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APPLICATION OF SWARA AND DNMA METHODS IN RECRUITING SOFTWARE

Abstract

Personnel selection is a complex, multi-criteria decision-making problem that involves both qualitative and quantitative factors. Despite various techniques being proposed across different industries, a robust method that adequately addresses uncertainty remains needed. This study introduces an integrated approach, combining the Step-wise Weight Assessment Ratio Analysis (SWARA) and the Double Normalization-Based Multiple Aggregation (DNMA) methods. The proposed framework first employs the SWARA method to determine the importance of criteria, followed by the application of the DNMA method to rank candidates based on a sequential evaluation process. The goal of the study is to select the most suitable candidate from five applicants for a vacant position in a company within the participatory software sector. The criteria weights were primarily determined by the decision-maker using the SWARA method, with computer and software skills, work experience, teamwork adaptability, foreign language proficiency, and problem-solving skills identified as the five key criteria. The DNMA method was then used to assess the candidates' performance, and the results indicated that one of the candidates was the best fit for the position. When compared with similar studies in the literature, it was found that while many multi-criteria decision-making methods have been employed, the combination of SWARA and DNMA methods is novel. This study demonstrates the effectiveness of these methods in personnel selection, offering a new approach to the literature on decision-making processes.

Keywords: SWARA, Multi-criteria decision making, personnel selection, DNMA.

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БАҒДАРЛАМАЛЫҚ ҚАМТАМАСЫЗ ЕТУ САЛАСЫНДАҒЫ ПЕРСОНАЛДЫ ІРІКТЕУДЕ SWARA ЖӘНЕ DNMA ӘДІСТЕРІН ҚОЛДАНУ

Аңдатпа

Персоналды іріктеу- сапалық және сандық факторларды қамтитын, көп критерийлі шешім қабылдау мәселесі болып табылады. Әртүрлі салаларда ұсынылған көптеген әдістерге қарамастан, белгісіздік жағдайларын толық ескеретін сенімді әдіс әлі де қажет. Бұл зерттеу критерийлердің маңыздылығын анықтау үшін кезеңмен SWARA және DNMA әдістерін біріктірген кешенді тәсілі ұсынылады. Алдымен SWARA әдісі арқылы критерийлердің маңыздылығы анықталып, кейін DNMA әдісі қолданылып, персоналдар реттік бағалау негізінде сұрыпталады. Зерттеудің мақсаты — қатысушы бағдарламалық қамтамасыз ету саласында жұмыс істейтін компаниядағы бос орынға бес үміткердің ішінен ең қолайлысын таңдау. Критерийлердің салмағы шешім қабылдаушы тарапынан SWARA әдісімен анықталды, ал негізгі бес критерий ретінде компьютерлік және бағдарламалық дағдылар, жұмыс өтілі, топтық жұмысқа бейімділік, шет тілін білу және мәселелерді шешу қабілеті қабылданды. Үміткерлердің нәтижелерін бағалау үшін DNMA әдісі қолданылды және бір үміткердің бос орынға ең лайықты екендігі анықталды. Әдебиеттердегі ұқсас зерттеулермен салыстырғанда, көптеген көп критерийлі шешім қабылдау әдістері қолданылғанымен, SWARA мен DNMA әдістерінің үйлесімі жаңалық болып табылатыны анықталды. Бұл зерттеу осы әдістердің персоналды іріктеуде тиімді қолданылуын көрсетіп, шешім қабылдау процестері жөніндегі әдебиетке жаңа тәсіл енгізеді.

Түйін сөздер: SWARA, көп критерийлі шешім қабылдау, персоналды іріктеу, бағдарламалық қамтамасыз ету секторы, DNMA.

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ПРИМЕНЕНИЕ МЕТОДОВ SWARA И DNMA В ПОДБОРЕ ПЕРСОНАЛА В ОБЛАСТИ ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ

Аннотация

Подбор персонала - это сложная многокритериальная проблема принятия решений, которая включает в себя как качественные, так и количественные факторы. Несмотря на то, что в различных отраслях предлагаются различные методы, по-прежнему требуется надежный метод, который адекватно учитывает неопределенность. В этом исследовании представлен комплексный подход, сочетающий поэтапный анализ коэффициента оценки веса (SWARA) и методы множественной агрегации на основе двойной нормализации (DNMA). В предлагаемой системе сначала используется метод SWARA для определения важности критериев, а затем применяется метод DNMA для ранжирования кандидатов на основе последовательного процесса оценки. Цель исследования - выбрать наиболее подходящего кандидата из пяти претендентов на вакантную должность в компании, занимающейся разработкой программного обеспечения с широким участием. Весовые коэффициенты критериев были в первую очередь определены лицом, принимающим решения, с использованием метода SWARA, при этом в качестве пяти ключевых критериев были определены навыки работы с компьютером и программным обеспечением, опыт работы, способность к адаптации в команде, знание иностранного языка и навыки решения проблем. Затем для оценки эффективности работы кандидатов был использован метод DNMA, и результаты показали, что один из кандидатов лучше всего подходит на эту должность. При сравнении с аналогичными исследованиями, опубликованными в литературе, было обнаружено, что, хотя было использовано много многокритериальных методов принятия решений, комбинация методов SWARA и DNMA является новой. Данное исследование демонстрирует эффективность этих методов при отборе персонала, предлагая новый подход к литературе о процессах принятия решений.

