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An Innovative Approach to the Intuitionistic Fuzzy PROMETHEE Method

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Abstract: Intuitionistic fuzzy PROMETHEE is a method that provides us numerous advantages thanks to its benefits such as allowing the researcher to observe the positive and negative rankings simultaneously, expressing the degree of hesitation, changing the significance weights of the criteria and using different methods when identifying the significance levels for each criterion, putting the degree of hesitation of significance weights into action, and enabling decision makers, who are given the opportunity to use different criteria types and different criteria types for alternatives and criteria, to establish a unique system. In line with the aims of this paper, an original application has been made and an innovative approach has been proposed in order to demonstrate the usefulness of the intuitionistic fuzzy PROMETHEE method.

Keywords: Intuitionistic Fuzzy Theory, Multi Criteria Decision Making, PROMETHEE Method, Intuitionistic Fuzzy PROMETHEE, Selection and Evaluation in Education.

1 Introduction

The fuzzy logic was uncovered by Zadeh in 1965 [44]. Thanks to fuzzy logic, we solve the uncertain problems in everyday life. Fuzzy logic has attracted the attention of many researchers for years, and efficient results have been achieved in most application areas. In this process, while researches and applications on fuzzy logic continue, the intuitionistic fuzzy set theory, which is the generalization of fuzzy logic in which sensitivity is also activated in cases of uncertainty, was put forward by Atanassov in 1983. [4]. With this theory, it has been possible to solve the problems that have the uncertainty that we encounter in our lives. One of the biggest problems faced by the researchers who investigated the fuzzy logic and evaluated it in the field of application was the situations in which the concept of hesitation or uncertainty came into play. The researchers defined a new concept, noticing situations of uncertainty and hesitation, where fuzzy logic was also inadequate. The concept of intuitionistic fuzzy, based on classical logic and fuzzy logic, was first described by Atanassov in 1983 [4]. Intuitionistic fuzzy theory, in addition to fuzzy logic, the concept of degree of hesitation (sensitivity) stands out. In a problem where there is only one criterion, the act of making a choice is an easy action. When alternatives (options) and criteria (criteria) increase, the action of calculating all the criteria at the same time and reaching the most accurate solution is a difficult task compared to normal. Due to these needs, multi-criteria decision-making problems that emerged in the 1960s have attracted the attention of many researchers and have been focused on them. The purpose of multi-criteria decision making (MCDM); When alternatives and criteria multiply, it is easiest to create a mechanism that may control them all when making decisions. MCDM (Multi Criteria Decision Making) or MCDA (Multi Criteria Decision Analysis) are well-known acronyms for multi-criteria decision making and multi-criteria decision analysis. Multi-criteria decision making is interested in structuring and solving decision and planning problems involving multiple criteria. Many researchers were developed applications using PROMETHEE methods, intuitionistic

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fuzzy sets, fuzzy logic, multi criteria decision making and in applicaton of statistical ([1,2,3,12,26,13,9,27,31,32]) . PROMETHEE i.e. Preference Ranking Organisation Method for Enrichment Evaluation was first developed by Brans in 1982 [8]. PROMETHEE I (partial sort) and PROMETHEE II (full ranking) were developed by Brans. A few years later, J.P. Brans and B. Mareschal developed PROMETHEE III (sorting by range) and PROMETHEE IV (continuous status). In 1988, the same authors proposed the visual interactive GAIA module, which provides a spectacular graphical representation that supports the PROMETHEE methodology. In 1992 and 1994, J.P. Brans and B. Mareschal also proposed two extensions: PROMETHEE V (MCDA with segmentation restrictions) and PROMETHEE VI (representation of the human brain) [11]. The PROMETHEE method was then thoroughly researched by Brans and Vincke and its foundations were laid out. They published a study that will be the main source for all researchers who want to understand the basic logic of the PROMETHEE method [10]. The PROMETHEE method is in the outranking method class, one of the multi-criteria decision-making methods. The most important features that distinguish the PROMETHEE method from other multi-criteria decision-making methods can be listed as follows:

– It allows you to determine a different preference function for each criterion. Therefore, the decision maker has the right to evaluate each criterion in its own way.
– It offers the chance to observe both positive and negative rankings at the same time, allowing us to make better guiding comments when commenting on net ranking.

2 Preliminaries

Definition 1. *([5],[4])Let $X \neq \emptyset$. An intuitionistic fuzzy set A in X;*

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in X\}, \tag{1}$$

$$\mu_A(x), \nu_A(x), \pi_A(x) : X \to [0,1] \tag{2}$$

defined membership, nonmembership and hesitation degree of the element $x \in X$ respectively.

$$\mu_A(x) + \nu_A(x) + \pi_A(x) = 1. \tag{3}$$

Intuitionistic fuzzy value (IFV) defined by Xu ([39]). Intuitionistic fuzzy value (IFV) is shown as follows: $\tilde{a} = (\mu_{\tilde{a}}, \nu_{\tilde{a}}, \pi_{\tilde{a}})$, where $\mu_{\tilde{a}}, \nu_{\tilde{a}}, \pi_{\tilde{a}} \in [0,1]$
For each IFS $\tilde{A}$;

$$\pi_{\tilde{A}} = 1 - \mu_{\tilde{A}} - \nu_{\tilde{A}} \tag{4}$$

In this paper; we will not write the third part so we'll show $\tilde{a} = (\mu_{\tilde{a}}, \nu_{\tilde{a}})$ shape instead of $\tilde{a} = (\mu_{\tilde{a}}, \nu_{\tilde{a}}, \pi_{\tilde{a}})$. The degree of hesitation may be obtained by equation 4.

For IFVs $\tilde{a} = (\mu_{\tilde{a}}, \nu_{\tilde{a}})$ and $\tilde{b} = (\mu_{\tilde{b}}, \nu_{\tilde{b}})$ the following operations were carried out([39],[38]):

$$(1) \quad \tilde{a} \oplus \tilde{b} = (\mu_{\tilde{a}} + \mu_{\tilde{b}} - \mu_{\tilde{a}}\mu_{\tilde{b}}, \nu_{\tilde{a}}\nu_{\tilde{b}}) \tag{5}$$

$$(2) \quad \tilde{a} \otimes \tilde{b} = (\mu_{\tilde{a}}\mu_{\tilde{b}}, \nu_{\tilde{a}} + \nu_{\tilde{b}} - \nu_{\tilde{a}}\nu_{\tilde{b}}) \tag{6}$$

$$(3) \ \oplus_{j=1}^{m} \tilde{a}_j = (1 - \prod_{j=1}^{m}(1-\mu_j), \prod_{j=1}^{m}\nu_j) \tag{7}$$

$$(4) \ \otimes_{j=1}^{m} \tilde{a}_j = (\prod_{j=1}^{m}\mu_j, \prod_{j=1}^{m}(1-\nu_j)) \tag{8}$$

Many researchers suggested approaches for comparing the IFVs ([28],[38]). The following method was used in this paper. This method was proposed by Szmidt and Kacprzyk, which leads to more consistent results than other methods. ([28]). This function was used to rank IFVs:

$$\rho(\alpha) = 0.5(1+\pi_\alpha)(1-\mu_\alpha)) \tag{9}$$

As the $\rho(\alpha)$ value decreases, the preferred value α increases.

