 1/SS | 1/VS | 1/VS | 1/FS | FS | E | SS |
| | **SC21** | | | **SC22** | | | **SC23** | | | **SC24** | | | **SC25** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | E | SS | E | E | SS | FS | E | SS | E | SS | E | E | E | E | SS |
| **SC12** | E | E | SS | SS | SS | SS | E | SS | SS | SS | SS | E | SS | E | FS |
| **SC13** | E | 1/SS | E | 1/SS | E | E | E | E | E | E | E | 1/SS | E | 1/SS | E |
| **SC14** | SS | SS | E | E | SS | SS | SS | SS | SS | E | SS | SS | FS | E | SS |
| **SC15** | E | E | E | E | 1/SS | 1/SS | E | 1/SS | 1/SS | E | E | 1/SS | 1/SS | E | 1/SS |
| **SC21** | E | E | E | E | E | E | 1/SS | 1/SS | E | SS | SS | E | SS | FS | SS |
| **SC22** | E | E | E | E | E | E | 1/SS | E | E | FS | SS | SS | E | SS | E |
| **SC23** | SS | SS | E | SS | E | E | E | E | E | SS | SS | E | E | SS | FS |
| **SC24** | 1/SS | 1/SS | E | 1/FS | 1/SS | 1/SS | 1/SS | 1/SS | E | E | E | E | 1/SS | 1/SS | E |
| **SC25** | 1/SS | 1/FS | 1/SS | E | 1/SS | E | E | 1/SS | 1/FS | SS | SS | E | E | E | E |
| **SC31** | E | 1/SS | 1/SS | 1/FS | 1/FS | 1/SS | E | 1/SS | 1/SS | E | E | E | SS | SS | SS |
| **SC32** | SS | SS | SS | FS | SS | SS | SS | SS | FS | SS | FS | FS | FS | FS | SS |
| **SC33** | VS | VS | VS | FS | VS | VS | VS | VS | VS | FS | FS | VS | VS | VS | FS |
| **SC34** | VS | VS | AS | AS | AS | AS | AS | AS | AS | AS | AS | AS | AS | AS | AS |
| **SC41** | 1/FS | 1/VS | 1/FS | 1/VS | 1/VS | 1/FS | 1/FS | 1/FS | 1/SS | 1/VS | 1/VS | 1/VS | 1/SS | 1/SS | 1/FS |
| **SC42** | 1/FS | 1/VS | 1/FS | 1/FS | 1/VS | 1/FS | 1/FS | 1/FS | 1/SS | 1/VS | 1/FS | 1/VS | 1/SS | 1/SS | 1/SS |
| **SC43** | 1/SS | 1/SS | 1/SS | 1/FS | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS | 1/SS | 1/SS | E | 1/SS | 1/SS | 1/SS |
| **SC51** | 1/AS | 1/AS | 1/AS | 1/AS | 1/VS | 1/FS | 1/VS | 1/VS | 1/AS | 1/VS | 1/FS | 1/VS | 1/VS | 1/VS | 1/AS |
| **SC52** | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS | E | 1/SS | 1/SS | 1/FS | 1/SS | E | E | 1/SS | 1/SS | E |
| **SC53** | 1/VS | 1/SS | 1/FS | 1/SS | E | E | 1/FS | 1/SS | 1/SS | E | E | E | 1/SS | 1/SS | 1/SS |
| **SC54** | 1/FS | 1/FS | 1/VS | 1/FS | 1/SS | 1/FS | 1/SS | 1/SS | 1/FS | E | 1/SS | E | 1/SS | E | E |