Ключевые слова: SWARA, многокритериальное принятие решений, отбор персонала, DNMA

Main provisions

The research focuses on the application of the SWARA (Step-wise Weight Assessment Ratio Analysis) and DNMA (Decision-making Matrix Approach) methods to enhance recruitment software systems. The main idea is that these methods can significantly improve decision-making processes by evaluating and ranking candidates based on various criteria. The study concludes that the integration of SWARA and DNMA provides a more structured, efficient, and objective way of selecting the most suitable candidates, ultimately improving recruitment outcomes. The research demonstrates that these methods offer a reliable framework for dealing with the complexity and subjectivity often present in traditional hiring processes, ensuring better alignment with organizational needs.

Introduction

Personnel selection is a methodical decision-making process for selecting individuals from a pool of candidates whose qualifications best match the requirements of open positions. Because individual characteristics are complex and each candidate usually has their own advantages and disadvantages[1]. Choosing the right candidate for internal audit leaders is a challenge. This is mainly due to the lack of clearly defined selection criteria and methods for measuring the qualifications of the candidate. Too often, hiring managers use their intuition to identify the best candidates, which can lead to failure in selecting the right candidate[2]. Making the wrong choice can lead to impaired team collaboration, extra financial costs, lower productivity, and a damaged corporate reputation. On the other hand, scientific personnel selection has the ability to predict the future performance of potential employees (Salgado, 2017). For this purpose, MCDM methods are required to increase the accuracy of decision making. For this study, it was considered to recruit a software specialist to a company working in the field of information technologies, which continues to develop actively[3].

For this purpose, candidates are selected for the open position according to the criteria requested by the company. In this study, SWARA, a weighting method for employee selection, and DNMA, one of the multi-criteria decision-making methods, were chosen. The DNMA method proposes the most suitable alternatives to the company among the candidates according to the criteria requested by the company. To see how accurate the DNMA method is for selection, a comparison was made with widely studied multi-criteria decision making methods such as MARCOS, TOPSIS, CoCoSo, MABAC, TODIM, MACBETH, EDAS.

Human resource management (HRM) is crucial in increasing the efficiency and competitiveness of an organization [4]. For this reason, companies focus on their employees as the main source of success, given their knowledge, skills and motivation. However, hiring qualified candidates is crucial for success and various channels such as the internet, employment agencies, newspapers should be used to reach potential candidates [5]. Choosing the wrong candidate can adversely affect the image and success of the organization, making personnel selection a critical component of HRM.

Personnel selection involves identifying the candidate with the necessary knowledge and qualifications to fulfill the job requirements. Considering that the success of an organization depends on the characteristics of its employees, it is very important to choose the right person for sustainability. However, choosing the best personnel among many alternatives is a multi-criteria decision-making problem that requires simultaneous evaluation of several criteria [6,7].

Filling out the application forms in personnel selection is no longer sufficient when using traditional methods such as interviews and tests. Multi-criteria decision making (MCDM) methods allow more accurate evaluation of alternatives by considering various criteria [8]. In this study, it is aimed to select the best software personnel for a Turkish software and consultancy firm by using SWARA and DNMA methods.

The study includes literature review, hierarchical structure and application of methods, then results and a general evaluation [9]. A practical approach is presented in the selection of personnel, in which more than one criterion is taken into account, by calculating the criteria weights by SWARA method and by ranking the alternatives with DNMA method [10]**.**

Research methodology

In the literature, it is possible to come across many studies from different fields in which MCDM methods are used (Esoy, 2021). In the following paragraphs, some personal selection studies using MCDM methods found in the literature are presented.

Ersoy (2021), in his study, tried to select the most suitable software personnel for a company working in the software industry by using entropy-based EDAS and CODAS methods. In the study, 5 alternative job candidates were evaluated by looking at 5 criteria. The weights of the criteria were determined using the entropy basis. In the EDAS and CODAS methods, criterion weights taken by the Entropy method were used [11].

Ulutaş (2020) proposes a Multi-Criteria Decision Making (MCDM) approach, which facilitates decision-making by choosing the most appropriate equipment to carry out logistics activities. He used the correlation coefficient and standard deviation (CCSD method) to determine the objective weights of the criteria. In addition, the semi-objective weights of the criteria considered were determined by the characteristic report analysis method based on the indifference threshold (ITARA) [12]. By combining the two methods in this way, he tried to specify the weights of the criteria more reliably. The final classification of alternatives used the compromise solutions (MARCOS) method to quantify and rank the alternatives [13]. A case study is conducted to demonstrate the feasibility of the proposed approach regarding the selection of the best manual stacker for a small warehouse.

In their study, Merdivenci (2020) used the entropy-based EDAS method to solve the personnel selection problem in logistics. Using this method, five logistics company candidates were evaluated according to four criteria. The criteria were first weighted with the Entropy method, and then the candidates were ranked with the EDAS method.

