Physician Selection with a Neutrosophic Multi-criteria Decision Making Method

Ahmet Sarucan, M. Emin Baysal, and Orhan Engin(✉)

Industrial Engineering Department, Konya Technical University, Konya, Turkey
sarucan@gmail.com, mebaysal@gmail.com,
orhanengin@yahoo.com

Abstract. In this study, it is done that the evaluation of neurology clinics of two hospitals under the Ministry of Health and their physicians, considering patient preferences. While effective service policies and procedures of hospitals increase customer satisfaction, the performance of physicians ensures preferability. Therefore, measuring satisfaction and performance is crucial for management. However, measurement includes many challenges in connection with many factors and uncertainty on these factors. Thus, neutrosophic multi-criteria decision-making methods have been particularly chosen to overcome these challenges in this study. The related literature on the subject shows that easy access, cleaning and comfort, technological infrastructure, and equipment, total service time, physicians' communication skills, recognition of physicians, treatment effectiveness, treatment rate, academic career are the main criteria. The values of weights for these criteria and the physicians ranking based on the values of those weights were found by using the Neutrosophic Analytical Hierarchy Process (N-AHP). It has been validated that the ranking is fitting to patient preferences in the Central Physicians Appointment System. As a result, the recommended method can be effectively used in selecting physicians.

Keywords: Neutrosophic sets · Physician selection · Multi-criteria decision making · Neutrosophic AHP

1 Introduction

As in the world, the healthcare sector in Turkey is one of the areas where most works and investments are made for the maintaining of human life, quality of life and well-being. To ensure the protection and continuity of people's health, the structure of all institutions and organizations producing health-related goods and services is generally called the "Healthcare Sector" [1]. The Covid-19 epidemic, the common agenda of the whole world, has also unquestionably increased the importance of this sector to the top. Hospitals are the most important unit of healthcare institutions. In addition to the services provided to patients, hospitals have tasks such as providing medical education, training nurses and medical personnel, doing medical studies, conducting research and development activities in the field of health, following rapidly developing technology and keeping hospitals up to date [2]. Hospitals in Turkey are divided into 3 groups: University Hospitals, Health Ministry Hospitals, and Private hospitals. Improving the quality and performance of the

C. Kahraman et al. (Eds.): INFUS 2020, AISC 1197, pp. 319–327, 2021.
https://doi.org/10.1007/978-3-030-51156-2_38

service provided in the health sector is possible by applying the correct diagnosis and treatment methods by physicians to patients who come to receive services. While patients evaluate the quality of the service they receive, they rate the hospital and physicians's performance together. Research on patient satisfaction shows that the medical proficiency level of the healthcare institution (physicians quality, etc.) and its physical structure, the behavior of the staff (communication, courtesy, etc.), patient waiting time, cleaning of the facility affect the satisfaction level [3]. Also, hospital types and outpatient departments in hospitals affect the number of patients who want to receive services. Besides, the number of applications of many health institutions, the recognition of physicians and their achievements in the field are also factors in the frequent preference of those healthcare institutions [4]. Physicians preferences of patients within these and similar criteria are a difficult problem. Naturally, multi-criteria decision-making (MCDM) methods are very suitable to compare the performance of alternatives, as there are many alternatives and criteria in the preference process. In fact, in a study in this field, the problem of hospital selection of heart patients in hospitals operating in Ankara was discussed by AHP and TOPSIS method which are well-known MCDM methods [5]. In this study, the evaluation of physicians at the center of healthcare was examined by the AHP method, which is one of the MCDM techniques based on neutrosophic sets. To the best of our knowledge, the N-AHP is the first time applied for a physicians selection as a neutrosophic multi-criteria decision-making method. The advantages of the applied method can be summarized as: (1) The method represents the both uncertainty and indeterminacy; (2) This study can be explanatory work for the researchers who intend to research on this topic. The rest of the paper has been organized as follows: In Sect. 2 neutrosophic sets are briefly summarized. In Sect. 3, the steps of N-AHP are briefly summarized. In Sect. 4, a healthcare application is carried out and, the results are analyzed. The paper is completed with a section of conclusion and, a suggestion for further studies.

2 Neutrosophic Sets

Some important definitions of neutrosophic sets are introduced as follow [6, 7].

