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Prioritizing Individuals Who Will Have Covid-19 Vaccine with Multi-Criteria Decision Making Methods

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Highlights

- This article focuses on prioritizing individuals to be vaccinated against COVID-19.
- A hybrid approach with AHP-PROMETHEE integration is proposed for prioritizing individuals in study.
- A decision model is proposed for efficient use of limited vaccine resources.

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Abstract

This study aims to prioritize individuals in vaccination for the effective use of the COVID-19 vaccine, which has limited supply and does not seem possible to be supplied by all countries at the same time. In the study, multi-criteria decision-making methods (MCDM), which offer practical solutions to decision problems, were used considering the structure of the problem. First, the analytic hierarchy process (AHP) method was used to calculate the weights of the criteria. Then, the ranking of the priorities of the individuals was carried out with the PROMETHEE method. Here, the AHP and PROMETHEE methods are used in an integrated manner. It has been determined that the highest priority individual in vaccination is a healthcare worker with a high potential for transmission. In order of priority, the second individual was identified as workers. In this study, a hierarchical structure was created to prioritize individuals who will be vaccinated against COVID-19 and the problem was solved in two stages. A health policy proposal was made to health managers to use limited vaccine resources by prioritizing individuals effectively. In terms of efficient and effective use of resources during possible pandemic periods, the application process of the study provides an exemplary solution for decision-makers and contributes to the solution of similar decision problems encountered both in the literature and in real life. At the same time, offers solution for disasters that require effective use of limited resources, etc. The implementation process of the study may also be taken into account in exceptional circumstances.

1. INTRODUCTION

The world has experienced many outbreaks such as plague, cholera, flower disease, Spanish flu, SARS, Swine flu, and Ebola. The black death, flower disease, and the Spanish flu, the number of deaths were the highest epidemics. To add these outbreaks, leading deaths of millions of people is is actually more than a new epidemic called COVID-19. The COVID-19 epidemic declared by the World Health Organization (WHO) has first appeared in late December 2019 in China's Wuhan Province. This epidemic, which started in Wuhan, transmitted from human to man, spread to all Earth countries [1].

In the COVID-19 outbreak causing the death of thousands of people every day, approximately 2,84 million people died throughout the world as of March 2021. In this process, health managers recommend taking various precautions for the control of the release and the protection of community health. Inserting the mask in public areas, isolating patient and contact individuals, and the social distance rules are at the beginning of these measures. Various methods have been applied to the treatment of the disease until today. In the late 2020, the vaccine between treatment methods was also added to the procedure. In vaccination, it was first reported by the Medicines and Health Products Regulatory Authority in the UK in December 2020 that the "BNT162b2"

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vaccine is safe for widespread use. However, vaccines with different effect levels in the treatment of COVID-19 are candidates to be included in the treatment process. After the vaccine candidates have been approved for implementation as a result of demonstrating their effectiveness in treatment, effective and fair planning of health management policies is essential in terms of reducing the social effects of the epidemic. However, since it is not possible to produce and supply a sufficient number of vaccines in a short time, managers who are in a decision-making position regarding vaccination applications should determine the individuals who are priority in vaccination by taking into account various criteria and define a vaccine policy accordingly.

The fact that the COVID-19 epidemic affects each individual differently makes it difficult for decision-makers to determine health policies. At the same time, considering an individual's age, chronic illness, risk of job environments, etc., is making the problem more complex. This case is seen as a multi-criteria decision-making (MCDM) problem since it requires considering many criteria in determining priority people in vaccination applications. In the literature on the selection and prioritization of alternative individuals, MCDM methods have a wide range of applications such as transportation, education, health, finance, and production.

Kabak and Kazançoğlu [2], used the fuzzy Analytic hierarchy process (AHP) method of teacher selection for a military school in the field of education, Özder, Bedir and Eren [3], used AHP and PROMETHEE methods to determine the researcher to be in the project team in the higher education institution, Kenger and Organ [4] used the ARAS method to select bank personnel in the financial sector and made the most appropriate choice.