Samanlıoğlu (2018) examined the recruitment process of the software department of a Turkish dairy company in his research and the problem of ranking employee candidates was solved as a multi-criteria group decision-making problem [14]. Fuzzy AHP and TOPSIS method, an integrated fuzzy MCDM method was applied to determine the uncertainty and uncertainty of process decisions.

Samanlıoğlu (2018) selected the appropriate software candidate in his studies by integrating the Intuitive Fuzzy Additive Ratio Estimation Method (IF-ARAS) with bias measurement, advanced score function and IF additive operators [15]. In the developed methodology, criterion and decision expert (DE) weights were calculated based on the proposed IF deviation measurement method and heuristic fuzzy preference estimation method. Then the decision experts' decision is to combine the proposed method to avoid data loss.

It is often modeled as a multi-criteria decision making (MCDM) problem, due to the various qualitative and quantitative criteria that must be considered in personnel selection. Some studies have attempted to establish personnel selection models in a net-based decision-making environment (Jiting, 2022) [16]. The above and other personnel selection efforts are shown in Table 1 below.

Table 1. Application of MCDM methods for personnel selection

Author (Year)	*Selection method*	*Weight determination method*	*Scenario*
Samanlıoğlu, F., Taşkaya, Y. E., Gülen, Ü. Ç., & Akbaş, E. (2018).	*blurred TOPSIS*	*blurred AHP*	*Selection of IT specialist in the company*
Karabasevic, D., Zavadskas, E. K., Stanujkic, D., Popovic, G., & Brzakovic, M. (2018)	*EDAS*	*SWARA*	*Selection of IT systems support specialists*
Nabeeh, N. A., Smarandache, F., Abdel-Basset, M., El-Ghareeb, H. A., & Aboelfetouh, A. (2019)	*TOPSİS*	*AHP*	
Huchang Liao, Xingli Wu. (2020)	*MABAC PROMETHEE*	*BWM*	*Personnel selection in an IT company*
Mishra, A. R., Sisodia, G., Pardasani, K. R., & Sharma, K. (2019)	*Intuitive blurred ARAS*	*Deviation criterion approach*	*Outsourcing personnel selection in IT company*
Ulutaş, A., Karabasevic, D., Popovic, G., Stanujkic, D., Nguyen, P. T., & Karaköy, Ç. (2020)	*OCRA-G*	*PİPRECİA-G*	*Manager selection in a textile factory*
Kilic, H. S., Demirci, A. E., & Delen, D. (2017)	*IF-ELECTRE under intuitive blurry environment*	*IF-DEMATEL under intuitive blurry environment*	*Industrial engineer selection in an air filter manufacturing company*
Lim, Y. R., Ariffin, A. S., Ali, M., & Chang, K. L. (2021)	*TOPSİS*	*AHP*	*Live Streamer Selection*
Uslu, Y. D., Yılmaz, E., & Yiğit, P. (2021)	*MULTIMOORA*	*AHP*	*Selection of qualified managers in the health institution*
Jiting Li, Renjie He, Tao Wang (2022)	*PLEAS ve IFN'ler*	*LGBWM*	*Personnel selection in a Chinese state-owned company*
Yel, İ., Sarucan, A., & Baysal, M. E. (2022)	*Neutrosophic Z-Number clusters (NZN) and Fuzzy EDAS*	*AHP*	*Determination of software specialist for the analyst position in the participation bank*

In this study, the method that will be used is the DNMA method, which is the ranking of alternatives and deciding on the best one. DNMA (Double Normalization based Multiple Aggregation) method is one of the new MCDM methods developed by Huchang Liao and Xingli Wu in 2019. The difference of the method from other MCDM methods is that the normalization process, which will be done only once, is performed twice (linear and vector normalization processes) in the DNMA method [17]. Thus, the shortcoming and disadvantage of a normalization operation to the DNMA method is intended to be compensated by the second normalization operation. Besides this feature, the DNMA method achieves sequencing of alternatives with three types of subcombination functions (full compensation-CCM, incomplete-UCM, incomplete-ICM compensators). Table 2 provides a structured comparison of various ranking methods based on utility value, focusing on several core characteristics that define how each method operates in multi-criteria decision-making (MCDM).

Table 2. Characteristics of ranking methods based on utility value

CCC method	*Normalization*	*Addition function*	*Criterion type*	*Criterion form*	*Theory*
SMART	*Linear*	*Arithmetic*	*Quantitative and Qualitative*	*Max, min*	*Addition*
TOPSIS	*Vektor*	*Arithmetic*	*Quantitative and Qualitative*	*Max, min*	*distance to the ideal*
VIKOR	*Linear*	*Arithmetic, max.*	*Quantitative and Qualitative*	*Max, min*	*distance to the ideal*
MULTIMOORA	*Vektor*	*Arithmetic, maximum, geometric*	*Quantitative and Qualitative*	*Max, min*	*Addition*
Target-based TOPSIS	*Linear*	*Arithmetic*	*Quantitative*	*Max, min, aim*	*distance to the ideal*
Target-based VIKOR	*Linear*	*Arithmetic, max.*	*Quantitative*	*Max, min, aim*	*distance to the ideal*
Target-based MULTIMOORA	*Linear*	*Arithmetic, maximum, geometric*	*Quantitative and Qualitative*	*Max, min, aim*	*Addition*
DNMA	*Vektor, Linear*	*Arithmetic, maximum, geometric*	*Quantitative and Qualitative*	*Maks, min, aim*	*distance to the ideal*