3 Materials and Methods

When a MCDM problem is encountered, the decision maker is expected to choose the best alternative among the alternatives according to certain criteria. However, the significance of all the criteria can vary. In such cases, the weighting of the criteria shall be taken into consideration. The benefit of the PROMETHEE method is to assess considering the weight of the criterion. The criteria's weights indicate how important they are. Considering both intuitionistic fuzzy sets and weights of criteria at the same time, more consistent and rational results will be obtained. Therefore; using intuitionistic fuzzy PROMETHEE method will provide advantageous results. The criteria's weights could be depicted as IFVs: $\tilde{w}_j$ where $\mu_{\tilde{w}_j} \in [0,1], \nu_{\tilde{w}_j} \in [0,1], \mu_{\tilde{w}_j} + \nu_{\tilde{w}_j} \leq 1, j = 1,2,...,m$. According to the weights, $\mu_{\tilde{\omega}_j}$ and $\nu_{\tilde{\omega}_j}$ demonstrate the membership and non-membership degrees of the alternative x_i respectively. Indeed; the concept of weight represents the importance of that criteria. The weights are expressed as IFV in the intuitionistic fuzzy PROMETHEE. It is of great importance for decision-makers to determine the specific importance level for each criterion. In this paper, controlled sets were used to express the importance of the criteria in the intuitionistic fuzzy PROMETHEE method in the form of intuitionistic fuzzy values. Some methods may help decision makers in determining intuitionistic fuzzy weights ([18,19,36,41,15,16]). The basic definitions for controlled sets are as follows:

Definition 2. *[15] Let E be an universe, α is a function from E to I then E is called $\alpha-$ set.*

Definition 3. *[15] Let E be an $\alpha-$ set. The set E is called $\alpha-$ controlled set if*

$$\forall x \in E, \exists y \in E \ni 1-\alpha(x) = \alpha(y). \tag{10}$$

The family of $\alpha-$ controlled set on an universe E is represented by $E \in CS(\alpha)$.

Definition 4. *[15] Let $E \in CS(\alpha)$ and $a \in E$. The following set is called control set of a,*

$$\bar{a} = \{b \in E | 1-\mu(a) = \mu(b)\} \tag{11}$$

Definition 5. *[16] Let E be an $\alpha-$ set. We define the following mapping on E so that*

$$\alpha^*(x) = \begin{cases} 1-\alpha(x), & x \in E_\alpha \\ sup_y \alpha(y), & y \in E \ni \alpha(x) < 1-\alpha(y) \\ 0, & otherwise. \end{cases} \tag{12}$$

where $E_\alpha = \cup_{a \in E} \bar{a}$.

Definition 6. *[16] Let E be $\alpha-$ set. Then the set $A = \{\langle x, \alpha(x), \alpha^*(x)\rangle | x \in E\}$ is called $(\alpha, \alpha^*)-$ controlled set.*

In this research, V shape criterion type has been used ([35]):

$$P(d) = \begin{cases} 0, & d \leq q \\ \frac{d-q}{p-q}, & q < d \leq p \\ 1, & d > p \end{cases} \tag{13}$$

Parameter thresholds q and p are indicated as indifference and strict preference, respectively. Decision makers are free to change these thresholds according to the desired situation. Evaluate the alternatives $x_i (i = 1, 2, ..., n)$ with respect to the criteria $c_j (j = 1, 2, ..., m)$ and determine the deviations based on pairwise comparisons:

$$d_j(x,y) = c_j(x) - c_j(y) \tag{14}$$

where $d_j(x,y)$ shows the distinction between the alternatives' the assessments x and y on the criterion c_j.

The decision maker first determines the assessment values of each alternative relative to different criteria and creates the paired preferences via the preference function, which is also called as the general criterion in the classical PROMETHEE. There are six different types of generalized criteria. The preferences are limited in $[0,1]$ by the generalized criterion. If these preference functions are handled with a fuzzy set, membership functions and preference values are represented by $P_j(x,y)$. Besides preference values can be taken directly as fuzzy numbers as they are limited to $[0,1]$. However, with the help of the fuzzy set, only the preferred density defined by the membership function can be expressed. It is more convenient for the decision maker to use intuitionistic fuzzy set because it addresses all aspects of the criteria. Also with the help of intuitionistic fuzzy set, PROMETHEE method is more advantageous. Since; the intuitionistic fuzzy set could express not only the intensity of preferred but also the degrees of non-preferred and uncertain.

Definition 7. *([40]) An intuitionistic fuzzy preference relation R on the set $X = x_1, x_2, ..., x_n$ is represented by a matrix $R = (r_{ik})_{n\times n}$, where $r_{ik} = \langle (x_i, x_k), \mu(x_i, x_k), \nu(x_i, x_k) \rangle$ for all $i, k = 1, 2, ..., n$. For convenience, we let $r_{ik} = (\mu_{ik}, \nu_{ik})$ where μ_{ik} denotes the degree to which the object x_i is preferred to the object x_k, ν_{ik} indicates the degree to which the object x_i is not preferred to the object x_k, and $\pi(x_i, x_k) = 1 - \mu(x_i, x_k) - \nu(x_i, x_k)$ is interpreted as an indeterminacy degree or a hesitancy degree, with the condition:*

$$\mu_{ik},\ \ \nu_{ik} \in [0,1],\ \ \mu_{ik} + \nu_{ik} \leq 1,\ \ \mu_{ik} = \nu_{ki},\ \ \mu_{ki} = \nu_{ik}, \tag{15}$$

$$\mu_{ii} = \nu_{ii} = 0.5,\ \ \pi_{ik} = 1 - \mu_{ik} - \nu_{ik}, \tag{16}$$

$$for\ \ all\ \ i, k = 1, 2, ..., n \tag{17}$$

4 Algorithm of Intuitionistic Fuzzy PROMETHEE

The preferences μ_{ik} between the alternatives x_i and x_k according to the criterion c_j could be calculated by Equations (14) and (13), and then the preference matrix according to the criterion c_j is obtained as follows ([20]):

$$U^{(j)} = (\mu_{ik}^{(j)})_{n\times n} = \begin{bmatrix} - & \mu_{12}^{(j)} & \dots & \mu_{1n}^{(j)} \\ \mu_{21}^{(j)} & - & \dots & \mu_{2n}^{(j)} \\ \vdots & \vdots & - & \vdots \\ \mu_{n1}^{(j)} & \mu_{n2}^{(j)} & \dots & - \end{bmatrix} \tag{18}$$