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| | SC11 | | | SC12 | | | SC13 | | | SC14 | | | SC15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **SC55** | 1/AS | 1/AS | 1/AS | 1/VS | 1/AS | 1/VS | 1/AS | 1/VS | 1/AS | 1/VS | 1/FS | 1/VS | 1/SS | 1/FS | 1/SS |
| | **SC31** | | | **SC32** | | | **SC33** | | | **SC34** | | | **SC41** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | E | E | SS | 1/SS | 1/SS | 1/SS | 1/VS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | SS | SS | SS |
| **SC12** | FS | E | SS | 1/SS | 1/SS | 1/SS | 1/FS | 1/FS | 1/VS | 1/VS | 1/AS | 1/AS | FS | FS | SS |
| **SC13** | E | SS | E | 1/SS | 1/SS | 1/FS | 1/VS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | SS | SS | SS |
| **SC14** | E | E | E | 1/SS | 1/FS | 1/SS | 1/VS | 1/FS | 1/VS | 1/AS | 1/VS | 1/AS | FS | SS | FS |
| **SC15** | 1/SS | 1/SS | E | 1/FS | 1/SS | 1/SS | 1/VS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | E | E | E |
| **SC21** | E | SS | SS | 1/SS | 1/SS | 1/SS | 1/VS | 1/VS | 1/VS | 1/VS | 1/VS | 1/AS | FS | VS | FS |
| **SC22** | FS | FS | SS | 1/FS | 1/SS | 1/SS | 1/FS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | VS | VS | FS |
| **SC23** | E | SS | SS | 1/SS | 1/SS | 1/FS | 1/VS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | FS | FS | SS |
| **SC24** | E | E | E | 1/SS | 1/FS | 1/FS | 1/FS | 1/FS | 1/VS | 1/AS | 1/AS | 1/AS | VS | VS | VS |
| **SC25** | 1/SS | 1/SS | 1/SS | 1/FS | 1/FS | 1/SS | 1/VS | 1/VS | 1/FS | 1/AS | 1/AS | 1/AS | SS | SS | FS |
| **SC31** | E | E | E | 1/SS | 1/FS | 1/SS | 1/FS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | SS | E | SS |
| **SC32** | SS | FS | SS | E | E | E | 1/FS | 1/VS | 1/SS | 1/AS | 1/VS | 1/AS | FS | FS | SS |
| **SC33** | FS | VS | VS | FS | VS | SS | E | E | E | 1/SS | 1/FS | 1/FS | VS | VS | AS |
| **SC34** | AS | AS | AS | AS | VS | AS | SS | FS | FS | E | E | E | AS | AS | AS |
| **SC41** | 1/SS | E | 1/SS | 1/FS | 1/FS | 1/SS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | 1/AS | E | E | E |
| **SC42** | 1/SS | 1/SS | E | 1/FS | 1/FS | 1/FS | 1/VS | 1/VS | 1/VS | 1/AS | 1/AS | 1/AS | E | E | E |
| **SC43** | 1/E | 1/SS | 1/SS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS |
| **SC51** | 1/SS | E | E | 1/SS | 1/FS | 1/FS | 1/VS | 1/VS | 1/FS | 1/AS | 1/AS | 1/AS | 1/FS | 1/SS | 1/FS |
| **SC52** | E | E | 1/SS | 1/SS | 1/FS | 1/SS | 1/VS | 1/VS | 1/FS | 1/AS | 1/AS | 1/AS | 1/SS | 1/SS | E |
| **SC53** | E | E | E | 1/SS | 1/FS | 1/FS | 1/VS | 1/VS | 1/FS | 1/AS | 1/AS | 1/AS | SS | E | SS |
| **SC54** | E | 1/SS | E | 1/SS | 1/FS | 1/SS | 1/VS | 1/AS | 1/VS | 1/AS | 1/AS | 1/AS | SS | E | E |
| **SC55** | 1/FS | 1/SS | 1/SS | 1/FS | 1/FS | 1/VS | 1/VS | 1/AS | 1/VS | 1/AS | 1/AS | 1/AS | 1/FS | 1/SS | 1/SS |
| | **SC42** | | | **SC43** | | | **SC51** | | | **SC52** | | | **SC53** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | SS | FS | SS | SS | SS | SS | AS | VS | AS | SS | SS | E | FS | FS | SS |
| **SC12** | SS | FS | SS | FS | FS | FS | AS | AS | AS | FS | FS | SS | VS | VS | FS |
| **SC13** | SS | SS | E | SS | SS | SS | AS | VS | AS | SS | SS | E | SS | E | SS |
| **SC14** | FS | SS | FS | SS | SS | SS | AS | AS | AS | E | E | SS | E | SS | E |
| **SC15** | SS | E | E | SS | SS | SS | VS | VS | AS | SS | SS | E | SS | E | SS |
| **SC21** | FS | VS | FS | SS | SS | SS | AS | AS | AS | FS | FS | SS | VS | SS | FS |
| **SC22** | FS | VS | FS | FS | FS | FS | AS | VS | FS | SS | SS | E | SS | E | E |
| **SC23** | FS | FS | SS | SS | SS | SS | VS | VS | AS | SS | SS | FS | FS | SS | SS |
| **SC24** | VS | FS | VS | SS | SS | E | VS | FS | VS | SS | E | E | E | E | E |
| **SC25** | SS | SS | SS | SS | SS | SS | VS | VS | AS | SS | SS | E | SS | SS | SS |
| **SC31** | SS | SS | E | E | SS | SS | SS | E | E | E | E | SS | E | E | E |
| **SC32** | FS | FS | FS | FS | FS | FS | SS | FS | FS | SS | FS | SS | SS | FS | FS |
| **SC33** | VS | VS | VS | FS | FS | FS | VS | VS | FS | VS | VS | FS | VS | VS | FS |
| **SC34** | AS | AS | AS | FS | FS | FS | AS | AS | AS | AS | AS | AS | AS | AS | AS |
| **SC41** | E | E | E | SS | SS | SS | FS | SS | FS | SS | SS | E | 1/SS | E | 1/SS |
| **SC42** | E | E | E | SS | SS | SS | FS | SS | SS | SS | SS | SS | E | 1/SS | 1/SS |
| **SC43** | 1/SS | 1/SS | 1/SS | E | E | E | E | E | SS | E | E | E | E | 1/SS | 1/SS |
| **SC51** | 1/FS | 1/SS | 1/SS | E | E | 1/SS | E | E | E | 1/FS | 1/FS | 1/SS | 1/SS | 1/SS | E |
| **SC52** | 1/SS | 1/SS | 1/SS | E | E | E | FS | FS | SS | E | E | E | E | 1/SS | E |
| **SC53** | E | SS | SS | E | SS | SS | SS | SS | E | E | SS | E | E | E | E |
| **SC54** | E | E | SS | SS | E | E | FS | SS | FS | VS | FS | SS | E | SS | E |
| **SC55** | 1/FS | 1/SS | 1/SS | SS | E | E | SS | SS | E | FS | FS | SS | FS | VS | FS |
| | **SC54** | | | **SC55** | | | | | | | | | | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | | | | | | | | | |
| **SC11** | SS | FS | SS | VS | VS | FS | | | | | | | | | |
| **SC12** | VS | AS | VS | AS | AS | VS | | | | | | | | | |
| **SC13** | SS | FS | E | VS | FS | SS | | | | | | | | | |
| **SC14** | SS | SS | FS | VS | VS | FS | | | | | | | | | |
| **SC15** | 1/SS | 1/SS | 1/FS | 1/FS | E | 1/SS | | | | | | | | | |
| **SC21** | FS | FS | VS | AS | AS | AS | | | | | | | | | |
| **SC22** | FS | SS | FS | VS | AS | VS | | | | | | | | | |
| **SC23** | SS | SS | FS | AS | VS | AS | | | | | | | | | |
| **SC24** | E | SS | E | VS | FS | VS | | | | | | | | | |
| **SC25** | SS | E | E | SS | FS | SS | | | | | | | | | |
| **SC31** | E | SS | E | FS | SS | SS | | | | | | | | | |
| **SC32** | SS | FS | SS | FS | FS | VS | | | | | | | | | |
| **SC33** | VS | AS | VS | VS | AS | VS | | | | | | | | | |
| **SC34** | AS | AS | AS | AS | AS | AS | | | | | | | | | |
| **SC41** | 1/SS | E | E | FS | SS | SS | | | | | | | | | |
| **SC42** | E | E | 1/SS | FS | SS | SS | | | | | | | | | |
| **SC43** | 1/SS | E | E | 1/SS | E | E | | | | | | | | | |

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| | SC11 | | | SC12 | | | SC13 | | | SC14 | | | SC15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **SC51** | 1/FS | 1/SS | 1/FS | 1/SS | 1/SS | E | | | | | | | | | |
| **SC52** | 1/VS | 1/FS | 1/SS | 1/FS | 1/FS | 1/SS | | | | | | | | | |
| **SC53** | E | 1/SS | E | 1/FS | 1/VS | 1/FS | | | | | | | | | |
| **SC54** | E | E | E | 1/VS | 1/VS | 1/SS | | | | | | | | | |
| **SC55** | VS | VS | SS | E | E | E | | | | | | | | | |