From Table 2 we can see that the common flaw of the current methods is that they remove the effects of different criteria dimensions based on only one normalization approach; this can skew the results as every normalization method may lose the original information to some extent. Also, calculating utility values by different aggregation operators is useful, but there is still a difficulty in comprehensively integrating the secondary utility values with the orderings of the alternatives to obtain the final ranking of the alternatives (Huchang, 2020). Multi-criteria decision making (MCDM) methods are often used to evaluate and prioritize candidates based on these criteria. These methods provide a systematic and objective approach to decision making by considering multiple criteria simultaneously and weighing their relative importance [18]. One study that uses MCDM methods to evaluate software engineering job candidates is "The Decision Making Framework for Candidate Selection in Software Engineering" by A. Mohamed and A. M. K. Sadiq. In this study, the authors identified six criteria for candidate evaluation: technical skills, teamwork and collaboration, communication skills, personality and behavior, work experience and education, and certification. They then used the Analytical Hierarchy Process (AHP) and the Order of Preference Technique by Similarity to Ideal Solution (TOPSIS) methods (Mohamed, 2019) to rank the candidates and evaluate the effectiveness of the framework. Another study using MCDM methods to evaluate software developers is "Multi-criteria decision making approach for selecting software developers" by E. Atashpaz-Gargari et al. In this study, the authors identified nine criteria for candidate evaluation: technical skills, social skills, educational background, work experience, ability to adapt and learn, teamwork, communication skills, salary expectations, and personality. They then used the AHP and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Atashpaz-Gargari, 2018) methods to rank the candidates and evaluate the effectiveness of the approach [19].

In general, technical skills and work experience are often considered the most important criteria for personnel selection in the software industry. However, the importance of other criteria such as teamwork, communication skills and adaptability should not be overlooked. By providing a comprehensive and objective approach to candidate evaluation and selection, MCDM methods can enable organizations to make informed decisions and recruit the candidates best suited to their needs.

Compared to other multi-criteria decision making methods such as EDAS, TOPSIS, PROMETHEE, PLEAS and ELECTRE, DNMA has several advantages that make it a superior choice for applications.

First, DNMA is a more robust method that is less affected by outliers and extreme values in the data. This is because the normalization step in DNMA uses the mean and standard deviation, which are more robust to extreme values compared to other normalization methods used in other methods.

Second, DNMA allows for more flexible weighting of different criteria that can be adjusted to the specific needs of the analysis. This is because DNMA uses a double normalization process that standardizes data from different sources and allows for easier comparison and weighting [20].

Third, DNMA is a more transparent method as it provides clear explanations of how the final score or metric is calculated. This can be important for decision-making processes that require a high degree of transparency and accountability.

Finally, DNMA is more computationally complex, making it more suitable for processing larger datasets or real-time decision-making applications. This is because the double normalization process in DNMA reduces the dimensionality of the data, which simplifies the aggregation process and reduces the computational burden.

Overall, the superiority of the DNMA method over other MCDM methods lies in its robustness, flexibility, transparency and computational efficiency, making it a viable choice for many different applications.

Results of the study

In this study, SWARA, DNMA method was used. SWARA method will be used for criterion weighting and DNMA method will be used to determine alternatives. SWARA, DNMA methods will be explained below.

SWARA method

The criterion weighting method, which has recently been used frequently among the criterion weighting methods, is the SWARA method (ÇAKIR, 2017). In 2010, Kersuliene, Zavadskas, and Turskis developed the SWARA method (Step Wise Weight Evaluation Rate Analysis), a MCDM method [21]. Due to its ease of use and the convenience of working with experts, it has been successfully applied to solve many problems until today. It is a method based on the SWARA method for assigning criterion weights. The SWARA method consists of the following steps after defining and creating the criteria for the decision-making process.

Step 1 Criteria should be given priority. In this step, experts rank the defined criteria in order of importance, for example most important first, least important last, and the criteria in between have a certain importance.

Step 2 s_j - Determines the comparative importance of the mean. Starting from the second-order criterion, it is necessary to determine their meanings as follows. If the s_j criterion is important, s_{j+1} is determined from 1 criterion.