Using the equations $\nu_{ki} = \mu_{ik}$ and $\nu_{ik} = \mu_{ki}$, the nonmembership degree of an IFV could be obtained. Matrix of the intuitionistic fuzzy preference relation is as follows:

$$R^{(j)} = (r_{ik}^{(j)})_{n\times n} = \begin{bmatrix} - & (\mu_{12}^{(j)}, \nu_{12}^{(j)}) & \dots & (\mu_{1n}^{(j)}, \nu_{1n}^{(j)}) \\ (\mu_{21}^{(j)}, \nu_{21}^{(j)}) & - & \dots & (\mu_{2n}^{(j)}, \nu_{2n}^{(j)}) \\ \vdots & \vdots & - & \vdots \\ (\mu_{n1}^{(j)}, \nu_{n1}^{(j)}) & (\mu_{n2}^{(j)}, \nu_{n2}^{(j)}) & \dots & - \end{bmatrix} \tag{19}$$

Then; considering the $c_j (j = 1, 2, \dots, m)$ criteria, we must establish the general preference index for each alternative. We can get what we want by using weighted aggregation operators. There are a number of aggregation operators for intuitionistic fuzzy sets, such as the IFWA, IFWG, IFOWA, IFOWG, IFHA and IFHG operators ([39,38]). We will use the IFWA operator in this paper. The all intuitionistic fuzzy preference index of the alternative x_i to x_k on all criteria can be derived as:

$$r(x_i, x_k) = r_{ik} = \bigoplus_{j=1}^{m} \left(\tilde{w}_j \bigotimes r_{ik}^{(j)} \right) \tag{20}$$

where $r(x_i, x_k) = r_{ik}$ shows the degree to which the alternative x_i is preferred to the alternative x_k all criteria. Also, r_{ik} is an IFV. $\tilde{w}_j = (\mu_{\tilde{w}j}, \nu_{\tilde{w}j})$, then according to Equation (5), (6):

$$\tilde{w}_j \bigotimes r_{ik}^{(j)} = \left(\mu_{ik}^{(j)} \mu_{\tilde{w}j}, \nu_{ik}^{(j)} + \nu_{\tilde{w}j} - \nu_{ik}^{(j)} \nu_{\tilde{w}j} \right) \tag{21}$$

If Equations (7),(20) and (21) are combined;

$$r(x_i, x_k) = \bigoplus_{j=1}^{m} \left(\tilde{w}_j \bigotimes r_{ik}^{(j)} \right) = \left(1 - \prod_{j=1}^{m} (1 - \mu_{ik}^{(j)} \mu_{\tilde{w}j}), \prod_{j=1}^{m} (\nu_{ik}^{(j)} + \nu_{\tilde{w}j} - \nu_{ik}^{(j)} \nu_{\tilde{w}j}) \right) \tag{22}$$

Overall intuitionistic fuzzy preference relationship is established as follows:

$$R = (r_{ik})_{n\times n} = \begin{bmatrix} - & (\mu_{12}, \nu_{12}) & \dots & (\mu_{1n}, \nu_{1n}) \\ (\mu_{21}, \nu_{21}) & - & \dots & (\mu_{2n}, \nu_{2n}) \\ \vdots & \vdots & - & \vdots \\ (\mu_{n1}, \nu_{n1}) & (\mu_{n2}, \nu_{n2}) & \dots & - \end{bmatrix} \tag{23}$$

Every alternative is compared to option $(n-1)$. As a result of intuitionistic fuzzy positive and negative outranking flow can be achieved as follows:

(1) The intuitionistic fuzzy positive outranking flow:

$$\tilde{\varphi}^{+}(x_i) = \frac{1}{n-1} \bigoplus_{k=1, k\neq i}^{n} r(x_i, x_k) = \frac{1}{n-1} \bigoplus_{k=1, k\neq i}^{n} r_{ik} \tag{24}$$

(2) The intuitionistic fuzzy negative outranking flow:

$$\tilde{\varphi}^{-}(x_i) = \frac{1}{n-1} \bigoplus_{k=1, k\neq i}^{n} r(x_k, x_i) = \frac{1}{n-1} \bigoplus_{k=1, k\neq i}^{n} r_{ki} \tag{25}$$

The relationship between $\tilde{\varphi}^{+}(x_i)$ and $\tilde{\varphi}^{-}(x_i)$ can be explained with the help of Equation (9). The intuitionistic fuzzy net cannot be obtained by directly subtraction the outranking flow. The difference between the intuitionistic fuzzy positive and negative outranking flow can be calculated using the function defined by Szmidt and Kacprzyk.

$$\rho(\varphi(x_i)) = \rho(\tilde{\varphi}^+(x_i)) - \rho(\tilde{\varphi}^-(x_i)) \tag{26}$$

Three different ranking for $\tilde{\varphi}^+(x_i)$ and $\tilde{\varphi}^-(x_i)$ can be achieved ([20]):

1.Partial ranking: x_i outranks x_k if $\tilde{\varphi}^+(x_i) \geq \tilde{\varphi}^+(x_k)$ and $\tilde{\varphi}^-(x_i) \leq \tilde{\varphi}^-(x_k)$;
2.Equality: $\tilde{\varphi}^+(x_i) = \tilde{\varphi}^+(x_k)$ and $\tilde{\varphi}^-(x_i) = \tilde{\varphi}^-(x_k)$ hold at the same time involves indifference between two options.
3.Incomparability: This takes if $\tilde{\varphi}^+(x_i) > \tilde{\varphi}^+(x_k)$ and $\tilde{\varphi}^-(x_i) > \tilde{\varphi}^-(x_k)$ or $\tilde{\varphi}^+(x_i) < \tilde{\varphi}^+(x_k)$ and $\tilde{\varphi}^-(x_i) < \tilde{\varphi}^+(x_k)$.

If incomparability happens, intuitionistic fuzzy net outranking flow can be obtained by the help of Equation (26).