In health, the AHP method was used to calculate the weights of the criteria determined in the selection of wearable health technology in the follow-up of COVID-19 patients, and the alternatives were evaluated with TOPSIS and PROMETHEE methods [5]. There are a few studies in the literature to prioritize candidates for vaccine during the COVID-19 process. In these studies, Dooling [6], considered a classification for occupational prioritization groups and stated that the most critical prioritization group was healthcare workers. Bubar et al. [7] and took into account age and serological conditions in vaccination. Another study is Hezam et al. [8]. This study suggested determining priority groups in vaccination using fuzzy AHP and TOPSIS methods. In addition, Liu et al. [9], for the selecting of personnel in the health sector used the VIKOR method for choosing nurses. In the literature TOPSIS [10,11], AHP [12,13], Analytic Network Process (ANP) [12], PROMETHEE [14,15], VIKOR [9,16], which contribute to the effective solution of decision problems that arise for various purposes such as vehicle selection, equipment selection, supplier selection, and personnel selection are methods. In recent years, it is seen that MCDM methods have applications in the field of chemistry [17,18].

The use of MCDM methods in the field of health is very common both before and during the COVID-19 period and before. The studies examined in this context are summarized in this paragraph. Yazıcı et al. [19] to determine an effective vaccination policy in the COVID-19 period, TOPSIS and PROMETHEE methods were used in the evaluation of the most appropriate vaccine alternative, taking into account the relations of the countries with the supplier countries. For the robustness of the proposed results, sensitivity analysis was performed with MCDM techniques. Ozkan et al. [20] considering the need for intensive care units during the COVID-19 period, the criteria to be considered in the admission of patients to the intensive care unit have been determined for the planning of intensive care resources. In the study, after the criterion weights were calculated with fuzzy AHP, the alternatives were ranked with the MOORA method. Liu et al.[21] determined the factors affecting the adoption of mobile health services and calculate the priority values of the criteria with MCDM methods. Verma and Dutta [22] determined the critical success criteria that are effective in increasing the quality of services in health with MCDM methods and evaluated them for three different purposes. Cihan et al.[23] determined the most suitable alternative by using AHP and TOPSIS methods in the selection of echocardiography devices in hospitals.

Although it is seen that studies on the selection or prioritization of individuals with MCDM methods are among the solution methods used in the literature, it has been observed that there are few studies on prioritizing individuals for treatment applications in the field of health. As a result of the research carried

out within the scope of the study, the contribution of this study to the literature can be summarized as follows;

- The study assists decision-makers in determining policies regarding health management. It facilitates decision-making by prioritizing individuals in the COVID-19 vaccination process.
- AHP-PROMETHEE methods, one of the MCDM methods, have been applied in an integrated manner in prioritizing individuals in health management policies. The PROMETHEE method, which allows quantitative and qualitative criteria to be sorted by considering different preference functions in evaluating alternatives, offers a significant advantage. Due to the nature of the criteria, it is necessary to use different preference functions in determining the individuals to be vaccinated. In this respect, individuals were prioritized more consistently in these study.
- In determining the priority of vaccination, taking into account the population density in the region where the individual lives to represent the intensity of COVID-19, unlike the literature, together with the criteria for age, gender, occupational risk, chronic disease, COVID-19 history, and routine drug use, it is a hierarchical for decision-makers in determining and implementing vaccination policies. It is thought that contributions to the literature will be provided with a decision support model proposal.

In the first section of the study, information about the subject and the literature are presented, and in the second section, MCDM methods are explained. In the third section, information about the methods used is given. In the fourth section, the definition of the problem and the weights of the criteria for the problem's solution were obtained with AHP. The priorities of the alternatives were obtained with PROMETHEE. In the fifth section, the results are evaluated.