Step 3 The coefficient k_j is calculated:

$$kj=\begin{cases} 1 & j=1 \\ S_j & j<1 \end{cases} \quad (1)$$

Step 4 Determine the recalculated weight q_j as follows:

$$qj=\begin{cases} 1 & j=1 \\ \frac{q_{j-1}}{k_j} & j>1 \end{cases} \quad (2)$$

Step 5 The calculation of the criterion weights (wj) is given by the following equation (equation 3).

$$wj=\frac{q_j}{\sum_{k=1}^{n} q_k} \quad (3)$$

DNMA method

Step 1 Normalization. The values in the decision matrix will be normalized using the linear and vector normalization of the DNMA method first. Its normalization with linear normalization is determined by Equation (4), and its normalization with vector normalization is determined by Equation (5).

$$\tilde{x}_{ij}^{1N} =1- \frac{|x^{ij}-r_j|}{max\{\max_i x^{ij},r_j\}-min\{\min_i x^{ij},r_j\}} \quad (4)$$

$$\tilde{x}_{ij}^{2N} =1- \frac{|x^{ij}-r_j|}{\sqrt{\sum_{i=1}^{m}(x^{ij})^2+(r_j)^2}} \quad (5)$$

Step 2 Determination of criterion weights.

The criteria weights are adjusted to provide a balance between the conflicting criteria. As it can be understood from this expression, criterion weights should be determined before using the method. Depending on the data structure, criterion weights can be calculated using objective or subjective weighting methods. This second step of the method consists of three stages.

(1) In Equation 6, the number of m criteria in the decision problem and the normalized deviation of c_j criteria are determined by σ_j.

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} \left(\frac{x^{ij}}{\max_i x^{ij}} - \frac{1}{m}\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}}\right)\right)^2}{m}} \quad (6)$$

(2) The criteria use the standard deviation values found in relation(2) to normalize.

$$\omega_j^{\sigma} = \frac{\sigma_j}{\sum_j^n \sigma_j} \quad (7)$$

(3) Then the weights are arranged using Equation (8).

$$\widetilde{\omega_J} = \frac{\sqrt{\omega_j^{\sigma}.\omega_j}}{\sum_{j=1}^{n}\sqrt{\omega_j^{\sigma}.\omega_j}} \quad (8)$$

Step 3 Calculation of utility functions. It is calculated with the following utility functions for each alternative: The CCM (complete compensatory model) function is calculated by Equation(9).

$$u_1(a_i) = \sum_{j=1}^{n} \tilde{\omega}_j . \tilde{x}_{ij}^{1N} / \max_i \tilde{x}_{ij}^{1N} \tag{9}$$

The UCM (un-compensatory model – incomplete compensatory model) function is calculated by Equation(10).

$$u_2(a_i) = \max_j \tilde{\omega}_j \left(1 - \tilde{x}_{ij}^{1N} / \max_i \tilde{x}_{ij}^{1N}\right) \tag{10}$$

The ICM (incomplete compensatory model) function is calculated by Equation(11).

$$u_3(a_i) = \prod_j (\tilde{x}_{ij}^{1N} / \max_i \tilde{x}_{ij}^{2N})^{\omega_j} \tag{11}$$

Step 4 Combining and sequencing utility functions. In this step, the CCM, UCM, ICM values calculated in the previous step are combined with Equation (12), that is, the Euclidean distance.

$$DN_i = w_1 . \sqrt{\varphi . (u_1(a_i)/max\, u_1(a_i))^2 + (1-\varphi) . \left(\frac{m - r_1(a_i) + 1}{m}\right)^2} - \\ - w_2 . \sqrt{\varphi . (u_2(a_i)/max\, u_2(a_i))^2} + (1-\varphi) . \left(\frac{m - r_2(a_i)}{m}\right)^2 + \\ + w_3 . \sqrt{\varphi . (u_3(a_i)/max\, u_3(a_i))^2} + (1-\varphi) . \left(\frac{m - r_3(a_i) + 1}{m}\right)^2 \tag{12}$$

Here φ refers to the relative importance between the utility value and should be between φ[0,1]. The architects of the method have stated that the φ value is 0.5. Figure 1 shows the working scheme of the DNMA method proposed in this study.

Finally, the alternatives are sorted in descending order of their DN values. In other words, the alternative with the largest DN value is the best or preferred alternative (Ecer, 2020).

Discussion

The criteria used in personnel selection in the software industry vary depending on specific job roles and organizational requirements. However, some commonly used criteria include technical skills, problem-solving skills, communication skills, teamwork, adaptability, and work experience.

In this study, criteria were determined according to the literature in order to realize the most suitable personnel selection process in the software industry. Then, by interviewing the HR managers of a company operating in the software sector, information was obtained according to the criteria they considered important in this process. As a result of the researches in the literature, five main criteria that they consider important in the selection of personnel in the software sector have been determined. In the study, the job postings published by the company operating in the software field in Turkey were analyzed from the websites (kariyer.net, iskur.gov.tr, sahibinden.com, yenibiris.com). SWARA and DNMA methods were used to determine the software personnel needed in the software field. In the DNMA method, criterion weights obtained by the SWARA method were used.

In the study, five alternative candidates were evaluated according to five criteria. Microsoft Excel 2016 program was used for the application of SWARA and DNMA methods. The criteria used in the application were selected from the job posting site by analyzing the criteria commonly used in personnel selection. These criteria were expressed in the study as K1 (computer and software skills), C2 (work experience), K3 (the ability to adapt to teamwork), K4 (foreign language knowledge), and C5 (problem solving skills). Five candidates for the software personnel required by the companies were not evaluated. Alternative candidates are expressed as A1, A2…, A5, respectively. Candidates were evaluated by the study author using a scale on a scale of 1 to 10. The criteria and results are given in Table 3. The hierarchical structure of the study is shown in Figure 1.