Definition 1. Let S be a space of points and $s \in S$. N neutrosophic set N in S is definite by a truth-membership function $T_N(s)$, an indeterminacy-membership function $I_N(s)$ and a falsity-membership function $F_N(s)$. Also, $T_N(s){:}S \rightarrow \left[{}^{-}0, 1^{+}\right]$, $I_N(s){:}S \rightarrow \left[{}^{-}0, 1^{+}\right]$ and $F_N(s){:}S \rightarrow \left[{}^{-}0, 1^{+}\right]$. There is no restriction on the sum of $T_N(s)$, $I_N(s)$ and $F_N(s)$ so $0^{-} \leq supT_N(s) + supI_N(s) + supF_N(s) \leq 3^{+}$.

Definition 2. Let S be a universe of discourse. N single valued neutrosophic set N over S is an object taking the form $N = \{\langle s, T_N(s), I_N(s), F_N(s) : \mathrm{s} \in \mathrm{S}\rangle\}$, where $T_N(s){:}S \rightarrow [0, 1]$, $I_N(s){:}S \rightarrow [0, 1]$ and $F_N(s){:}S \rightarrow [0, 1]$ with $0 \leq T_N(s) + I_N(s) + F_N(s) \leq 3$ for all $s \in S$. The intervals $T_N(s)$, $I_N(s)$ and $F_N(s)$ represent the truth-membership degree, the indeterminacy membership degree and the falsity membership degree of s to N, respectively. For convenience, a single valued neutrosophic number is represented by $N = (t, y, z)$, where $t, y, z \in [0, 1]$ and $t + y + z \leq 3$.

Definition 3. The single valued triangular neutrosophic number, $\tilde{t} = \langle (t_1, t_2, t_3); \alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \rangle$ is a neutrosophic set on the real line set R, whose truth, indeterminacy and falsity membership functions are as follows:

$$T_{\tilde{t}}(s) = \begin{cases} \alpha_{\tilde{t}}\left(\frac{s-t_1}{t_2-t_1}\right) & (t_1 \leq s \leq t_2) \\ \alpha_{\tilde{t}} & (s = t_2) \\ \alpha_{\tilde{t}}\left(\frac{t_3-s}{t_3-t_2}\right) & (t_2 \leq s \leq t_3) \\ 0 & otherwise \end{cases} \tag{1}$$

$$I_{\tilde{t}}(s) = \begin{cases} \frac{(t_2-s+\theta_{\tilde{t}}(s-t_1))}{(t_2-t_1)} & (t_1 \leq s \leq t_2) \\ \theta_{\tilde{t}} & (s = t_2) \\ \frac{(s-t_2+\theta_{\tilde{t}}(t_3-s))}{(t_3-t_2)} & (t_2 \leq s \leq t_3) \\ 1 & otherwise \end{cases} \tag{2}$$

$$F_{\tilde{t}}(s) = \begin{cases} \frac{(t_2-s+\beta_{\tilde{t}}(s-t_1))}{(t_2-t_1)} & (t_1 \leq s \leq t_2) \\ \beta_{\tilde{t}} & (s = t_2) \\ \frac{(s-t_2+\beta_{\mathrm{t}}(t_3-s))}{(t_3-t_2)} & (t_2 \leq s \leq t_3) \\ 1 & otherwise \end{cases} \tag{3}$$

where $\alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \in [0, 1]$ and $\mathrm{t}_1, \mathrm{t}_2, \mathrm{t}_3 \in \mathrm{R}$, $\mathrm{t}_1 \leq \mathrm{t}_2 \leq \mathrm{t}_3$.

Definition 4. Let $\tilde{t} = \langle (t_1, t_2, t_3); \alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \rangle$ and $\tilde{y} = \langle (y_1, y_2, y_3); \alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \rangle$ be two single-valued triangular neutrosophic numbers and $\gamma \neq 0$ be any real number. Then:

Addition of two triangular neutrosophic numbers

$$\tilde{t} + \tilde{y} = \langle (t_1 + y_1, t_2 + y_2, t_3 + y_3); \alpha_{\tilde{t}} \wedge \alpha_{\tilde{y}}, \theta_{\tilde{t}} \vee \theta_{\tilde{y}}, \beta_{\tilde{t}} \vee \beta_{\tilde{y}} \rangle$$

Subtraction of two triangular neutrosophic numbers

$$\tilde{t} - \tilde{y} = \langle (t_1 - y_3, t_2 - y_2, t_3 + y_1); \alpha_{\tilde{t}} \wedge \alpha_{\tilde{y}}, \theta_{\tilde{t}} \vee \theta_{\tilde{y}}, \beta_{\tilde{t}} \vee \beta_{\tilde{y}} \rangle$$