In the general algorithm mentioned below; the steps of the algorithm that may be applied in every field are explained in detail. The algorithm we need to use when we want the best, the most accurate and the smartest solution, where the importance of the criteria are different, multiple criteria and alternatives are together, is given below by explaining all the steps. This algorithm is an algorithm that has an application area in all areas of multi-criteria decision making and will give us the most accurate result in any situation. At the same time, by using this algorithm in our study, we have shown its application and usefulness in the field of education. When we want to choose among alternatives with more than one criteria, not only in the field of education, this algorithm is used to make the best choice and the most accurate ranking among the alternatives. The general algorithm for the intuitionistic fuzzy PROMETHEE have been created as follows [32] :
Step 1: Alternatives $X = x_1, x_2, \ldots, x_n$ to be evaluated are determined. And criteria $C = c_1, c_2, \ldots, c_m$ that are important to evaluate alternatives are determined.
Step 2: The importance degree of the criteria is determined $\tilde{w}_j(j = 1, 2, \ldots, m)$ where $\mu_{\tilde{w}_j} + \nu_{\tilde{w}_j} \leq 1, \mu_{\tilde{w}_j} \in [0,1], \ \nu_{\tilde{w}_j} \in [0,1]$.
Step 3: The parameters q as an indifference threshold and p as a strict preference threshold are determined. Deviations $d_j(x,y)$ using Equation (14), the preferences $\mu_{ik}^{(j)}$ for the alternative x_i against alternative x_k with respect to the criterion c_j by using the V-shape with indifference criterion are calculated. Then, the preference matrix $U^{(j)}(j = 1, 2, \ldots, m)$ are created.
Step 4: The intuitionistic fuzzy preference relation $R^{(j)} = (r_{ik}^{(j)})_{n \times n}$ is created.
Step 5: The overall intuitionistic fuzzy preference relation $R = (r_{ik})_{n \times n}$ using Equation (20) is obtained.
Step 6: The IF positive outranking flow $\tilde{\varphi}^+(x_i)$ and the intuitionistic fuzzy negative outranking flow $\tilde{\varphi}^-(x_i)$ by using Equation (22) and (23) are obtained.
Step 7: The relationship between $\tilde{\varphi}^+(x_i)$ and $\tilde{\varphi}^-(x_i)$ is determined. According to this relationship is made a ranking.

5 A Current Application of Intuitionistic Fuzzy PROMETHEE Method

The general algorithm was made a unique application of the intuitionistic fuzzy PROMETHEE method given above. In this application, which is aimed at bringing innovation and improvement in the education system, a decision-making mechanism was established in which the factors affecting student success are discussed together with the exam results when evaluating student success. Today, there are official exams organized by the Ministry of National Education in the education system [22,23]. In these official exams, selection and placement are made by considering only the course success of the students. Thanks to the method proposed by us, the current system may be updated by taking into account the factors affecting the success of the students. The goal of this application is; to create a system where the factors affecting the achievements of the students as well as the exam results are discussed together. In this study, all calculations were made with the help of the Excel program. For this reason, the calculations of this method, which we have already given the general intuitionistic fuzzy PROMETHEE algorithm above, explained the steps one by one and explained the formulas by simplifying them, were made in the background the tables with the actual results were shared in this application section.

Step 1: In the studies carried out in line with the necessary literature review and expert opinions, the factors affecting student achievement were investigated. The factors used in the implementation of the intuitionistic fuzzy PROMETHEE method are listed below:

- For students;
  - Academic Motivation
  - Anxiety
  - Attitude Toward Science and Technology
  - Attitude Toward English
  - Attitude Toward Mathematics
  - Attitude Toward Social Studies
  - Attitude Toward Turkish
- For Teachers;
  - School Culture

Step 2: Scales were determined and applied to students and teachers with the help of literature review and expert opinion necessary to evaluate the factors affecting the achievements of students [33,34,43,6,37,24,7,25,17,29,42,30].

In this algorithm, alternatives represent 30 students, while criteria represent the main factors affecting student success. The alternatives and criteria that form the basis of our algorithm are as follows:

- $A = \{A_1,A_2,A_3,A_4,A_5,A_6,A_7,A_8,A_9,A_{10},A_{11},A_{12},A_{13},A_{14},A_{15},A_{16},A_{17},A_{18},A_{19},A_{20},$ $A_{21},A_{22},A_{23},A_{24},A_{25},A_{26},A_{27},A_{28},A_{29},A_{30}\}$ being set of alternatives, each alternative represents a student.
- $K = \{K_1,K_2,K_3,K_4,K_5,K_6,K_7,K_8,K_9,K_{10},K_{11},K_{12},K_{13},K_{14}\}$ being set of criteria.

The classification of criteria is as follows:

- K_1: Turkish Course Exam Result
- K_2: Social Studies Course Exam Result
- K_3: Religious Culture and Moral Knowledge Course Exam Result
- K_4: English Course Exam Result
- K_5: Mathematics Course Exam Result
- K_6: Science and Technology Course Exam Result
- K_7: Academic Motivation Scale
- K_8: Test Anxiety Scale
- K_9: Attitude Scale for Science and Technology Course
- K_{10}: Attitude Scale for English Course
- K_{11}: Attitude Scale for Social Studies Course
- K_{12}: Attitude Scale for Mathematics Course
- K_{13}: Attitude Scale for Turkish Course
- K_{14}: School Culture Scale

The value of each criterion for each alternative was calculated separately. Classification of criteria as mentioned above is explained in the alternative/criterion table of the students' exam results and the scale applied to students and teachers. The average of the results of the scales was averaged for the degrees of answers to questions of each scale and the data was indicated in Table 1:

	$K1$	$K2$	$K3$	$K4$	$K5$	$K6$	$K7$	$K8$	$K9$	$K10$	$K11$	$K12$	$K13$	$K14$
$A1$	2,67	7,33	5,67	0	0	6	2,32	1,4	3,4	2,78	2,48	2,91	2,1	3,77286
$A2$	6,67	2,33	7,67	4,33	1	3,67	1,86	1,97	2,5	2,56	2,24	3,14	2,45	3,77286
$A3$	0,33	0,33	5,33	0	0,67	2	3,93	2,9	3,7	2,78	2,66	2,5	2,1	3,77286
$A4$	16	5	6,33	1,33	6,33	8,33	2	2,33	3,25	3,11	2,48	3,32	2,6	3,77286
$A5$	8	2	4,67	0	0	0	3,75	1,77	3,35	3	2,97	3,09	3,05	3,77286
$A6$	6	6	7,33	3,33	0,67	3,67	3,5	2,3	3,25	3,07	2,9	2,91	2,9	3,77286
$A7$	16	6	6	3,33	0	6,67	2,75	2,4	2,8	3	2,97	3	2,9	3,77286
$A8$	14,67	6	6	8,67	10,67	13,33	3,82	3,13	3,15	2,56	2,76	3,14	2,55	3,77286
$A9$	17,33	7,33	7,33	1,33	1,33	17,33	3,93	1,53	3,45	2,85	2,38	2,27	3	3,77286
$A10$	17,67	4,67	7,33	7,33	5,33	14,67	2,82	3,03	2,55	2,78	2,34	3,09	2,45	3,77286
$A11$	18,67	8,67	8,67	2,67	10,67	14,67	3,43	2,3	3,3	2,44	2,66	2,77	2,65	3,77286
$A12$	20	8,67	8,67	4,67	7,67	18,67	4	1,53	3,55	1,44	2,86	2,82	3	3,77286
$A13$	9,33	4,67	7,33	4,67	3,33	8,67	4,07	3,1	3,45	2,93	3,1	2,95	3,25	3,77286
$A14$	10,67	7,33	10	8,67	0,33	9,67	3,29	2,03	2,45	2,74	1,9	2,68	2,9	3,77286
$A15$	14,67	3,33	10	4,67	2	10,67	3,14	2,43	2,4	2,56	2,28	2,77	2,45	3,77286
$A16$	16	8,67	8,67	6	8	13,33	2,68	1,83	3,6	3,15	2,93	3,09	3,05	3,77286
$A17$	3	3,67	6	6,67	0,67	3,33	1,79	2,33	2,8	2,96	3,17	3,14	2,8	3,77286
$A18$	8,67	6,33	5,67	1,33	2,33	10,33	4,18	1,73	3,4	2,81	2,9	3,09	2,95	3,77286
$A19$	17,33	7,33	7,33	10	6	17,67	2,93	1,57	3,25	2,3	2,24	2,95	2,5	3,77286
$A20$	17,33	7,33	10	10	8,33	18,67	3,96	1,4	3,55	3,11	2,52	3,09	3	3,77286
$A21$	13,67	7,33	6	4,67	2	7,67	4,21	3,1	3,6	2,78	3,07	3	3	3,77286
$A22$	18,67	7,33	7,33	10	10	18,67	3,46	2,3	2,95	3,19	3,03	3,18	2,75	3,77286
$A23$	18,67	8,67	10	4,67	8	15,33	3,43	1,97	3,25	3,33	2,69	3,09	2,85	3,77286
$A24$	10,67	6	8,67	4,67	9,67	9,33	4,07	2,37	3,25	2,59	3,03	2,91	2,55	3,77286
$A25$	16	2	7,33	3,33	11,33	17,33	3,29	2,8	3,3	2,93	3	2,91	2,6	3,77286
$A26$	5,67	2,33	6	3,67	0	4	3,82	3,3	3,05	2,96	3,24	2,95	3,3	3,77286
$A27$	16	6	8,67	6	7,33	14,67	3	2,9	3,55	2,96	2,1	2,95	3,25	3,77286
$A28$	17,33	6	8,67	10	5,67	13,67	2,64	2,37	2,5	2,19	2,17	2,91	3	3,77286
$A29$	15	3,33	4,67	0	0	6,67	3,93	2,93	3,2	2,7	2,55	2,77	3,25	3,77286
$A30$	12,67	0	7,33	0	1	0,33	2,57	1,7	2,65	2,07	2,52	3,45	2,8	3,77286

Table 1: Values of Alternatives by Criteria

In this study, it is aimed to create a system that takes into account the factors affecting the students' success along with the questions they answer in the exam when calculating the central exam score. In the algorithm established in this direction, courses and factors were included in the system at the same time and evaluated together. Criterion weights represented the importance of criteria. While criterion weights were expressed as intuitionistic fuzzy values, controlled sets defined by Çuvalcıoğlu (2013,2014) were used and the importance of the criteria $\tilde{w}_j(j=1,2,\ldots,m)$ was specified in Table 2 [15,16]:

Weights	$\mu_{\tilde{w}_j}$	$\nu_{\tilde{w}_j}$
$\tilde{w}_1$	1	0
$\tilde{w}_2$	0,25	0,259
$\tilde{w}_3$	0,25	0,259
$\tilde{w}_4$	0,25	0,259
$\tilde{w}_5$	1	0
$\tilde{w}_6$	1	0
$\tilde{w}_7$	0,14	0,259
$\tilde{w}_8$	0,01	0,15
$\tilde{w}_9$	0,21	0,259
$\tilde{w}_{10}$	0,21	0,259
$\tilde{w}_{11}$	0,21	0,259
$\tilde{w}_{12}$	0,21	0,259
$\tilde{w}_{13}$	0,21	0,259
$\tilde{w}_{14}$	0,26	0,25

Table 2: Membership and Non-Membership Values of The Weights of the Criteria

Step 3: Type V linear criteria type was used in the algorithm, criteria types were selected by the decision makers. The reason for this; is for using indifference and strict preference thresholds. The equation (14) was used to calculate deviations of $d_j(x,y)$ in type V linear criteria. In this type of criteria, it is necessary to determine the parameters p,q, including q a difference threshold and p a strict preference threshold. In this study, threshold values specific to each criterion determined by decision makers were taken into account.

Step 4: When creating the preference matrix $U^{(j)}(j=1,2,\ldots,m)$ according to the c_j criterion, the equations (14) and (13) were used for the μ_{ik} preferences between the x_i and x_k alternatives. The preference matrix, whose basic format is 18, was created separately for each criterion according to the data in our algorithm.

Step 5: For each criterion, the $R^{(j)}=(r_{ik}^{(j)})_{n\times n}$ intuitionistic fuzzy preference relationship was created using the equations $\nu_{ik}=\mu_{ki}$ and $\nu_{ki}=\mu_{ik}$. For all criteria $R=(r_{ik})_{n\times n}$ was created with the help of the general intuitive fuzzy preference matrix relationship (22) equation.

Step 6: Using the equations (24) and (25), $\tilde{\varphi}^+(x_i)$ intuitionistic fuzzy positive outranking flow and $\tilde{\varphi}^-(x_i)$ intuitionistic fuzzy negative outranking flow were calculated and were expressed in Table 3. When determining the relationship, the graphs of both the positive outranking flow and the negative outranking flow were given in Figure 1 and Figure 2, respectively. When the values in Figure 1 and Figure 2 were examined, the positive and negative rankings of the alternatives may be visually examined. An alternative that is better in a positive sense is expected to be worse in a negative sense, and the visual figure in the graph may be examined to understand this.