## Appendix C. Linguistic evaluations of decision-makers for the alternatives

| | A1 | | | A2 | | | A3 | | | A4 | | | A5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **SC11** | E | E | E | SS | SS | SS | E | E | SS | AS | FS | FS | E | E | SS |
| **SC12** | E | E | E | SS | SS | SS | E | E | E | SS | SS | FS | E | E | E |
| **SC13** | SS | SS | SS | FS | FS | FS | SS | SS | SS | AS | AS | AS | E | E | E |
| **SC14** | FS | FS | FS | SS | SS | SS | SS | E | E | SS | FS | SS | E | E | E |
| **SC15** | SS | SS | SS | SS | SS | SS | SS | SS | SS | VS | VS | VS | E | E | E |
| **SC21** | E | E | E | FS | FS | FS | E | SS | E | FS | FS | FS | SS | SS | SS |
| **SC22** | SS | SS | SS | SS | SS | SS | FS | FS | FS | FS | FS | FS | SS | SS | SS |
| **SC23** | E | E | E | SS | SS | SS | FS | SS | SS | AS | AS | AS | E | E | SS |
| **SC24** | SS | SS | SS | FS | FS | FS | SS | SS | SS | FS | FS | FS | E | E | E |
| **SC25** | SS | SS | SS | SS | SS | SS | SS | SS | SS | AS | AS | AS | SS | E | E |
| **SC31** | SS | SS | SS | E | E | E | SS | SS | SS | FS | FS | FS | SS | SS | SS |
| **SC32** | SS | E | E | E | E | E | E | E | E | SS | SS | SS | SS | SS | SS |
| **SC33** | SS | SS | SS | E | E | E | E | SS | SS | E | E | E | SS | SS | SS |
| **SC34** | E | E | E | E | E | E | E | SS | SS | E | E | SS | E | E | E |
| **SC41** | E | E | SS | SS | SS | SS | E | SS | SS | FS | FS | FS | E | SS | E |
| **SC42** | SS | SS | SS | SS | E | E | SS | SS | SS | SS | SS | SS | SS | E | SS |
| **SC43** | E | E | SS | E | E | E | E | SS | SS | SS | SS | SS | E | E | E |
| **SC51** | SS | SS | SS | SS | SS | SS | E | E | E | VS | VS | VS | SS | SS | SS |
| **SC52** | SS | E | E | SS | SS | SS | E | E | SS | FS | FS | FS | SS | SS | SS |
| **SC53** | SS | E | E | E | E | E | E | E | E | VS | VS | VS | SS | SS | SS |
| **SC54** | SS | SS | SS | E | E | SS | E | E | E | E | E | E | VS | E | SS |
| **SC55** | SS | SS | SS | E | E | SS | SS | SS | SS | FS | FS | SS | SS | E | E |
| | **A6** | | | **A7** | | | **A8** | | | **A9** | | | **A10** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | E | E | E | SS | SS | SS | FS | SS | FS | SS | SS | SS | FS | FS | FS |
| **SC12** | SS | SS | SS | SS | SS | SS | SS | SS | SS | E | E | E | SS | SS | SS |
| **SC13** | E | E | E | SS | SS | SS | E | SS | E | SS | SS | SS | FS | FS | FS |
| **SC14** | SS | SS | SS | SS | E | E | SS | SS | SS | SS | SS | SS | SS | SS | E |
| **SC15** | E | SS | SS | SS | SS | E | SS | SS | SS | SS | SS | SS | FS | FS | FS |
| **SC21** | SS | SS | SS | E | E | E | E | E | E | SS | SS | SS | FS | FS | FS |
| **SC22** | E | E | E | E | E | E | SS | SS | SS | FS | FS | FS | FS | FS | FS |
| **SC23** | FS | SS | FS | SS | SS | SS | E | E | SS | E | E | E | SS | SS | SS |
| **SC24** | E | E | E | E | SS | E | E | E | E | SS | SS | SS | FS | FS | FS |
| **SC25** | E | E | E | SS | SS | SS | E | E | SS | E | SS | SS | E | SS | E |
| **SC31** | SS | SS | SS | E | E | SS | SS | E | E | SS | SS | SS | E | E | E |
| **SC32** | FS | FS | FS | SS | SS | SS | SS | E | SS | FS | FS | FS | SS | SS | E |
| **SC33** | E | E | SS | SS | SS | SS | E | E | E | E | E | E | E | E | E |
| **SC34** | E | E | E | SS | SS | SS | E | E | E | SS | SS | SS | E | E | E |
| **SC41** | E | E | E | SS | SS | SS | E | E | SS | E | E | E | E | SS | E |
| **SC42** | E | E | E | E | E | E | E | SS | SS | SS | SS | SS | E | E | E |
| **SC43** | E | E | SS | SS | E | E | E | E | E | SS | E | SS | E | E | SS |
| **SC51** | SS | SS | SS | E | E | E | SS | SS | E | SS | SS | FS | VS | VS | VS |
| **SC52** | E | E | E | SS | SS | E | FS | FS | FS | E | E | SS | VS | VS | VS |
| **SC53** | SS | SS | SS | E | E | E | FS | FS | FS | E | SS | E | SS | SS | SS |
| **SC54** | E | E | E | E | E | SS | SS | E | SS | FS | VS | SS | SS | SS | VS |
| **SC55** | E | E | E | SS | SS | SS | FS | FS | SS | SS | SS | SS | AS | AS | AS |
| | **A11** | | | **A12** | | | **A13** | | | **A14** | | | **A15** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS |
| **SC12** | E | E | E | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS |
| **SC13** | E | E | E | SS | SS | SS | SS | SS | SS | E | E | E | SS | E | E |
| **SC14** | E | E | E | E | E | E | SS | E | E | E | E | E | SS | SS | SS |
| **SC15** | SS | SS | SS | SS | SS | SS | FS | FS | FS | E | E | E | E | E | E |
| **SC21** | E | E | E | SS | SS | SS | SS | SS | SS | E | SS | E | E | E | SS |

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| | A1 | | | A2 | | | A3 | | | A4 | | | A5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| **SC22** | FS | FS | FS | E | E | E | SS | SS | FS | FS | FS | FS | E | E | SS |
| **SC23** | SS | SS | SS | E | SS | E | FS | FS | FS | SS | E | E | SS | SS | SS |
| **SC24** | SS | SS | SS | E | E | E | SS | SS | FS | SS | SS | SS | SS | SS | SS |
| **SC25** | E | E | E | FS | FS | FS | SS | SS | SS | E | E | SS | SS | FS | SS |
| **SC31** | SS | E | E | FS | SS | SS | E | E | E | FS | FS | FS | SS | FS | SS |
| **SC32** | SS | SS | SS | SS | SS | SS | SS | SS | SS | E | E | E | E | SS | E |
| **SC33** | E | E | E | SS | E | SS | E | E | E | E | E | E | E | SS | SS |
| **SC34** | E | E | E | E | E | SS | SS | E | E | E | E | SS | E | E | SS |
| **SC41** | E | E | E | SS | SS | SS | E | E | E | SS | SS | SS | SS | SS | SS |
| **SC42** | E | E | E | E | SS | SS | SS | E | SS | E | SS | SS | E | SS | SS |
| **SC43** | SS | SS | SS | E | E | SS | SS | E | E | E | E | E | E | E | SS |
| **SC51** | SS | SS | FS | E | E | E | E | SS | E | SS | SS | SS | E | E | E |
| **SC52** | E | E | E | SS | SS | SS | SS | SS | FS | E | E | E | SS | SS | SS |
| **SC53** | FS | FS | FS | E | E | E | SS | SS | SS | E | E | E | SS | E | SS |
| **SC54** | E | E | E | SS | SS | SS | SS | SS | SS | E | E | SS | SS | SS | E |
| **SC55** | FS | VS | FS | E | E | E | SS | SS | SS | SS | SS | SS | E | SS | E |
| | **A16** | | | **A17** | | | **A18** | | | **A19** | | | **A20** | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **SC11** | FS | FS | FS | SS | SS | SS | E | E | SS | SS | SS | SS | SS | SS | SS |
| **SC12** | FS | FS | FS | SS | SS | SS | E | E | E | E | E | E | SS | SS | SS |
| **SC13** | E | E | E | E | E | E | E | E | E | SS | SS | SS | E | E | E |
| **SC14** | FS | FS | FS | SS | SS | SS | SS | SS | SS | SS | E | E | E | E | E |
| **SC15** | VS | VS | VS | E | E | E | E | SS | E | SS | SS | SS | SS | SS | SS |
| **SC21** | FS | FS | FS | E | E | E | E | E | SS | E | SS | E | E | E | E |
| **SC22** | SS | SS | SS | E | E | E | SS | SS | SS | FS | FS | FS | SS | SS | SS |
| **SC23** | FS | FS | FS | E | E | SS | E | SS | E | SS | SS | SS | SS | SS | SS |
| **SC24** | FS | FS | FS | SS | SS | SS | SS | SS | SS | FS | FS | FS | SS | SS | SS |
| **SC25** | SS | SS | SS | SS | E | E | SS | E | E | E | E | E | E | E | E |
| **SC31** | SS | SS | SS | E | E | SS | E | E | SS | SS | SS | SS | SS | SS | SS |
| **SC32** | FS | FS | FS | SS | SS | SS | E | E | E | SS | SS | E | E | E | SS |
| **SC33** | E | E | E | E | E | E | E | E | E | E | E | E | E | E | SS |
| **SC34** | E | E | E | E | E | E | E | E | E | E | E | E | E | E | E |
| **SC41** | E | E | E | SS | E | E | E | E | E | SS | SS | SS | E | E | E |
| **SC42** | SS | SS | SS | E | E | E | E | SS | E | E | E | SS | E | E | E |
| **SC43** | E | E | E | SS | E | E | E | E | SS | SS | SS | SS | E | E | SS |
| **SC51** | FS | FS | FS | E | E | E | E | E | E | E | E | E | E | SS | E |
| **SC52** | VS | VS | VS | E | E | E | E | E | E | SS | SS | SS | E | SS | SS |
| **SC53** | SS | SS | SS | E | E | E | E | E | E | E | SS | E | FS | FS | FS |
| **SC54** | E | E | E | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | SS | E |
| **SC55** | FS | FS | SS | E | E | SS | E | SS | E | E | E | E | SS | SS | SS |
| | **A21** | | | **A22** | | | | | | | | | | | |
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | | | | | | | | | |
| **SC11** | SS | SS | SS | FS | FS | FS | | | | | | | | | |
| **SC12** | SS | SS | SS | FS | FS | FS | | | | | | | | | |
| **SC13** | SS | SS | SS | SS | SS | SS | | | | | | | | | |
| **SC14** | FS | FS | FS | E | E | E | | | | | | | | | |
| **SC15** | SS | SS | FS | SS | SS | SS | | | | | | | | | |
| **SC21** | FS | FS | FS | SS | SS | SS | | | | | | | | | |
| **SC22** | E | SS | SS | SS | FS | SS | | | | | | | | | |
| **SC23** | E | E | E | FS | FS | FS | | | | | | | | | |
| **SC24** | SS | SS | SS | SS | SS | SS | | | | | | | | | |
| **SC25** | FS | FS | FS | FS | FS | FS | | | | | | | | | |
| **SC31** | FS | FS | FS | FS | FS | FS | | | | | | | | | |
| **SC32** | SS | SS | SS | SS | SS | SS | | | | | | | | | |
| **SC33** | SS | SS | SS | E | E | E | | | | | | | | | |
| **SC34** | E | E | E | E | E | E | | | | | | | | | |
| **SC41** | SS | E | E | SS | SS | SS | | | | | | | | | |
| **SC42** | E | SS | E | E | E | E | | | | | | | | | |
| **SC43** | E | E | SS | E | E | E | | | | | | | | | |
| **SC51** | SS | E | E | FS | FS | FS | | | | | | | | | |
| **SC52** | FS | FS | FS | FS | FS | FS | | | | | | | | | |
| **SC53** | E | E | E | SS | SS | SS | | | | | | | | | |
| **SC54** | E | SS | SS | FS | SS | SS | | | | | | | | | |
| **SC55** | E | E | E | SS | SS | SS | | | | | | | | | |