Inverse of a triangular neutrosophic number

$$\tilde{t}^{-1} = \langle \frac{1}{t_3}, \frac{1}{t_2}, \frac{1}{t_1}; \alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \rangle, where\ (\tilde{t} \neq 0)$$

3 Neutrosophic AHP

Radwan et al. [8] proposed a neutrosophic AHP method and applied it to the selection of the best learning management system. They stated that the traditional AHP method considers the definite judgments of decision makers. While the neutrosophic set theory makes the experts judgments more flexible. Bolturk and Kahraman [9] presented a new

AHP method with interval-valued neutrosophic sets and an interval-valued neutrosophic AHP based on cosine similarity measures. An application is given in energy alternative selection by proposed method. Another paper which is related to neutrosophic AHP is published by Abdel-Basset et al. They developed a neutrosophic AHP-Delphi group decision-making model based on trapezoidal neutrosophic numbers in order to handle experts' non-deterministic evaluation values [10]. Abdel-Basset et al. [7] proposed a method with the group decision making based on N-AHP and solved a real life problem structured by the experts from Zagazig Universityin Egypt. Ortega et al. [11] focused on an environmental problem related to water quality from a river basin by using N-AHP and TOPSIS linked to fuzzy cognitive map. Yücesan [12] presented an application of Failure Mode Effect Analysis Integrated N-AHP. Abdel-Bassed et al. [6] studied on the decision making process as an extension to N-AHP and SWOT analysis for developing a strategy.

In this study, the steps of physicians' selection study with N-AHP method are shown below [8].

Step 1: Identifies the criteria, sub criteria and alternatives of the decision-making problem. Then follows the constructing of the hierarchy of the considered problem.

Step 2: Defines the neutrosophic numbers that correspond to the 1–9 Saaty scale, they are used to compare different criteria and physicians.

Step 3: Determines the neutrosophic preference via the pairwise comparison between each criterion and sub criterion. Afterwards comes the comparing of the alternatives under each criterion or sub criterion.

Step 4: Presents the calculation of the neutrosophic relative weight of each preference relation. The relative weight is calculated by the addition of each column in the matrix, then each number in the matrix is divided on the sum of its column, with averaging across the rows being the last step.

Step 5: Ranks the overall weights, and a choice is made of the best alternative, by having the structure of the number of alternatives multiplied by the number of criteria.

4 Application

In this study, the evaluation of physicians and hospitals in the Neurology department of 2 hospitals operating under the Ministry of Health in Konya was carried out by a decision-making group created. This group consists of academics, health managers and people receiving services from the hospital. The purpose of choosing the neurology department is that this problem has not been studied in the literature. All data of 2 public hospitals were last accessed by the Public Hospitals Statistics Report published in 2018 by the General Directorate of Public Hospitals [4].

Step 1: There are a total of 5 physicians working in the Neurology department of the designated hospitals. The names of these physicians and which hospital they served were kept secret and encoded as P1, P2,…, P5. The information of physicians was accessed from the Turkish Ministry of Health Central Physicians Appointment System in January 2020 through the appointment portal. Besides, comments on forum sites were used in the evaluation of physicians.

8 criteria were determined as a result of the literature screening. The criteria used in the study are encoded as C1, C2,…, C8 as follows. The characteristics of both hospitals and physicians were considered together when determining the criteria used during the physician's selection problem phase of the study. Hospital and physician concepts are interconnected factors. All activities of physicians depend on hospital conditions and facilities, regardless of their knowledge, skills and, experience. Since these factors cannot be considered independent of each other, the 8 criteria selected were evaluated together (C1: Ease of transportation, C2: Cleaning and comfort, C3: Technological infrastructure and equipment, C4: Total service time, C5: physicians communication skills, C6: physicians recognition, C7: Treatment effectiveness, treatment rate, C8: Academic career). The first four of these criteria are of hospital characteristics and the last four criteria belong to physicians' characteristics [13].

The hierarchical structure of physicians selection is shown in Fig. 1.