Table 3. Ranking of criteria and s_j value

Criteria Name	Order of importance	Ranking Criteria		Comparative Significance of Mean Value(s_j)
Computer and software skills (K1)	1	K1	1	
Work experience(K2)	3	K4	2	0,10
Ability to adapt to teamwork(K3)	5	K2	3	0,15
Foreign language knowledge (K5)	4	K5	4	0,20
Problem solving skills(K4)	2	K3	5	0,10

In the study, the weights of the criteria were calculated using the SWARA method. DNMA method results and alternatives are listed. SWARA and DNMA method results are given below.

SWARA Method Results. In this section, the weighting of the personnel selection criteria will be carried out with the SWARA method. The basic criteria to be considered in the selection of employees are determined by choosing among a number of criteria. First, the criteria are listed. The criteria are then listed in descending order from the most important criteria to the decision maker's rating. As seen in Table 3, according to the importance of the K4 criterion, K2 is in the 3rd place, K5 is in the 4th place, and K2 is in the 5th place. Then, starting from the 2nd order criterion to determine the value of "importance of comparing the mean value" (s_j); The criteria in the 2nd place and the criteria in the 1st place; The criterion in the 3rd place is compared with the criterion in the 2nd place. In this way, the criteria are; Starting with the second criterion, it is compared with the previous criterion. For example; K5(4th place) and K2(3rd place) criteria were compared in terms of importance. He stated that K2 is 20% more important than K5. This value is entered in the relevant column as the sj value of K5. Table 3 shows the criteria, ranked criteria and s_j values. Table 4 shows the layout of the data in Table 3 and the calculation of parameters in the Excel software.

Table 4. Calculation of parameters

Criteria Name	Order of impor-tance	Ranking Criteria		s_j	k_j	q_j	w_j
Computer and software skills (K1)	1	K1	1		1	1,000	0,256
Work experience(K2)	3	K4	2	0,10	1,1	0,909	0,233
Ability to adapt to teamwork(K3)	5	K2	3	0,15	1,15	0,791	0,202
Foreign language knowledge (K5)	4	K5	4	0,20	1,2	0,659	0,169
Problem solving skills(K4)	2	K3	5	0,20	1,2	0,549	0,140

We can see that the most important one among the calculated criteria in Table 4 is K1 with w_1= 0.256. It has been revealed that K3 has the least importance among the criteria. The order of importance of the criteria calculated by the SWARA method was taken as K1>K4>K2>K5>K3.

DNMA Method Results

Table 5 shows the results of the weight values according to the calculation of the SWARA method.

Table 5. Personnel selection criteria

Kriter	*Kod*	*Optimization*	*Weight*
Computer and software skills (K1)	*K1*	*Max*	*0.256*
Work experience(K2)	*K2*	*Max*	*0.233*
Ability to adapt to teamwork(K3)	*K3*	*Max*	*0.202*
Foreign language knowledge (K5)	*K4*	*Min*	*0.169*
Problem solving skills(K4)	*K5*	*Min*	*0.140*

In order to determine the most suitable personnel for the software sector, the ratings of the personnel of 5 alternatives were determined according to 5 criteria, as seen in Table 6.

Table 6. Evaluations of alternative personnel

Criteria / Alternatives	*Computer and software skills*	*Work experience*	*Ability to adapt to teamwork*	*Foreign language knowledge*	*Problem solving skills*
	Max	*Max*	*Max*	*Min*	*Min*
A1	*3*	*5*	*1*	*7*	*2*
A2	*2*	*2*	*3*	*2*	*5*
A3	*4*	*3*	*7*	*5*	*3*
A4	*8*	*4*	*4*	*2*	*6*
A5	*5*	*2*	*2*	*3*	*4*

Step 1 Normalization. The first thing to do is to normalize the evaluations. Therefore, it is linearly normalized by Equation (4) results in Table 7 below.

Table 7. Linear normalization results

Criteria / Alternatives	*K1*	*K2*	*K3*	*K4*	*K5*
A1	*0,1667*	*1,0000*	*0,0000*	*0,0000*	*1,0000*
A2	*0,0000*	*0,0000*	*0,3333*	*1,0000*	*0,2500*
A3	*0,3333*	*0,3333*	*1,0000*	*0,4000*	*0,7500*
A4	*1,0000*	*0,6667*	*0,5000*	*1,0000*	*0,0000*
A5	*0,5000*	*0,0000*	*0,1667*	*0,8000*	*0,5000*

Linear normalized results are used for CCM vein UCM and vector normalization is used for ICM. The vector normalization calculation is calculated as shown in Equation 5, and the results are shown in Table 8 below.