$\rho(\tilde{\varphi}^+(x_1))=$	0,950750602	$\rho(\tilde{\varphi}^-(x_1))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_2))=$	0,950502653	$\rho(\tilde{\varphi}^-(x_2))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_3))=$	0,974403439	$\rho(\tilde{\varphi}^-(x_3))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_4))=$	0,948870394	$\rho(\tilde{\varphi}^-(x_4))=$	0,948870413
$\rho(\tilde{\varphi}^+(x_5))=$	0,958798321	$\rho(\tilde{\varphi}^-(x_5))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_6))=$	0,950305245	$\rho(\tilde{\varphi}^-(x_6))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_7))=$	0,948870811	$\rho(\tilde{\varphi}^-(x_7))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_8))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_8))=$	0,949012443
$\rho(\tilde{\varphi}^+(x_9))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_9))=$	0,948872061
$\rho(\tilde{\varphi}^+(x_{10}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{10}))=$	0,949027996
$\rho(\tilde{\varphi}^+(x_{11}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{11}))=$	0,95064103
$\rho(\tilde{\varphi}^+(x_{12}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{12}))=$	0,952843556
$\rho(\tilde{\varphi}^+(x_{13}))=$	0,948873896	$\rho(\tilde{\varphi}^-(x_{13}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{14}))=$	0,948870426	$\rho(\tilde{\varphi}^-(x_{14}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{15}))=$	0,948870399	$\rho(\tilde{\varphi}^-(x_{15}))=$	0,948870415
$\rho(\tilde{\varphi}^+(x_{16}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{16}))=$	0,949418488
$\rho(\tilde{\varphi}^+(x_{17}))=$	0,950474271	$\rho(\tilde{\varphi}^-(x_{17}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{18}))=$	0,948875383	$\rho(\tilde{\varphi}^-(x_{18}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{19}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{19}))=$	0,95146312
$\rho(\tilde{\varphi}^+(x_{20}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{20}))=$	0,965903314
$\rho(\tilde{\varphi}^+(x_{21}))=$	0,94887075	$\rho(\tilde{\varphi}^-(x_{21}))=$	0,948870393
$\rho(\tilde{\varphi}^+(x_{22}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{22}))=$	0,97098849
$\rho(\tilde{\varphi}^+(x_{23}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{23}))=$	0,952615048
$\rho(\tilde{\varphi}^+(x_{24}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{24}))=$	0,94887043
$\rho(\tilde{\varphi}^+(x_{25}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{25}))=$	0,948979765
$\rho(\tilde{\varphi}^+(x_{26}))=$	0,953449856	$\rho(\tilde{\varphi}^-(x_{26}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{27}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{27}))=$	0,94945694
$\rho(\tilde{\varphi}^+(x_{28}))=$	0,948870392	$\rho(\tilde{\varphi}^-(x_{28}))=$	0,949229282
$\rho(\tilde{\varphi}^+(x_{29}))=$	0,948876266	$\rho(\tilde{\varphi}^-(x_{29}))=$	0,948870392
$\rho(\tilde{\varphi}^+(x_{30}))=$	0,949142587	$\rho(\tilde{\varphi}^-(x_{30}))=$	0,948870392

Table 3: Relationship Between Intuitionistic Fuzzy Positive and Negative Outranking Flow Values

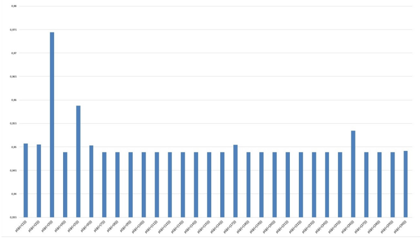

Fig. 1: Graphic of Positive Outranking

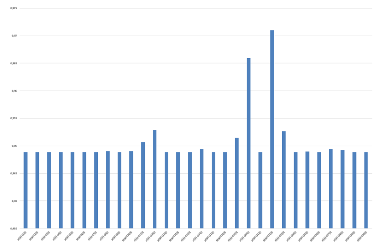

Fig. 2: Graphic of Negative Outranking

Step 7: By looking at the positive and negative outranking flow above, it was seen that the rankings were incomparable. Due to this incomparableness, net outranking flow calculation was performed to obtain clear ranking. Net outranking flow values are specified in Table 4 with the help of 26. A graphic of the net outranking flow is given in Figure 3. The smaller ρ value, the higher the rank of that alternative. In other words, the smaller ρ value, the higher the alternative's suitability for selection. By examining the values in Figure 3, net ranking was obtained when the values of the alternatives are ordered from smallest to largest. Thanks to Figure 3, the values of the alternatives were examined visually together with the numerical data. While examining this graph, it should be kept in mind that as the values of the alternatives decrease, that alternative is better.

$\rho(\tilde{\varphi}(x_1)) =$	0,001880209
$\rho(\tilde{\varphi}(x_2)) =$	0,001632261
$\rho(\tilde{\varphi}(x_3)) =$	0,025533046
$\rho(\tilde{\varphi}(x_4)) =$	-0,00000001
$\rho(\tilde{\varphi}(x_5)) =$	0,009927929
$\rho(\tilde{\varphi}(x_6)) =$	0,001434853
$\rho(\tilde{\varphi}(x_7)) =$	0,0000004
$\rho(\tilde{\varphi}(x_8)) =$	-0,00014205
$\rho(\tilde{\varphi}(x_9)) =$	-0,000001
$\rho(\tilde{\varphi}(x_{10})) =$	-0,000157604
$\rho(\tilde{\varphi}(x_{11})) =$	-0,001770638
$\rho(\tilde{\varphi}(x_{12})) =$	-0,003973164
$\rho(\tilde{\varphi}(x_{13})) =$	0,000003
$\rho(\tilde{\varphi}(x_{14})) =$	0,00000003
$\rho(\tilde{\varphi}(x_{15})) =$	-0,00000001
$\rho(\tilde{\varphi}(x_{16})) =$	-0,000548096
$\rho(\tilde{\varphi}(x_{17})) =$	0,001603879
$\rho(\tilde{\varphi}(x_{18})) =$	0,000004
$\rho(\tilde{\varphi}(x_{19})) =$	-0,002592727
$\rho(\tilde{\varphi}(x_{20})) =$	-0,017032922
$\rho(\tilde{\varphi}(x_{21})) =$	0,0000003
$\rho(\tilde{\varphi}(x_{22})) =$	-0,022118097
$\rho(\tilde{\varphi}(x_{23})) =$	-0,003744656
$\rho(\tilde{\varphi}(x_{24})) =$	-0,00000003
$\rho(\tilde{\varphi}(x_{25})) =$	-0,000109372
$\rho(\tilde{\varphi}(x_{26})) =$	0,004579464
$\rho(\tilde{\varphi}(x_{27})) =$	-0,000586547
$\rho(\tilde{\varphi}(x_{28})) =$	-0,00035889
$\rho(\tilde{\varphi}(x_{29})) =$	0,000005
$\rho(\tilde{\varphi}(x_{30})) =$	0,000272195

Table 4: Intuitionistic Fuzzy Net Outranking Flow Values

If these values and charts are interpreted; the relationship between available system that is evaluated only by exam success and the system we have established where the factors are also in operation has been examined. When only the exam success is evaluated, the correct ranking between these students from the successful student to the unsuccessful student can be stated as follows:

$$A_{22}, A_{20}, A_{12}, A_{11}, A_{25}, A_{23}, A_{19}, A_8, A_{16}, A_{27}, A_{28}, A_{10}, A_9, A_{24}, A_4,$$
$$A_{15}, A_{14}, A_{21}, A_{13}, A_{18}, A_7, A_{29}, A_2, A_6, A_{30}, A_{26}, A_1, A_{17}, A_5, A_3$$

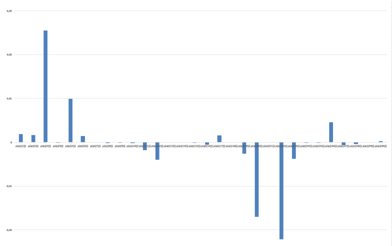

Fig. 3: Graphic of Net Outranking

The factors affecting success and the ranking according to the net outranking flow calculated in the algorithm established by us to evaluate the test success together are as follows:

$$A_{22}, A_{20}, A_{12}, A_{23}, A_{19}, A_{11}, A_{27}, A_{16}, A_{28}, A_{10}, A_{8}, A_{25}, A_{9}, A_{24}, A_{4}, A_{15}, A_{14}, A_{21}, A_{7}, A_{13}, A_{18}, A_{29}, A_{30}, A_{6}, A_{17}, A_{2}, A_{1}, A_{26}, A_{5}, A_{3}$$