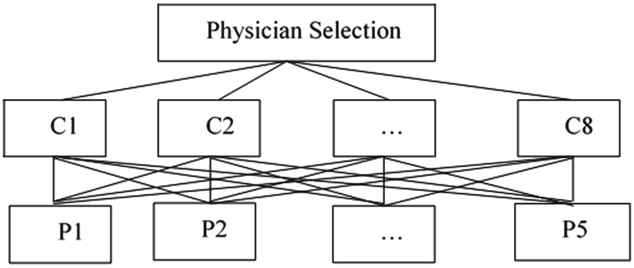

Fig. 1. The hierarchy of a physician's selection problem

Step 2: Defines the neutrosophic numbers that correspond to the 1–9 Saaty scale, they are used to compare different criteria and physicians.

Structure the neutrosophic pair-wise comparison matrix of criteria and physicians, through the linguistic terms which are shown in Table 1.

Table 1. Linguistic terms and the identical triangular neutrosophic numbers.

Saaty Scale	Explanation	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle (1, 1, 1); 0.50, 0.50, 0.50 \rangle$
3	Slightly influential	$\tilde{3} = \langle (2, 3, 4); 0.30, 0.75, 0.70 \rangle$
5	Strongly influential	$\tilde{5} = \langle (4, 5, 6); 0.80, 0.15, 0.20 \rangle$
7	Very strongly influential	$\tilde{7} = \langle (6, 7, 8); 0.90, 0.10, 0.10 \rangle$
9	Absolutely influential	$\tilde{9} = \langle (9, 9, 9); 1.00, 0.00, 0.00 \rangle$
2 4 6 8	Intermediate values	$\tilde{2} = \langle (1, 2, 3); 0.40, 0.65, 0.60 \rangle$ $\tilde{4} = \langle (3, 4, 5); 0.60, 0.35, 0.40 \rangle$ $\tilde{6} = \langle (5, 6, 7); 0.70, 0.25, 0.30 \rangle$ $\tilde{8} = \langle (7, 8, 9); 0.85, 0.10, 0.15 \rangle$

Step 3: Determines the neutrosophic preference via the pairwise comparison between each criterion and sub criterion. Afterwards comes the comparing of the alternatives under each criterion or sub criterion.

The values in Table 2 pertain to the decision maker group. The pair-wise comparison matrix of criteria is presented in Table 2. In table shows the linguistic scale and their corresponding neutrosophic numbers that will be structure the neutrosophic pair-wise comparison matrix of criteria and physicians, through the linguistic terms which are shown in Table 1.

Table 2. The neutrosophic comparison matrix of criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	$\tilde{1}$	$\tilde{2}$	$\widetilde{5^{-1}}$	$\widetilde{6^{-1}}$	$\widetilde{4^{-1}}$	$\widetilde{7^{-1}}$	$\widetilde{8^{-1}}$	$\tilde{3}$
C2	$\widetilde{2^{-1}}$	$\tilde{1}$	$\widetilde{4^{-1}}$	$\widetilde{5^{-1}}$	$\widetilde{3^{-1}}$	$\widetilde{6^{-1}}$	$\widetilde{7^{-1}}$	$\tilde{2}$
C3	$\tilde{5}$	$\tilde{4}$	$\tilde{1}$	$\widetilde{3^{-1}}$	$\tilde{2}$	$\widetilde{4^{-1}}$	$\widetilde{5^{-1}}$	$\tilde{5}$
C4	$\tilde{6}$	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	$\tilde{4}$	$\widetilde{3^{-1}}$	$\widetilde{4^{-1}}$	$\tilde{6}$
C5	$\tilde{4}$	$\tilde{3}$	$\widetilde{2^{-1}}$	$\widetilde{4^{-1}}$	$\tilde{1}$	$\widetilde{5^{-1}}$	$\widetilde{6^{-1}}$	$\tilde{4}$
C6	$\tilde{7}$	$\tilde{6}$	$\tilde{4}$	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\widetilde{3^{-1}}$	$\tilde{7}$
C7	$\tilde{8}$	$\tilde{7}$	$\tilde{5}$	$\tilde{4}$	$\tilde{6}$	$\tilde{3}$	$\tilde{1}$	$\tilde{8}$
C8	$\widetilde{3^{-1}}$	$\widetilde{2^{-1}}$	$\widetilde{5^{-1}}$	$\widetilde{6^{-1}}$	$\widetilde{4^{-1}}$	$\widetilde{7^{-1}}$	$\widetilde{8^{-1}}$	$\tilde{1}$

Step 4: Calculate the weight of the criteria and physicians.

The neutrosophic pair-wise comparison matrix, by transforming it to a deterministic matrix using the following equations [6].