Table 8 Vector normalization results

Criteria / Alternatives	*K1*	*K2*	*K3*	*K4*	*K5*
A1	*0,6294*	*1,0000*	*0,4697*	*0,4870*	*1,0000*
A2	*0,5553*	*0,6707*	*0,6464*	*1,0000*	*0,6906*
A3	*0,7035*	*0,7805*	*1,0000*	*0,6922*	*0,8969*
A4	*1,0000*	*0,8902*	*0,7348*	*1,0000*	*0,5874*
A5	*0,7776*	*0,6707*	*0,5581*	*0,8974*	*0,7937*

*Step 2 Fixing the criterion weights***.** In the first study of this step, the standard deviation is calculated using Equation (3). Standard deviations can be found with a program such as IBM SPSS, Excel (ECER, 2020). Table 9 shows standard deviation values.

Table 9. Standard deviations

σ1	*σ2*	*σ3*	*σ4*	*σ5*	*Toplam*
0,2574	*0,2332*	*0,2942*	*0,2770*	*0,2357*	*1,2975*

In the second step of the 2nd step, the standard deviation values should be normalized according to Equation (4). Values at this stage are shown in Table 10.

Table 10. Normalized standard deviation values

$\boldsymbol{\omega_1^\sigma}$	$\boldsymbol{\omega_2^\sigma}$	$\boldsymbol{\omega_3^\sigma}$	$\boldsymbol{\omega_4^\sigma}$	$\boldsymbol{\omega_5^\sigma}$
0,1984	0,1798	0,2267	0,2135	0,1817

Finally, the weights are determined using Equation (5). Table 11 shows the weight values determined.

Table 11. Adjusted weight values

$\boldsymbol{\tilde{\omega}_1}$	$\boldsymbol{\tilde{\omega}_2}$	$\boldsymbol{\tilde{\omega}_3}$	$\boldsymbol{\tilde{\omega}_4}$	$\boldsymbol{\tilde{\omega}_5}$
0,2268	0,2159	0,2425	0,2353	0,2171

Step 3. Calculation of utility functions: In this step, the CCM, UCM and ICM utility functions are calculated using Equation (6), Equation (7) and Equation (8).
The rankings according to the CCM, UCM and ICM utility function values obtained in this step are shown in Table 12.

Table 12. CCM, UCM and ICM values

Alternatives	*CCM*	*Descending order*	*UCM*	*Descending order*	*ICM*	*Descending order*
A1	*0,4708*	*4*	*0,2442*	*1*	*0,1440*	*5*
A2	*0,3704*	*5*	*0,2425*	*3*	*0,1663*	*4*
A3	*0,6470*	*2*	*0,1617*	*5*	*0,3409*	*2*
A4	*0,7274*	*1*	*0,2424*	*4*	*0,3843*	*1*
A5	*0,5633*	*3*	*0,2431*	*2*	*0,2345*	*3*

Step 4 Combining and sequencing utility functions. Using the results obtained in step 3, the alternatives will be ranked by Equation (12). After obtaining the performance values of the alternatives, the ranking will be made from the alternative with the highest value to the alternative with the lowest value. The performance values and rankings of the alternatives are shown in Table 13.

Table 13. Performance values and rankings of alternatives

Alternatives	Values	Rankings
DN1	*0,7176*	*4*
DN2	*0,6974*	*5*
DN3	*0,8952*	*2*
DN4	*0,9289*	*1*
DN5	*0,7847*	*3*

As shown in Table 14, alternatives are followed by A4, A3, A5, A1, A2, respectively, according to their values. A4 is the best performing and most suitable staff selected for the vacant position of the company. Figure 1 shows the performance results of the alternatives graphically below.

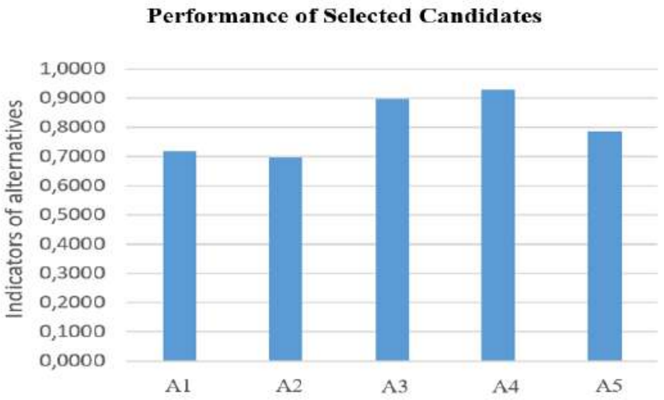

Figure 1. Performances of the most suitable personnel for the company

If we compare the results obtained from the DNMA method with other MCDM methods, we will see the following results: TOPSIS, CoCoSo, TODIM and DNMA methods have calculated the same results for all alternatives, MARCOS and MACBETH have calculated the same results, and MABAC and EDAS other MCDM methods have calculated slightly different results.