In order to better see the difference between these two rankings, the rankings were examined with the help of Table 5. Here, the ranking in the evaluation made only by exam success is called the first ranking, and the net ranking calculated by net outranking flow is called net ranking:

Only students who differed in ranking compared to the order obtained according to the algorithm we established with the ranking of the students evaluated by exam success were represented above. While some students were more at the forefront of the first ranking, they fell behind in the net ranking; or there are students who are behind in the first ranking and who are at the forefront of the net ranking. All criteria related to students who experienced changes in ranking were examined and interpreted one by one. With the system we have established, a unique decision-making mechanism has been established when evaluating the achievements of students, taking into account the factors affecting success. With this system, which includes the achievements of the students, it has been observed that these factors have a significant impact on success. Their responses to the scales applied to measure both exam results and other factors affecting success related to students who experienced changes in ranking were examined and interpreted one by one. The findings are as follows:

- In some courses, the exam results are very good, while in some courses the nets are very low. While this is not an obstacle for the real exam to succeed, it shows that in the system we have established, the student is not successful in average terms, but only works results-oriented by loading them into some courses.
- It has been observed that more objective results will be obtained by evaluating with a system in which the factors affecting student success are also in effect.
- Improvements can be made to the evaluation system not only according to the exam results, but also thanks to the original algorithm we have prepared.
- According to the original evaluation mechanism we created, the factors affecting the success of the students cause a serious change in the exam results.
- An original evaluation system can be created by examining the effect levels of the factors affecting the success of the students and adding variables such as individual study, preliminary preparation and study system to each student according to these effects.

First Ranking	Net Ranking
A_{22}	A_{22}
A_{20}	A_{20}
A_{12}	A_{12}
A_{11}	A_{23}
A_{25}	A_{19}
A_{23}	A_{11}
A_{19}	A_{27}
A_{8}	A_{16}
A_{16}	A_{28}
A_{27}	A_{10}
A_{28}	A_{8}
A_{10}	A_{25}
A_{9}	A_{9}
A_{24}	A_{24}
A_{4}	A_{4}
A_{15}	A_{15}
A_{14}	A_{14}
A_{21}	A_{21}
A_{13}	A_{7}
A_{18}	A_{13}
A_{7}	A_{18}
A_{29}	A_{29}
A_{2}	A_{30}
A_{6}	A_{6}
A_{30}	A_{17}
A_{26}	A_{2}
A_{1}	A_{1}
A_{17}	A_{26}
A_{5}	A_{5}
A_{3}	A_{3}

Table 5: Comparison of Student Achievement Ranking

6 Conclusion and Suggestions

In this study, our goal is; to address every aspect of the intuitionistic fuzzy PROMETHEE method and to create a system that will evaluate all the positive or negative factors that affect success at the same time by establishing an algorithm with this method, allowing us to give each of these factors a degree of importance (contribution score) individually, and eventually sort and select by giving us an evaluation score. The intuitionistic fuzzy based-PROMETHEE algorithm, which aims to study the factors affecting the student's success and contribute to the education system, is a unique algorithm and is the first to shed light on many researchers. Intuitionistic fuzzy PROMETHEE method; it is a method that benefits us because of its benefits such as giving the researcher the chance to observe the positive and negative order at the moment, expressing degrees of hesitation, changing the importance weights of the criteria and allowing us to use different methods when determining the importance ratings for each criterion, also putting in place degrees of hesitation of importance weights, allowing decision makers who are given the chance to use different types of criteria and different criteria types for alternatives and criteria to establish a unique system and which we use in our field of application. In this study, V shape criterion type was used. It is planned to make different applications using this method in the future. New applications will be made using the Gaussian criterion type and other types. Both PROMETHEE, fuzzy PROMETHEE and intuitionistic fuzzy PROMETHEE method have attracted the attention of many researchers and are incorporated into their application areas. The general algorithm of the intuitionistic fuzzy PROMETHEE method is available in all application areas and is explained in detail in this study for researchers to benefit from. This method is easily used by researchers who want to create a multi-criterion decision-making mechanism and think that hesitation should be understood in the decision-making problem. In this study, the training area was selected and applied as the application area of the intuitionistic fuzzy PROMETHEE method.

We think that this method will lead to studies that will shed light on both the field of education and the field of decision making. The decision-making mechanism project, which will evaluate and improve the current education system by developing this method, will be proposed to the Ministry of National Education. In this method, the effect of different criteria types on the result will be investigated by changing the criteria types. In addition, the number of students participating in the study will be increased and the study will be implemented with wider alternatives and wider criteria.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors have contributed to all parts of the article. All authors read and approved the final manuscript.

References

[1] Akdemir, H.G., Expectiles for Fuzzy Variables and Their Applications to Network Flow Problems with Non-Negative Fuzzy Costs, New Trends in Mathematical Sciences, 8(3):1-8,(2020).

[2] Albadvi, A., Formulating National Information Technology Strategies: A Preference Ranking Model Using PROMETHEE Method", European Journal of Operational Research, 153:290-296, (2004).

[3] Albadvi, A., Chaharsooghi, S.K., Esfahanipour, A., Decision making in stock trading: An application of PROMETHEE, European Journal of Operational Research, 177:673-683, (2007).

[4] Atanassov, K.T., Intuitionistic Fuzzy Sets, VII ITKR Session, Sofia, 20-23 June 1983. (Deposed in Centr. Sci.-Techn. Library of the Bulg. Acad. of Sci., 1697/84) (in Bulgarian), Reprinted: Int. J. Bioautomation 20(S1), (2016).

[5] Atanassov, K.T., Intuitionistic Fuzzy Sets, Fuzzy Sets and Systems, 20(1):87-96, (1986).

[6] Aydın, U., Bulgan, G., Adaptation of Children's Test Anxiety Scale to Turkish, Elementary Education Online, 16(2):887-899, (2017).

[7] Baş, G., Attitude Scale for Elementary English Course: Validity and Reliability Study, International Online Journal of Educational Sciences, 4(2):411-424, (2012).

[8] Brans, J.P., L'ingenierie de la decision: l'elaboration d'instruments d'aide a la decision. Colloq. d'aide a la decision, Universite Laval, Quebec, Canada, Aou, (1982).

[9] Brans, J.P., Mareschal, B., Vincke, P., PROMETHEE: A New Family of Outranking Methods in Multicriteria Analysis, Operational Research, IFORS, 84:477-490, (1984).