Let $\widetilde{t_{ij}} = \langle (t_1, y_1, z_1), \alpha_{\tilde{t}}, \theta_{\tilde{t}}, \beta_{\tilde{t}} \rangle$ be a single triangular neutrosophic number; then,

$$C\left(\tilde{t}_{ij}\right) = \frac{1}{8}[t_1 + y_1 + z_1] \times (2 + \alpha_{\tilde{t}} - \theta_{\tilde{t}} - \beta_{\tilde{t}}) \tag{4}$$

and

$$N\left(\mathrm{t}_{ij}\right) = \frac{1}{8}[t_1 + y_1 + z_1] \times (2 + \alpha_{\tilde{t}} - \theta_{\tilde{t}} - \beta_{\tilde{t}}) \tag{5}$$

which are the score and accuracy degrees of $\tilde{t}_{ij}$ respectively.

To get the score and the accuracy degree of $\tilde{t}_{ij}$, we use the following equations:

$$C\left(\tilde{t}_{ij}\right) = \frac{1}{C\left(\tilde{t}_{ij}\right)} \tag{6}$$

$$N\left(\tilde{t}_{ij}\right) = \frac{1}{N\left(\tilde{t}_{ij}\right)} \tag{7}$$

The crisp matrix is presented in Table 3 (by using Eq. (4)).

Table 3. The crisp comparison matrix of criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	1	1/5	1/5	1/3	1/7	1/8	1
C2	1	1	1/3	1/5	1	1/5	1/7	1
C3	5	3	1	1	1	1/3	1/5	5
C4	5	5	1	1	3	1	1/3	5
C5	3	1	1	1/3	1	1/5	1/5	3
C6	7	5	3	1	5	1	1	7
C7	8	7	5	3	5	1	1	8
C8	1	1	1/5	1/5	1/3	1/7	1/3	1

The crisp matrix must be normalized as follows when it is created. (1) Calculate the sum of each column of the crisp matrix. (2) Divide each matrix element into this total value. (3) Calculate the average of the row elements of the normalized matrix.

The normalized comparison matrix of criteria and calculated the weight of the criteria ($W_{criteria)}$ is presented in Table 4.

Table 4. The result matrix of criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	$W_{criterion}$
C1	0.03	0.04	0.02	0.03	0.02	0.04	0.04	0.03	0.03
C2	0.03	0.04	0.03	0.03	0.06	0.05	0.05	0.03	0.04
C3	0.16	0.13	0.09	0.14	0.06	0.08	0.06	0.16	0.11
C4	0.16	0.21	0.09	0.14	0.18	0.25	0.11	0.16	0.16
C5	0.10	0.04	0.09	0.05	0.06	0.05	0.06	0.10	0.07
C6	0.23	0.21	0.26	0.14	0.30	0.25	0.32	0.23	0.24
C7	0.26	0.29	0.43	0.43	0.30	0.25	0.32	0.26	0.32
C8	0.03	0.04	0.02	0.03	0.02	0.04	0.04	0.03	0.03

Between step 2 and 4 are repeated and neutrosophic evaluation of physicians is made for each criterion. Then next step is taken.

Step 5: Determine the total priority of each physicians (alternative) and the final ranking.

The relative scores for each physician (alternative) is calculated as follows:

$$W_{P1} = 0.19 \times 0.03 + 0.56 \times 0.04 + 0.34 \times 0.11 + 0.11 \times 0.16 + 0.07 \times 0.07 + 0.09 \times 0.24 + 0.15 \times 0.32 + 0.23 \times 0.03 = 0.17$$

$$W_{P2} = 0.15 \times 0.03 + 0.16 \times 0.04 + 0.11 \times 0.11 + 0.15 \times 0.16 + 0.44 \times 0.07 + 0.06 \times 0.24 + 0.14 \times 0.32 + 0.31 \times 0.03 = 0.15$$

$$W_{P3} = 0.33 \times 0.03 + 0.08 \times 0.04 + 0.05 \times 0.11 + 0.23 \times 0.16 + 0.16 \times 0.07 + 0.41 \times 0.24 + 0.19 \times 0.32 + 0.15 \times 0.03 = 0.23$$

$$W_{P4} = 0.19 \times 0.03 + 0.09 \times 0.04 + 0.43 \times 0.11 + 0.19 \times 0.16 + 0.04 \times 0.07 + 0.27 \times 0.24 + 0.19 \times 0.32 + 0.28 \times 0.03 = 0.22$$

$$W_{P5} = 0.14 \times 0.03 + 0.10 \times 0.04 + 0.08 \times 0.11 + 0.32 \times 0.16 + 0.29 \times 0.07 + 0.16 \times 0.24 + 0.33 \times 0.32 + 0.03 \times 0.03 = 0.23$$

Finally, the N-AHP ranking of physicians selection are shown in Table 5.