## Appendix D. Normalized direct-relation matrix for the main criteria

| | MC1 | MC2 | MC3 |
|---|---|---|---|
| **MC1** | (0.05,0.05,0.05,0.05; 1,1)<br>(0.05,0.05,0.05,0.05; 1,1) | (0.08,0.11,0.16,0.18; 1,1)<br>(0.08,0.11,0.15,0.17; 0.8,0.8) | (0.05,0.07,0.09,0.09; 1,1)<br>(0.06,0.07,0.08,0.09; 0.8,0.8) |
| **MC2** | (0.02,0.02,0.03,0.04; 1,1)<br>(0.02,0.02,0.03,0.03; 0.8,0.8) | (0.05,0.05,0.05,0.05; 1,1)<br>(0.05,0.05,0.05,0.05; 1,1) | (0.05,0.09,0.14,0.16; 1,1)<br>(0.06,0.09,0.13,0.15; 0.8,0.8) |
| **MC3** | (0.03,0.03,0.04,0.05; 1,1)<br>(0.03,0.03,0.04,0.05; 0.8,0.8) | (0.02,0.02,0.03,0.05; 1,1)<br>(0.02,0.02,0.03,0.05; 0.8,0.8) | (0.05,0.05,0.05,0.05; 1,1)<br>(0.05,0.05,0.05,0.05; 1,1) |
| **MC4** | (0.02,0.02,0.03,0.04; 1,1)<br>(0.02,0.02,0.03,0.03; 0.8,0.8) | (0.01,0.01,0.02,0.03; 1,1)<br>(0.01,0.01,0.02,0.02; 0.8,0.8) | (0.01,0.01,0.03,0.05; 1,1)<br>(0.01,0.01,0.02,0.05; 0.8,0.8) |
| **MC5** | (0.02,0.02,0.03,0.05; 1,1)<br>(0.02,0.02,0.03,0.05; 0.8,0.8) | (0.03,0.03,0.04,0.05; 1,1)<br>(0.03,0.03,0.04,0.05; 0.8,0.8) | (0.03,0.03,0.04,0.05; 1,1)<br>(0.03,0.03,0.04,0.05; 0.8,0.8) |
| | **MC4** | **MC5** | |
| **MC1** | (0.08,0.11,0.16,0.18; 1,1)<br>(0.08,0.11,0.15,0.17; 0.86,0.86) | (0.05,0.09,0.14,0.16; 1,1)<br>(0.06,0.09,0.13,0.15; 0.86,0.86) | |
| **MC2** | (0.11,0.17,0.28,0.34; 1,1)<br>(0.13,0.18,0.27,0.33; 0.8,0.8) | (0.05,0.07,0.09,0.09; 1,1)<br>(0.06,0.07,0.08,0.09; 0.93,0.93) | |
| **MC3** | (0.05,0.11,0.22,0.27; 1,1)<br>(0.07,0.12,0.21,0.26; 0.8,0.8) | (0.05,0.07,0.09,0.09; 1,1)<br>(0.06,0.07,0.08,0.09; 0.93,0.93) | |
| **MC4** | (0.05,0.05,0.05,0.05; 1,1)<br>(0.05,0.05,0.05,0.05; 1,1) | (0.02,0.02,0.03,0.05; 1,1)<br>(0.02,0.02,0.03,0.05; 0.86,0.86) | |
| **MC5** | (0.05,0.09,0.14,0.16; 1,1)<br>(0.06,0.09,0.13,0.15; 0.86,0.86) | (0.05,0.05,0.05,0.05; 1,1)<br>(0.05,0.05,0.05,0.05; 1,1) | |

## Appendix E. Total relationship matrix for the main criteria

| | MC1 | MC2 | MC3 |
|---|---|---|---|
| **MC1** | (0.06,0.07,0.09,0.11; 1,1)<br>(0.07,0.07,0.08,0.1; 1,1) | (0.09,0.13,0.2,0.24; 1,1)<br>(0.1,0.14,0.19,0.23; 0.8,0.8) | (0.07,0.1,0.15,0.19; 1,1)<br>(0.08,0.1,0.14,0.17; 0.8,0.8) |
| **MC2** | (0.02,0.03,0.06,0.09; 1,1)<br>(0.03,0.03,0.05,0.08; 0.8,0.8) | (0.06,0.07,0.09,0.11; 1,1)<br>(0.07,0.07,0.08,0.1; 1,1) | (0.07,0.11,0.18,0.23; 1,1)<br>(0.07,0.11,0.17,0.22; 0.8,0.8) |
| **MC3** | (0.04,0.04,0.06,0.09; 1,1)<br>(0.04,0.05,0.06,0.08; 0.8,0.8) | (0.03,0.03,0.06,0.1; 1,1)<br>(0.03,0.04,0.06,0.09; 0.8,0.8) | (0.06,0.07,0.09,0.12; 1,1)<br>(0.06,0.07,0.08,0.11; 1,1) |
| **MC4** | (0.02,0.02,0.04,0.06; 1,1)<br>(0.02,0.02,0.03,0.05; 0.8,0.8) | (0.01,0.02,0.03,0.05; 1,1)<br>(0.01,0.02,0.03,0.04; 0.8,0.8) | (0.01,0.02,0.04,0.08; 1,1)<br>(0.02,0.02,0.04,0.07; 0.8,0.8) |
| **MC5** | (0.02,0.03,0.05,0.08; 1,1)<br>(0.02,0.03,0.05,0.07; 0.8,0.8) | (0.04,0.04,0.06,0.09; 1,1)<br>(0.04,0.05,0.06,0.08; 0.8,0.8) | (0.04,0.05,0.07,0.1; 1,1)<br>(0.04,0.05,0.07,0.09; 0.8,0.8) |
| | **MC4** | **MC5** | |
| **MC1** | (0.11,0.17,0.3,0.39; 1,1)<br>(0.12,0.18,0.29,0.37; 0.86,0.86) | (0.07,0.12,0.2,0.25; 1,1)<br>(0.08,0.13,0.19,0.24; 0.86,0.86) | |
| **MC2** | (0.14,0.22,0.4,0.51; 1,1)<br>(0.15,0.24,0.38,0.48; 0.8,0.8) | (0.07,0.09,0.14,0.18; 1,1)<br>(0.07,0.1,0.13,0.17; 0.93,0.93) | |
| **MC3** | (0.07,0.14,0.3,0.4; 1,1)<br>(0.09,0.16,0.28,0.37; 0.8,0.8) | (0.07,0.09,0.12,0.16; 1,1)<br>(0.07,0.09,0.12,0.15; 0.93,0.93) | |
| **MC4** | (0.06,0.07,0.09,0.12; 1,1)<br>(0.06,0.07,0.09,0.11; 1,1) | (0.02,0.03,0.05,0.09; 1,1)<br>(0.02,0.03,0.05,0.08; 0.86,0.86) | |
| **MC5** | (0.07,0.11,0.2,0.26; 1,1)<br>(0.08,0.12,0.19,0.25; 0.86,0.86) | (0.06,0.07,0.08,0.11; 1,1)<br>(0.07,0.07,0.08,0.1; 1,1) | |