[10] Brans, J.P., Vincke, P.H., A Preference Ranking Organisation Method (The PROMETHEE Method for Multiple Criteria Decision Making), Management Science, 31(6):647-656, (1985).

[11] Brans, J.P., Mareschal, B., Chapter 5: PROMETHEE Methods. In:Multiple Criteria Decision Analysis: State of the Art Surveys, International Series in Operations Research- Management Science, 78, (2005), https://doi.org/10.1007/0-387-23081-5-5.

[12] Behzadian, M., Kazemzadeh, R.B., Albadvi, A., Aghdasi, M., PROMETHEE:A Comprehensive Literature Reviewon Methodologies and Applications, European Journal of Operational Research, 200:198-215, (2010).

[13] Büyüközkan, G., Göçer, F., Application of A New Combined Intuitionistic Fuzzy MCDM Approach Based on Axiomatic Design Methodology for The Supplier Selection Problem, Applied Soft Computing, 52:1222-1238, (2017).

[14] Çitil, M., Tuğrul, F., Yılmaz, B., An Application of Multi Criteria Decision Making: Ranking of School Success, Celal Bayar University Journal of Science, 15(1):45-50, (2019).

[15] Çuvalcıoğlu, G., Controlled Set Theory, Bogolyubov Readings DIF-2013, Ukraine,342, (2013).

[16] Çuvalcıoğlu, G., Some Properties of Controlled Set Theory, Notes on Intuitionistic Fuzzy Set, 20(2):37-42, (2014).

[17] Gömleksiz, M.N., Kan, A.Ü., A Study of Validity and Reliability of an Attitude Scale on Social Studies Course, Fırat University Journal of Social Science, 23(2):139-148, (2013).

[18] Liao, H., Xu, Z., Priorities of Intuitionistic Fuzzy Preference Relation Based on Multiplicative Consistency, IEEE Transactions on Fuzzy Systems, 22(6):1669-1681, (2014).

[19] Liao, H., Xu, Z., Some Algorithms for Group Decision Making with Intuitionistic Fuzzy Preference Information, International Journal of Uncertainty Fuzziness and Knowledge-Based Systems, 22(4):505-529, (2014).

[20] Liao, H., Xu, Z., Multi-Criteria Decision Making with Intuitionistic Fuzzy PROMETHEE, Journal of Intelligent Fuzzy Systems, 27:1703-1717, (2014).

[21] Majumder, M., Multi Criteria Decision Making, Chapter 2, Springer, 35-47, (2015).

[22] Republic of Turkey Ministry of National Education (MEB), 2023 Education Vision,(2020a), https://2023vizyonu.meb.gov.tr/.

[23] Republic of Turkey Ministry of National Education (MEB), Central Examination For Secondary Education Institutions,(2020b), http://www.meb.gov.tr/meb_sinavindex.php?KATEGORI=34-35-36-37&B=7

[24] Nuhoğlu, H., The Development of an Attitude Scale for Science and Technology Course, Elementary Education Online, 7(3):627-639, (2008).

[25] Önal, N., A Study on the Development of a Middle School Students' Attitudes towards Mathematics Scale, Elementary Education Online, 12(4):938-948, (2013).

[26] Shamilov, A., İnce, N., A New Method Of Approximation For Fuzzy Membership Function With Application, Anadolu University Journal of Science and Technology B-Theoretical Sciences, 5(1):1-12, (2016).

[27] Sözeyatarlar, M., Şahin, M., Yavuz, E., Statistical Relations Measures, Journal of Universal Mathematics, 4(2):283-295,(2021).

[28] Szmidt, E., Kacprzyk, J., Amount of Information and Its Reliability in the Ranking of Atanassov's Intuitionistic Fuzzy Alternatives, in: E. Rakus-Andersson, R.R. Yager, N. Ichalkaranje, L. Jain, ed. Recent advances in decision making (Studies in Computational Intelligence), Berlin, Germany: Springer, 7-19, (2009).

[29] Taşlıtarla, Ö.A., The Factors Affecting Mathematics Achievement, MSc Thesis, Hacettepe University,(1998).

[30] Terzi, A.R., Organizational Culture in Primary Schools, Kuram ve Uygulamada Eğitim Yönetimi (in Turkish), 43:423-442, (2005).

[31] Tuğrul, F., Çitil, M., A New Perspective on Evaluation System in Education with Intuitionistic Fuzzy Logic and PROMETHEE Algorithm, Journal of Universal Mathematics, 4(1):13-24, (2021).

[32] Tuğrul, F., Application of Intuitionistic Fuzzy Logic with a New Method in Multi Criteria Decision Making Process, PhD Thesis, Kahramanmaraş Sütcü İmam University, (2021).

[33] Vallerand, R.J., Blais, M.R., Briere, N.M., Pelletier, L.G., Construction et validation de l'Echelle de Motivation en Education (EME). Revue canadienne des sciences du comportement, 21:323-349, (1989).

[34] Vallerand, R.J., Pelletier, L.G., Blais, M.R., Briere, N.M., Senecal, C., Vallieres, E.F., The Academic Motivation Scale: A Measure of Intrinsic, Extrinsic, and Amotivation in Education, Educational and Psychological Measurement, 52:1003-1017, (1992).

[35] Vincke, P.H., Brans, J.P., A Preference Ranking Organization Method. The PROMETHEE method for MCDM, Management Science, 31(6):647-656, (1985).

[36] Wang,, Z.J., Derivation Of Intuitionistic Fuzzy Weights Based On Intuitionistic Fuzzy Preference Relations, Applied Mathematical Modelling, 37:6377-6388, (2013).

[37] Wren, D.G., Benson, J., Measuring Test Anxiety in Children: Scale Development and Internal Construct Validation, Anxiety, Stress & Coping, 17(3):227-240, (2004).

[38] Xu, Z., Yager, R.R., Some Geometric Aggregation Operators Based on Intuitionistic Fuzzy Set, International Journal of General Systems, 35:417-433, (2006).

[39] Xu, Z., Intuitionistic Fuzzy Aggregation Operators, IEEE Transactions on Fuzzy Systems, 15:1179-1187, (2007).

[40] Xu, Z., Intuitionistic Preference Relations and Their Application in Group Decision Making, Information Sciences, 177(11):2363-2379, (2007).

[41] Xu, Z., Liao, H., Intuitionistic Fuzzy Analytic Hierarchy Process, IEEE Transactions on Fuzzy Systems, 22(4):749-761, (2014).

[42] Yetim, H., It Is A Study About Academic Achievement Of The Students In Maths And Turkish Subjects, MSc Thesis, Dokuz Eylül University, (2002).

[43] Yurt, E., Bozer, E.N., The Adaptation of the Academic Motivation Scale for Turkish Context, Gaziantep University Journal of Social Sciences, 14(3):669-685, (2015).

[44] Zadeh, L.A., Fuzzy Sets , Information and Control, 8:338-353, (1965).