2. MULTI CRITERIA DECISION MAKING METHODS

Decision-making is defined as the process of choosing the most suitable for a purpose. In this process, various methods are available to select the optimal alternative by systematically evaluating the knowledge and experiences of the decision-maker in the face of uncertainty and complexities. Among these methods, the MCDM methods evaluate multiple alternatives by various criteria to help the decision-maker. The MCDM methods are rated by comparing the alternatives of the prominent number and feature candidate, the plan, policy, strategy and the form of action, and the decision-making process is selected the most appropriate alternative to the purpose. In this process, they solve complex problems with conflicting qualities using the criterion weight information. In solving the problem addressed in this study, the AHP method, which offers effective results with its ease of application, which is frequently used in the literature, was used in weighting the criteria. In prioritizing the alternatives, the PROMETHEE method, which provides the opportunity to define a function for each criterion, taking into account the differences of the criteria considered within the scope of the problem, was used.

2.1. Analytic Hierarchy Process Method

AHP method, defining the decision problem and showing all the elements of the problem to be evaluated in a hierarchical structure is the first step of the method. At this stage, the purpose of the problem, that is, the decision to be made, should be determined. The application algorithm of the AHP method consists of six steps given below [24].

Step 1: Decision problem, alternatives, and criteria are determined.

Step 2: The criteria weights are calculated with pairwise comparisons. Using Saaty's 1-9 point scale, the relative importance of the weights of the evaluation criteria in the hierarchy is found and pairwise comparison matrices are created (Table 1).

Table 1. *The importance scale of AHP*

Intensity of Importance	Definition
1	Equal
3	Moderate Importance
5	Strong Importance
7	Very Strong
9	Extremely
2, 4, 6, 8	Intermediate Values

Step 3: The normalized decision matrix is created.

Step 4: Calculate the consistency index (CI) measured as follows: Firstly, calculated the λ_{max} (pairwise comparison the largest value of the matrix) value for total consistency;
The n value used here refers to the matrix size. The consistency index are calculated as in Equation (1)

$$CI = \frac{\lambda_{max} - n}{n-1}. \tag{1}$$

Step 5: The consistency ratio (CR) are calculated. If the CR is less than 0.10 (CR < 0.1), then the ratio shows an acceptable level of consistency in the AHP. If CR is more than 0.10 (CR > 0.1), the ratio is inconsistent as follows:

$$CR = \frac{CI}{RI}. \tag{2}$$

Random index (RI) are given in Table 2 according to the size of the comparison matrix. RI takes different values based on the size of the comparison matrix and is the average of the CI values of the pairwise comparison matrices [25].

Table 2. *Random index (RI)*

N	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56

2.2. PROMETHEE Method

PROMETHEE method is a sorting algorithm developed by Brans in 1982. The method determines the order of decision points with the main stages PROMETHEE I (partial order) and PROMETHEE II (full order). PROMETHEE method is based on binary comparisons of decision points according to evaluation factors. The main difference of the PROMETHEE method from other MCDM methods is that besides the importance weights showing the relationship level between the evaluation factors, each evaluation factor also considers its internal relationship [26].

Step 1: Establish a decision matrix (Table 3)

Table 3. *Data matrix*

		Evaluation Factors				
		f_1	f_2	f_3	…	f_k
Decision Point	A	f_1 (A)	f_2 (A)	f_3 (A)	…	f_k(A)
	B	f_1 (B)	f_2 (B)	f_3 (B)	…	f_k(B)
	C	f_1 (C)	f_2 (C)	f_3 (C)	…	f_k(C)
	…	…	…	…	…	…
Weights	W_i	W_1	W_2	W_3	…	W_k

Step 2: Determining preference functions for each criterion (Table 4)