Table 5. The physicians selection ranking

Physicians	Priority	Ranking
P1	0.17	3
P2	0.15	4
P3	0.23	1
P4	0.22	2
P5	0.23	1

5 Conclusion

To look at the results of the study, the first place has been shared by the P3 and the P5. The second place is the P4. It has been a remarkable result that these physicians served in the same hospital. We have taken the criteria C6 and C7 with the highest criteria weights to this result. P3 was in the first place according to the Criterion C6. According to the criterion of C7, the P5 was the first. Since the total weight of these two criteria in decision-making is 56%, these criteria have also determined the physician's ranking. In the physician selection problem, the weight of the hospital criteria was calculated by 34%, and the physician's criteria were calculated by 66%.

This research has been limited to public hospitals. For this reason, it will be useful to compare the results by applying them to the neurology departments of private hospitals. Also, for further study, we suggest the solution of the physician selection problem be compared with the solution of the interval-valued spherical fuzzy AHP.

References

1. Temür, Y., Bakırcı, F.: Türkiye'de sağlık kurumlarının performans analizi bir VZA uygulaması. Sosyal Bilimler Dergisi. **10**(3), 261–282 (2008)
2. Karahan, A., Özgür, E.: Hastanelerde Performans Yönetim Sistemi ve Veri Zarflama Analizi. Nobel Yayın Dağıtım, Ankara (2011)
3. Kılıç, T., Topuz, R.: Hastalarla iletişimin, hasta memnuniyetine etkisi: özel, devlet ve üniversite hastanesi karşılaştırması. Sağlıkta Performans Kalite Dergisi. **2015**(9), 81–82 (2015)
4. Başara, B.B., Soytutan, Ç.İ.: T.C. Sağlık Bakanlığı Sağlık İstatistikleri Yıllığı 2017. Yayın No: 1106 (2018)
5. Taş, C., Bedir, N., Eren, T., Alağaş, H.M., Çetin, S.: Policlinic evaluation with integrating AHP-TOPSIS methods: an application in Ankara. Sağlık Yönetimi Dergisi **2**(1), 1–17 (2018)
6. Abdel-Basset, M., Mohamed, M., Smarandache, F.: An extension of neutrosophic AHP–SWOT analysis for strategic planning and decision-making. Symmetry **10**(116), 1–18 (2018)
7. Abdel-Basset, M., Mohamed, M., Zhou, Y., Hezam, I.: Multi-criteria group decision making based on neutrosophic analytic hierarchy process. J. Intell. Fuzzy Syst. **33**, 4055–4066 (2017)
8. Radwan, N.M., Senousy, M.B., Riad, A.E.D.M.: Neutrosophic AHP multi criteria decision making method applied on the selection of learning management system. Int. J. Adv. Comput. Technol. (IJACT) **8**(5), 95–105 (2016)
9. Bolturk, E., Kahraman, C.: A novel interval-valued neutrosophic AHP with cosine similarity measure. Soft. Comput. **22**(15), 4941–4958 (2018)
10. Abdel-Basset, M., Mohamed, M., Sangaiah, A.K.: Neutrosophic AHP-Delphi group decision making model based on trapezoidal neutrosophic numbers. J Ambient Intell. Hum. Comput. **9**, 1–17 (2017)
11. Ortega, R.G., Vázquez, M.L., Figueiredo, J.A.S., Guijarro-Rodríguez, A.: Sinos river basin social-environmental prospective assessment of water quality management using fuzzy cognitive maps and neutrosophic AHP-TOPSIS. Neutrosophic Sets Syst. **23**, 160–171 (2018)
12. Yücesan, M.: FMEA analysis in mechanical installation project based on best worst and neutrosophic AHP integrated model. Electron. J. Soc. Sci. **19**(73), 363–382 (2020)
13. Doğan, E.: Hizmet Performansının Çok Ölçütlü Karar Verme Yöntemleri ile Değerlendirilmesi: Sağlık Sektöründe Bir Uygulama. Yüksek Lisans Tezi, Konya Teknik Üniversitesi Lisansüstü Eğitim Enstitüsü, Konya (2019)