## Appendix F. Defuzzified the total-relation matrix for the main criteria

.

| | MC1 | MC2 | MC3 | MC4 | MC5 |
|---|---|---|---|---|---|
| **MC1** | 0.1094 | 0.2137 | 0.1545 | 0.3142 | 0.2082 |
| **MC2** | 0.0687 | 0.1208 | 0.1974 | 0.4417 | 0.1713 |
| **MC3** | 0.1099 | 0.1014 | 0.1601 | 0.4205 | 0.2081 |
| **MC4** | 0.1418 | 0.1138 | 0.1612 | 0.3813 | 0.2019 |
| **MC5** | 0.1098 | 0.1421 | 0.1507 | 0.3945 | 0.2029 |

## Appendix G. The unweighted supermatrix for main criteria

| | MC1 | MC2 | MC3 | MC4 | MC5 |
|---|---|---|---|---|---|
| **MC1** | 0.1094 | 0.0687 | 0.1099 | 0.1418 | 0.1098 |
| **MC2** | 0.2137 | 0.1208 | 0.1014 | 0.1138 | 0.1421 |
| **MC3** | 0.1545 | 0.1974 | 0.1601 | 0.1612 | 0.1507 |
| **MC4** | 0.3142 | 0.4417 | 0.4205 | 0.3813 | 0.3945 |
| **MC5** | 0.2082 | 0.1713 | 0.2081 | 0.2019 | 0.2029 |

## Appendix H. The weighted supermatrix for subcriteria

| | SC11 | SC12 | SC13 | SC14 | SC15 | SC21 | SC22 | SC23 | SC24 | SC25 | SC31 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SC11** | 0.002 | 0.001 | 0.002 | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 |
| **SC12** | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 |
| **SC13** | 0.003 | 0.003 | 0.003 | 0.004 | 0.003 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.003 |
| **SC14** | 0.005 | 0.003 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.004 |
| **SC15** | 0.003 | 0.006 | 0.004 | 0.005 | 0.005 | 0.002 | 0.003 | 0.003 | 0.002 | 0.004 | 0.008 |
| **SC21** | 0.006 | 0.004 | 0.004 | 0.008 | 0.008 | 0.002 | 0.002 | 0.004 | 0.002 | 0.001 | 0.002 |
| **SC22** | 0.009 | 0.008 | 0.004 | 0.008 | 0.005 | 0.002 | 0.002 | 0.003 | 0.001 | 0.002 | 0.001 |
| **SC23** | 0.006 | 0.006 | 0.006 | 0.011 | 0.005 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| **SC24** | 0.006 | 0.006 | 0.005 | 0.008 | 0.006 | 0.004 | 0.007 | 0.004 | 0.003 | 0.006 | 0.004 |
| **SC25** | 0.006 | 0.007 | 0.005 | 0.009 | 0.005 | 0.007 | 0.003 | 0.005 | 0.002 | 0.003 | 0.010 |
| **SC31** | 0.004 | 0.005 | 0.006 | 0.004 | 0.004 | 0.007 | 0.014 | 0.007 | 0.005 | 0.003 | 0.006 |
| **SC32** | 0.001 | 0.001 | 0.002 | 0.001 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| **SC33** | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| **SC34** | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| **SC41** | 0.019 | 0.019 | 0.024 | 0.025 | 0.014 | 0.039 | 0.047 | 0.034 | 0.067 | 0.040 | 0.030 |
| **SC42** | 0.021 | 0.016 | 0.017 | 0.024 | 0.018 | 0.039 | 0.042 | 0.034 | 0.060 | 0.034 | 0.030 |
| **SC43** | 0.023 | 0.023 | 0.025 | 0.022 | 0.036 | 0.023 | 0.037 | 0.026 | 0.032 | 0.037 | 0.036 |
| **SC51** | 0.031 | 0.025 | 0.042 | 0.032 | 0.055 | 0.024 | 0.021 | 0.024 | 0.025 | 0.032 | 0.014 |
| **SC52** | 0.010 | 0.013 | 0.012 | 0.008 | 0.016 | 0.012 | 0.008 | 0.012 | 0.007 | 0.010 | 0.012 |
| **SC53** | 0.016 | 0.018 | 0.012 | 0.007 | 0.016 | 0.013 | 0.005 | 0.012 | 0.006 | 0.013 | 0.009 |
| **SC54** | 0.014 | 0.020 | 0.014 | 0.014 | 0.004 | 0.015 | 0.013 | 0.011 | 0.007 | 0.007 | 0.011 |
| **SC55** | 0.024 | 0.022 | 0.025 | 0.024 | 0.006 | 0.022 | 0.022 | 0.024 | 0.024 | 0.016 | 0.025 |
| | **SC32** | **SC33** | **SC34** | **SC41** | **SC42** | **SC43** | **SC51** | **SC52** | **SC53** | **SC54** | **SC55** |
| **SC11** | 0.004 | 0.005 | 0.005 | 0.003 | 0.003 | 0.005 | 0.002 | 0.004 | 0.002 | 0.002 | 0.001 |
| **SC12** | 0.004 | 0.004 | 0.005 | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 |
| **SC13** | 0.005 | 0.005 | 0.005 | 0.003 | 0.004 | 0.005 | 0.002 | 0.004 | 0.003 | 0.002 | 0.001 |
| **SC14** | 0.005 | 0.005 | 0.005 | 0.002 | 0.002 | 0.005 | 0.002 | 0.005 | 0.004 | 0.002 | 0.001 |
| **SC15** | 0.005 | 0.006 | 0.005 | 0.007 | 0.005 | 0.006 | 0.003 | 0.004 | 0.004 | 0.014 | 0.010 |
| **SC21** | 0.004 | 0.005 | 0.004 | 0.001 | 0.001 | 0.004 | 0.003 | 0.003 | 0.002 | 0.001 | 0.001 |
| **SC22** | 0.004 | 0.004 | 0.005 | 0.001 | 0.001 | 0.002 | 0.003 | 0.005 | 0.005 | 0.002 | 0.001 |
| **SC23** | 0.004 | 0.005 | 0.005 | 0.002 | 0.002 | 0.004 | 0.003 | 0.003 | 0.003 | 0.002 | 0.001 |
| **SC24** | 0.005 | 0.004 | 0.005 | 0.001 | 0.001 | 0.005 | 0.004 | 0.006 | 0.008 | 0.004 | 0.002 |
| **SC25** | 0.005 | 0.005 | 0.005 | 0.002 | 0.003 | 0.004 | 0.003 | 0.005 | 0.004 | 0.004 | 0.002 |
| **SC31** | 0.007 | 0.007 | 0.008 | 0.005 | 0.005 | 0.007 | 0.014 | 0.007 | 0.008 | 0.005 | 0.003 |
| **SC32** | 0.002 | 0.005 | 0.006 | 0.002 | 0.002 | 0.003 | 0.005 | 0.003 | 0.002 | 0.002 | 0.001 |
| **SC33** | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 | 0.003 | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 |
| **SC34** | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| **SC41** | 0.025 | 0.026 | 0.023 | 0.020 | 0.020 | 0.017 | 0.017 | 0.017 | 0.041 | 0.022 | 0.008 |
| **SC42** | 0.028 | 0.024 | 0.023 | 0.020 | 0.019 | 0.017 | 0.020 | 0.014 | 0.040 | 0.022 | 0.008 |
| **SC43** | 0.029 | 0.017 | 0.014 | 0.051 | 0.048 | 0.042 | 0.063 | 0.039 | 0.045 | 0.037 | 0.030 |
| **SC51** | 0.015 | 0.014 | 0.014 | 0.038 | 0.033 | 0.023 | 0.028 | 0.049 | 0.023 | 0.034 | 0.018 |
| **SC52** | 0.011 | 0.011 | 0.011 | 0.019 | 0.027 | 0.017 | 0.009 | 0.013 | 0.015 | 0.034 | 0.031 |
| **SC53** | 0.012 | 0.011 | 0.011 | 0.007 | 0.007 | 0.010 | 0.015 | 0.010 | 0.011 | 0.011 | 0.040 |
| **SC54** | 0.011 | 0.012 | 0.011 | 0.008 | 0.008 | 0.012 | 0.009 | 0.005 | 0.009 | 0.009 | 0.037 |
| **SC55** | 0.017 | 0.014 | 0.013 | 0.031 | 0.031 | 0.013 | 0.016 | 0.006 | 0.005 | 0.004 | 0.009 |