Table 14. Comparison of the results of the DNMA method with other MCDM methods

Method	*A1*	*A2*	*A3*	*A4*	*A5*
MARCOS	*3*	*5*	*2*	*1*	*4*
TOPSIS	*4*	*5*	*2*	*1*	*3*
CoCoSo	*4*	*5*	*2*	*1*	*3*
MABAC	*3*	*4*	*2*	*1*	*5*
TODIM	*4*	*5*	*2*	*1*	*3*
MACBETH	*3*	*5*	*2*	*1*	*4*
EDAS	*1*	*3*	*4*	*2*	*5*
DNMA	*4*	*5*	*2*	*1*	*3*

For the A4 alternative, which was shown by the DNMA method for the selection of the most suitable personnel, which is our aim, other MCDM methods showed the same results except for the EDAS method. The results in Table 10 are shown graphically in Figure 2.

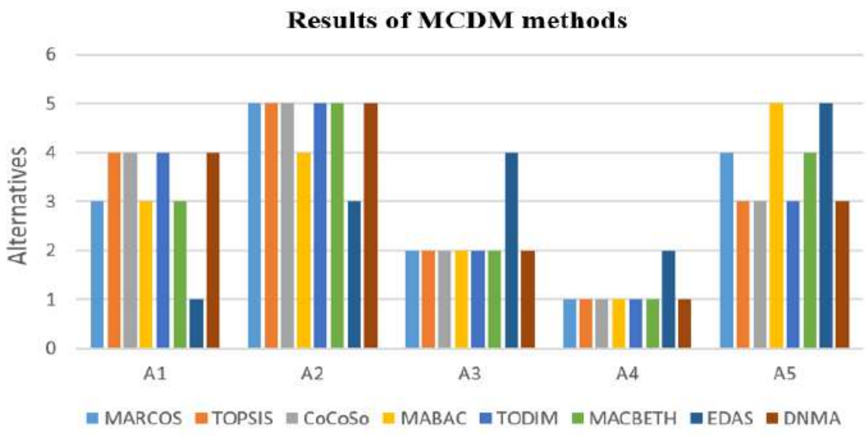

Figure 2. Performance results of MCDM methods for alternatives

Seperman and Kedall Tests

To see the suitability and applicability of 8 MCDM methods to select the best personnel in the study, they were compared using Seperman and Kedall criteria[21].

To compare the DNMA method with other methods using the Spearman and Kendall criteria, we need to calculate the correlation coefficients between the rankings generated by the DNMA and the rankings generated by each of the other methods. The correlation coefficients will tell us how similar the rankings are and whether there is a meaningful relationship between them.

To calculate the correlation coefficients, we will convert the ranks to ranks (i.e. replace values with ordinal orders) and then apply the Spearman and Kendall correlation formulas. The results are shown in Table 15 and Table 16 below.

Table 15. Spearman correlation coefficients

Method	*Spearman coefficient*
MARCOS	*0.7*
TOPSIS	*0.8*
CoCoSo	*0.8*
MABAC	*0.6*
TODIM	*0.8*
MACBETH	*0.7*
EDAS	*0.5*
DNMA	*1.0*

Table 16. Kendall correlation coefficients

Method	*Kendall coefficient*
MARCOS	*0.5*
TOPSIS	*0.6*
CoCoSo	*0.6*
MABAC	*0.4*
TODIM	*0.6*
MACBETH	*0.5*
EDAS	*0.3*
DNMA	*1.0*

When DNMA is compared with other methods, both Spearman and Kendall coefficients show that DNMA is most similar to TOPSIS, CoCoSo and TODIM and least similar to EDAS. In general, Spearman correlation coefficients are higher than Kendall correlation coefficients, indicating stronger relationships between rankings. After calculating the rankings for each alternative according to the given criteria, we can conclude that the DNMA method outperforms the value-based methods in terms of consistency and stability of the rankings. Both Spearman and Kendall criteria show that the DNMA method has the highest correlation and agreement with other methods [22,23].

Conclusion

In this study, SWARA and DNMA methods, which are among the MCDM methods, were integrated in the selection of recruiters for an open position in a software company. The criteria to be taken first in the recruitment process of the candidate personnel are respectively defined as computer and software skills, work experience, ability to adapt to teamwork, foreign language knowledge, and problem solving skills. In this study, first of all, the importance levels were calculated according to the criteria determined by the SWARA method.

According to the SWARA method, the five criteria that are important are respectively K1-computer and software skills (0.256), K2-problem solving skills (0.233), P3-work experience, K4-

foreign language knowledge (0.169), K5-the ability to adapt to teamwork (0.140). defined as. After calculating with the SWARA method, the best alternative among the five candidates was searched by the DNMA method. According to the results of this method, it was determined that the most suitable candidate for the said position was A4. As a result of the literature review, it is thought that the studies on the integrated use of SWARA and DNMA methods in the recruitment process will contribute to the relevant literature, since there is very little use. It is hoped that SWARA and DNMA methods will be used more together in the future, both in personnel and in research in other fields.

This research proposes a decision-making system in a process where software companies create a form for applicants when they post job postings for open positions, and companies rank candidates from 1 to 10 according to their own criteria. This system will allow applicants to evaluate the criteria through a web-based system using the DNMA decision making method, and will save time for companies. In this way, companies will be able to make more accurate and efficient decisions when selecting the most suitable candidates.

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