## Appendix I. The limit supermatrix for subcriteria

| | SC11 | SC12 | SC13 | SC14 | SC15 | SC21 | SC22 | SC23 | SC24 | SC25 | SC31 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SC11** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC12** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC13** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |

(*continued on next page*)

(*continued*)

| | SC11 | SC12 | SC13 | SC14 | SC15 | SC21 | SC22 | SC23 | SC24 | SC25 | SC31 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SC14** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC15** | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| **SC21** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC22** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC23** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC24** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| **SC25** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| **SC31** | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0004 | 0.0003 | 0.0004 | 0.0003 | 0.0003 |
| **SC32** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC33** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC34** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC41** | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0011 | 0.0010 | 0.0011 | 0.0010 | 0.0010 |
| **SC42** | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0011 | 0.0010 | 0.0011 | 0.0010 | 0.0010 |
| **SC43** | 0.0017 | 0.0016 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0018 | 0.0016 | 0.0019 | 0.0017 | 0.0016 |
| **SC51** | 0.0014 | 0.0014 | 0.0014 | 0.0015 | 0.0014 | 0.0015 | 0.0016 | 0.0014 | 0.0017 | 0.0015 | 0.0014 |
| **SC52** | 0.0008 | 0.0008 | 0.0008 | 0.0009 | 0.0008 | 0.0009 | 0.0009 | 0.0008 | 0.0010 | 0.0009 | 0.0008 |
| **SC53** | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0007 | 0.0007 | 0.0006 | 0.0008 | 0.0007 | 0.0006 |
| **SC54** | 0.0005 | 0.0005 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0007 | 0.0006 | 0.0006 |
| **SC55** | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0009 | 0.0008 | 0.0009 | 0.0008 | 0.0008 |
| | **SC32** | **SC33** | **SC34** | **SC41** | **SC42** | **SC43** | **SC51** | **SC52** | **SC53** | **SC54** | **SC55** |
| **SC11** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC12** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC13** | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0001 | 0.0002 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC14** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC15** | 0.0003 | 0.0002 | 0.0002 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0002 |
| **SC21** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC22** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC23** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 |
| **SC24** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| **SC25** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| **SC31** | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0004 | 0.0003 | 0.0003 |
| **SC32** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC33** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC34** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **SC41** | 0.0010 | 0.0009 | 0.0009 | 0.0011 | 0.0011 | 0.0010 | 0.0010 | 0.0010 | 0.0011 | 0.0010 | 0.0010 |
| **SC42** | 0.0010 | 0.0009 | 0.0009 | 0.0011 | 0.0011 | 0.0010 | 0.0010 | 0.0010 | 0.0011 | 0.0010 | 0.0010 |
| **SC43** | 0.0016 | 0.0015 | 0.0015 | 0.0017 | 0.0017 | 0.0016 | 0.0016 | 0.0016 | 0.0018 | 0.0016 | 0.0016 |
| **SC51** | 0.0014 | 0.0013 | 0.0012 | 0.0015 | 0.0015 | 0.0013 | 0.0014 | 0.0013 | 0.0016 | 0.0014 | 0.0014 |
| **SC52** | 0.0008 | 0.0008 | 0.0007 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 | 0.0009 | 0.0008 | 0.0008 |
| **SC53** | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0007 | 0.0006 | 0.0006 |
| **SC54** | 0.0005 | 0.0005 | 0.0005 | 0.0006 | 0.0006 | 0.0005 | 0.0006 | 0.0005 | 0.0006 | 0.0005 | 0.0005 |
| **SC55** | 0.0008 | 0.0007 | 0.0007 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0009 | 0.0008 | 0.0008 |

## Appendix J. The limit supermatrix for alternatives

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SC11** | 1.18E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC12** | 7E-13 | 7E-13 | 6E-13 | 8E-13 | 7E-13 | 7E-13 | 7E-13 | 7E-13 | 8E-13 | 7E-13 | 7E-13 |
| **SC13** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC14** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC15** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC21** | 8E-13 | 8E-13 | 7E-13 | 8E-13 | 8E-13 | 8E-13 | 7E-13 | 7E-13 | 8E-13 | 8E-13 | 8E-13 |
| **SC22** | 1E-12 | 1E-12 | 9E-13 | 1E-12 | 9E-13 | 9E-13 | 9E-13 | 9E-13 | 1E-12 | 9E-13 | 1E-12 |
| **SC23** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC24** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC25** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC31** | 3E-12 | 3E-12 | 2E-12 | 3E-12 | 3E-12 | 3E-12 | 2E-12 | 3E-12 | 3E-12 | 3E-12 | 3E-12 |
| **SC32** | 1E-12 | 1E-12 | 9E-13 | 1E-12 | 1E-12 | 1E-12 | 9E-13 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC33** | 7E-13 | 7E-13 | 6E-13 | 7E-13 | 6E-13 | 6E-13 | 6E-13 | 6E-13 | 7E-13 | 7E-13 | 7E-13 |
| **SC34** | 5E-13 | 5E-13 | 4E-13 | 5E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 5E-13 | 4E-13 | 4E-13 |
| **SC41** | 8E-12 | 9E-12 | 7E-12 | 9E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 9E-12 | 8E-12 | 8E-12 |
| **SC42** | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 |
| **SC43** | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 |
| **SC51** | 8E-12 | 8E-12 | 7E-12 | 9E-12 | 8E-12 | 8E-12 | 7E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 |
| **SC52** | 7E-12 | 7E-12 | 6E-12 | 8E-12 | 7E-12 | 7E-12 | 6E-12 | 7E-12 | 7E-12 | 7E-12 | 7E-12 |
| **SC53** | 4E-12 | 5E-12 | 4E-12 | 5E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 5E-12 | 4E-12 | 4E-12 |

(*continued on next page*)

(*continued*)

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SC54** | 5E-12 | 5E-12 | 4E-12 | 5E-12 | 5E-12 | 5E-12 | 4E-12 | 5E-12 | 5E-12 | 5E-12 | 5E-12 |
| **SC55** | 8.78E-12 | 9E-12 | 8E-12 | 9E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 9E-12 | 8E-12 | 9E-12 |
| | **A12** | **A13** | **A14** | **A15** | **A16** | **A17** | **A18** | **A19** | **A20** | **A21** | **A22** |
| **SC11** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC12** | 7E-13 | 7E-13 | 7E-13 | 7E-13 | 7E-13 | 7E-13 | 6E-13 | 7E-13 | 7E-13 | 7E-13 | 6E-13 |
| **SC13** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC14** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC15** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC21** | 8E-13 | 7E-13 | 8E-13 | 8E-13 | 7E-13 | 8E-13 | 7E-13 | 8E-13 | 7E-13 | 8E-13 | 7E-13 |
| **SC22** | 1E-12 | 9E-13 | 1E-12 | 9E-13 | 9E-13 | 1E-12 | 9E-13 | 9E-13 | 9E-13 | 1E-12 | 9E-13 |
| **SC23** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 |
| **SC24** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC25** | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 | 2E-12 |
| **SC31** | 3E-12 | 3E-12 | 3E-12 | 3E-12 | 3E-12 | 3E-12 | 2E-12 | 3E-12 | 2E-12 | 3E-12 | 2E-12 |
| **SC32** | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 1E-12 | 9E-13 | 1E-12 | 9E-13 | 1E-12 | 9E-13 |
| **SC33** | 7E-13 | 6E-13 | 7E-13 | 7E-13 | 6E-13 | 7E-13 | 6E-13 | 7E-13 | 6E-13 | 7E-13 | 6E-13 |
| **SC34** | 5E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 4E-13 | 5E-13 | 4E-13 |
| **SC41** | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 8E-12 | 7E-12 |
| **SC42** | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 |
| **SC43** | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 | 1E-11 |
| **SC51** | 8E-12 | 7E-12 | 8E-12 | 8E-12 | 7E-12 | 8E-12 | 7E-12 | 8E-12 | 7E-12 | 8E-12 | 7E-12 |
| **SC52** | 7E-12 | 7E-12 | 7E-12 | 7E-12 | 7E-12 | 7E-12 | 6E-12 | 7E-12 | 6E-12 | 7E-12 | 6E-12 |
| **SC53** | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 | 4E-12 |
| **SC54** | 5E-12 | 5E-12 | 5E-12 | 5E-12 | 5E-12 | 5E-12 | 4E-12 | 5E-12 | 4E-12 | 5E-12 | 4E-12 |
| **SC55** | 9E-12 | 8E-12 | 9E-12 | 8E-12 | 8E-12 | 9E-12 | 8E-12 | 8E-12 | 8E-12 | 9E-12 | 8E-12 |

## References


[1] S.F. Zhang, S.Y. Liu, A GRA-based intuitionistic fuzzy multi-criteria group decision-making method for personnel selection, Expert Syst. Appl. 38 (9) (2011) 11401–11405, https://doi.org/10.1016/j.eswa.2011.03.012.

[2] T. Dereli, A. Durmusoglu, S.U. Seckiner, N. Avlanmaz, A fuzzy approach for the personnel selection process, Turkish Journal of Fuzzy Systems 1 (2) (2010) 126–140.

[3] Z. Gungor, G. Serhadlioglu, S.E. Kesen, A fuzzy AHP approach to personnel selection problem, Appl. Soft Comput. 9 (2) (2009) 641–646, https://doi.org/10.1016/j.asoc.2008.09.003.

[4] M. Dagdeviren, A hybrid multi-criteria decision-making model for personnel selection in manufacturing systems, J. Intell. Manuf. 21 (2010) 451–460, https://doi.org/10.1007/s10845-008-0200-7.

[5] M.R. Fathi, H.Z. Matin, M.K. Zarchi, S. Azizollahi, The application of fuzzy TOPSIS approach to personnel selection for Padir Company, Iran, J. Manag. Res. 3 (2) (2011) 1–14, https://doi.org/10.5296/jmr.v3i2.663.

[6] M. Kabak, S. Burmaoglu, Y. Kazancoglu, A fuzzy hybrid MCDM approach for professional selection, Expert Syst. Appl. 39 (3) (2012) 3516–3525, https://doi.org/10.1016/j.eswa.2011.09.042.

[7] M. Kabak, A fuzzy DEMATEL-ANP based multi criteria decision making approach for personnel selection, J. Mult.-Valued Log. Soft Comput. 20 (2013).

[8] E. Kose, M. Kabak, H. Aplak, Grey theory based MCDM procedure for sniper selection problem, Grey Syst. Theor. Appl. (2013), https://doi.org/10.1108/20439371311293688.

[9] L. Abdullah, N. Zulkifli, Integration of fuzzy AHP and interval type-2 fuzzy DEMATEL: an application to human resource management, Expert Syst. Appl. 42 (9) (2015) 4397–4409, https://doi.org/10.1016/j.eswa.2015.01.021.

[10] R.M. Alguliyev, R.M. Aliguliyev, R.S. Mahmudova, Multi-criteria personnel selection by the modified fuzzy VIKOR method, Sci. World J. (2015), https://doi.org/10.1155/2015/612767.

[11] K.L. Chang, The use of a hybrid MCDM model for public relations personnel selection, Informatica 26 (3) (2015) 389–406, https://doi.org/10.15388/Informatica.2015.54.

[12] N.S. Tomar, S. Dev, R. Chaudhary, J. Kumar, Application of analytic hierarchy process (AHP) for prioritizing the personnel in India, International Journal of Multidisciplinary Research and Development 2 (11) (2015) 245–249.

[13] M. Aghaee, R. Aghaee, Selection of logistics personnel by using and hybrid Fuzzy DEMATEL and Fuzzy ANP, Int. Res. J. Med. Sci. 4 (1) (2016) 14–22.

[14] M. Bilgehan Erdem, A fuzzy analytical hierarchy process application in personnel selection in it companies: a case study in a spin-off company, Acta Phys. Pol., A 130 (1) (2016) 331–334, https://doi.org/10.12693/APhysPolA.130.331.

[15] M. Gul, E. Celik, A.T. Gumus, A.F. Guneri, Emergency department performance evaluation by an integrated simulation and interval type-2 fuzzy MCDM-based scenario analysis, Eur. J. Ind. Eng. 10 (2) (2016) 196–223, https://doi.org/10.1504/EJIE.2016.075846.

[16] N. Kundakci, Personnel selection with grey relational analysis, Management Science Letters 6 (5) (2016) 351–360, https://doi.org/10.5267/j.msl.2016.3.002.

[17] K. Salehi, An integrated approach of fuzzy AHP and fuzzy VIKOR for personnel selection problem, Global Journal of Management Studies and Researches 3 (3) (2016) 89–95.

[18] R.A. Ali, M. Nikolić, A. Zahra, Personnel selection using group fuzzy AHP and SAW methods, Journal of Engineering Management and Competitiveness (JEMC) 7 (1) (2017) 3–10.

[19] Y. Ozdemir, K.G. Nalbant, H. Basligil, Evaluation of personnel selection criteria using consistent fuzzy preference relations, Int. J. Manag. Sci. 4 (6) (2017) 76–81.

[20] S. Urosevic, D. Karabasevic, D. Stanujkic, M. Maksimovic, An approach to personnel selection in the tourism industry based on the SWARA and the WASPAS methods, Econ. Comput. Econ. Cybern. Stud. Res. 51 (1) (2017) 75–88.

[21] Y. Celikbilek, Using an integrated grey AHP-MOORA approach for personnel selection: an application on manager selection in the health industry, Alphanumeric Journal 6 (1) (2018) 69–82, https://doi.org/10.17093/alphanumeric.378904.

[22] B. Efe, M. Kurt, A systematic approach for an application of personnel selection in assembly line balancing problem, Int. Trans. Oper. Res. 25 (3) (2018) 1001–1025, https://doi.org/10.1111/itor.12439.

[23] A.C. Ilce, Trainee evaluations and recruitment based on fuzzy AHP: an application in furniture sector, Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi 19 (2) (2018) 129–137, https://doi.org/10.17474/artvinofd.424696.
[24] M. Jasemi, E. Ahmadi, A new fuzzy ELECTRE based multiple criteria method for personnel selection, Sci. Iran. 25 (2) (2018) 943–953.
[25] D. Karabasevic, E.K. Zavadskas, D. Stanujkic, G. Popovic, M. Brzakovic, An approach to personnel selection in the IT industry based on the EDAS method, Transform. Bus. Econ. 17 (2018) 54–65.
[26] Y. Kazancoglu, Y.D. Ozkan-Ozen, Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL, J. Enterprise Inf. Manag. 31 (6) (2018) 891–907, https://doi.org/10.1108/JEIM-01-2017-0015.
[27] K.G. Nalbant, Y. Ozdemir, Personnel selection using fuzzy VIKOR methodology, Int. J. Manag. Sci. 5 (2) (2018) 10–17.
[28] A.E. Demirci, H.S. Kilic, Personnel selection based on integrated multi-criteria decision-making techniques, International Journal of Advances in Engineering and Pure Sciences 31 (2) (2019) 163–178, https://doi.org/10.7240/jeps.505970.
[29] N.A.Q. Zulkifly, Z. Kasim, J. Bidin, Selection of personal medical and health insurance company by using Fuzzy TOPSIS, Jurnal Intelek 14 (1) (2019) 36–46.
[30] U. Cebeci, Selecting lean six sigma manager by using type-2 fuzzy AHP with a real case application in a logistics firm, Proceedings on Engineering 2 (3) (2020) 223–236, https://doi.org/10.24874/PES02.03.002.
[31] H.S. Kilic, A.E. Demirci, D. Delen, An integrated decision analysis methodology based on IF-DEMATEL and IF-ELECTRE for personnel selection, Decis. Support Syst. 137 (2020), 113360, https://doi.org/10.1016/j.dss.2020.113360.
[32] D. Priyadharshini, T.S. Poornappriya, R. Gopinath, A fuzzy MCDM approach for measuring the business impact of employee selection, Int. J. Manag. 11 (7) (2020) 1769–1775, https://doi.org/10.34218/IJM.11.7.2020.159.
[33] A. Ulutas, G. Popovic, D. Stanujkic, D. Karabasevic, E.K. Zavadskas, Z. Turskis, A new hybrid MCDM model for personnel selection based on a novel grey PIPRECIA and grey OCRA methods, Mathematics 8 (10) (2020) 1698, https://doi.org/10.3390/math8101698.
[34] R.M. Zulqarnain, X.L. Xin, M. Saeed, N. Ahmad, F. Dayan, B. Ahmad, Recruitment of medical staff in health department by using TOPSIS method, Int. J. Pharmaceut. Sci. Rev. Res. 62 (1) (2020) 1–7.
[35] E. Ozgormus, A.A. Senocak, H.G. Goren, An integrated fuzzy QFD-MCDM framework for personnel selection problem, Scientia Iranica. Transaction E, Industrial Engineering 28 (5) (2021) 2972–2986.
[36] M. Popović, An MCDM approach for personnel selection using the CoCoSo method, Journal of process management and new technologies 9 (3–4) (2021) 78–88, https://doi.org/10.5937/jpmnt9-34876.
[37] T. Danisan, E. Ozcan, T. Eren, Personnel selection with multi-criteria decision making methods in the ready-to-wear sector, Teh. Vjesn. 29 (4) (2022) 1339–1347, https://doi.org/10.17559/TV-20210816220137.
[38] S. Dumnić, K. Mostarac, M. Ninović, B. Jovanović, S. Buhmiler, Application of the Choquet integral: a case study on a personnel selection problem, Sustainability 14 (9) (2022) 5120, https://doi.org/10.3390/su14095120.
[39] D. Gottwald, S. Jovčić, P. Lejskova, Multi-criteria decision-making approach in personnel selection problem–A case study at the University of Pardubice, Econ. Comput. Econ. Cybern. Stud. Res. 56 (2) (2022) 149–164.
[40] K.G. Nalbant, Using an integrated consistent fuzzy preference relations and interval type-2 fuzzy TOPSIS methodology for personnel selection and promotion, WSEAS Trans. Comput. 20 (2022) 158–164, https://doi.org/10.37394/23205.2022.21.20.
[41] S. Edinsel, Sales manager selection with multi-criteria decision making methods, Giresun Üniversitesi İktisadi ve İdari Bilimler Dergisi 9 (1) (2023) 210–228, https://doi.org/10.46849/guiibd.1267171.
[42] T.L. Chuang, K.L. Chang, Flight attendants selection by an integrated mcdm model, J. Mult.-Valued Log. Soft Comput. 41 (1/2) (2023) 67–83.
[43] G. Jin, Selection of virtual team members for smart port development projects through the application of the direct and indirect uncertain TOPSIS method, Expert Syst. Appl. 217 (2023), 119555, https://doi.org/10.1016/j.eswa.2023.119555.
[44] K. Kara, S. Edinsel, G.C. Yalcin, Hybrid approach to supply chain project manager selection problem, Avrupa Bilim ve Teknoloji Dergisi (46) (2023) 98–108, https://doi.org/10.31590/ejosat.1206786.
[45] S. Khalil, U.M. Modibbo, A.A. Raina, I. Ali, A personnel selection problem in healthcare system using fuzzy-TOPSIS approach, Journal of Nonlinear Modeling & Analysis 5 (2) (2023) 311–324.
[46] S. Yenilmezel, I. Ertugrul, Blue collar personnel selection for a manufacturing company with fuzzy COPRAS method based on fuzzy PIPRECIA, Journal of Internet Applications and Management 14 (1) (2023) 1–15, https://doi.org/10.34231/iuyd.1252843.
[47] H. Dincer, S. Yuksel, L. Martínez, Interval type 2-based hybrid fuzzy evaluation of financial services in E7 economies with DEMATEL-ANP and MOORA methods, Appl. Soft Comput. 79 (2019) 186–202, https://doi.org/10.1016/j.asoc.2019.03.018.
[48] K. Aliyeva, Multifactor personnel selection by the fuzzy TOPSIS method, in: 13th International Conference on Theory and Application of Fuzzy Systems and Soft Computing—ICAFS-2018 13, Springer International Publishing, 2019, pp. 478–483.
[49] C. Kahraman, B. Oztaysi, I.U. Sarı, E. Turanoglu, Fuzzy analytic hierarchy process with interval type-2 fuzzy sets, Knowl. Base Syst. 59 (2014) 48–57, https://doi.org/10.1016/j.knosys.2014.02.001.