Table 4. *PROMETHEE method preference function*

Type	Function	Parameter
Usual	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 & d > 0 \end{cases}$	…
U Type	$P(d) = \begin{cases} 0 & d \le q \\ 1 & d > q \end{cases}$	Q
V Type	$P(d) = \begin{cases} 0 & d \le 0 \\ \frac{d}{p} & 0 < d \le p \\ 1 & d > p \end{cases}$	P
Level	$P(d) = \begin{cases} 0 & d \le q \\ \frac{1}{2} & q < d \le p \\ 1 & d > p \end{cases}$	p, q
Linear	$P(d) = \begin{matrix} 0 & d \le q \\ \frac{(d-s)}{r} & s \le d \le s+r \\ 1 & d \ge s+r \end{matrix}$	s, r
Gaussian	$P(d) = \begin{matrix} 0 & d \le 0 \\ 1 - e^{-\frac{x^2}{2\sigma^2}} & d \ge 0 \end{matrix}$	Σ

Step 3: Global preference functions are determined for alternative pairs based on preference functions

$$P(a,b) = \begin{Bmatrix} 0 & , f(a) \le f(b) \\ P[f(a) - f(b)], & f(a) > f(b) \end{Bmatrix}. \quad (3)$$

Step 4: Computing the global preference index for each alternative.

$$\pi_{(a,b)} = \frac{\sum_{i=1}^{k} w_i P_i(a,b)}{\sum_{i=1}^{k} w_i} \quad . \quad (4)$$

Step 5: Calculating the positive and negative outranking flows with concerning the alternatives. By Equations (5) and (6), respectively

$$\emptyset^{+}(\alpha) = \sum \pi(a,x) \quad x = (b,c,d,\dots) \quad (5)$$

$$\emptyset^{-}(\alpha) = \sum \pi(x,a) \quad x = (b,c,d,\dots) \quad . \quad (6)$$

Step 6: Calculating partial priorities with PROMETHEE I.

Alternative a is preferred to alternative b in Equations (7), (8), and (9)

$$\emptyset^{+}(a) > \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) < \emptyset^{-}(b), \quad (7)$$

$$\emptyset^{+}(a) > \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) = \emptyset^{-}(b), \quad (8)$$

$$\emptyset^{+}(a) = \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) < \emptyset^{-}(b). \quad (9)$$

In situations where alternatives do not have superiority over each other, Equation (10):

$$\emptyset^{+}(\alpha) = \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) = \emptyset^{-}(b). \tag{10}$$

Alternative b is preferred to alternative a: in Equations (11) and (12)

$$\emptyset^{+}(\alpha) > \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) > \emptyset^{-}(b), \tag{11}$$

$$\emptyset^{+}(\alpha) < \emptyset^{+}(b) \text{ ve } \emptyset^{-}(a) < \emptyset^{-}(b). \tag{12}$$

Step 7: Calculating full priorities with PROMETHEE II

$$\emptyset(\alpha) = \emptyset^{+}(a) - \emptyset^{-}(a). \tag{13}$$

3. PRIORITIZING INDIVIDUALS WHO WILL BE VACCINATED WITH COVID-19 VACCINE

Many vaccine studies have been done and are being done in the treatment of the COVID-19 epidemic. However, not every vaccine can be approved for use in treatment. With the introduction of vaccines that have been approved within the scope of treatment, there has been great competition between countries for vaccine supply. However, it seems difficult to supply a sufficient number of vaccines to all countries in the world in a short time. For this reason, countries that can supply vaccines should determine a vaccination policy that will reduce the spread of the epidemic in vaccination. Since it is not possible to vaccinate all individuals simultaneously, it is essential to determine the priorities among individuals and plan the vaccination schedule accordingly in terms of effective and efficient management of both the epidemic and the vaccination. This problem, which arises for the determination of health management policy, is an important problem for all countries in the world. In this study, the problem of which individuals should be administered primarily to the vaccines provided for the health management policy towards COVID-19 vaccination has been addressed. In solving the problem, the weights of the criteria determined by the AHP method were calculated. The solution to the problem was achieved by applying the PROMETHEE method to prioritize the alternatives. The application flow chart of the study is given in Figure 1.

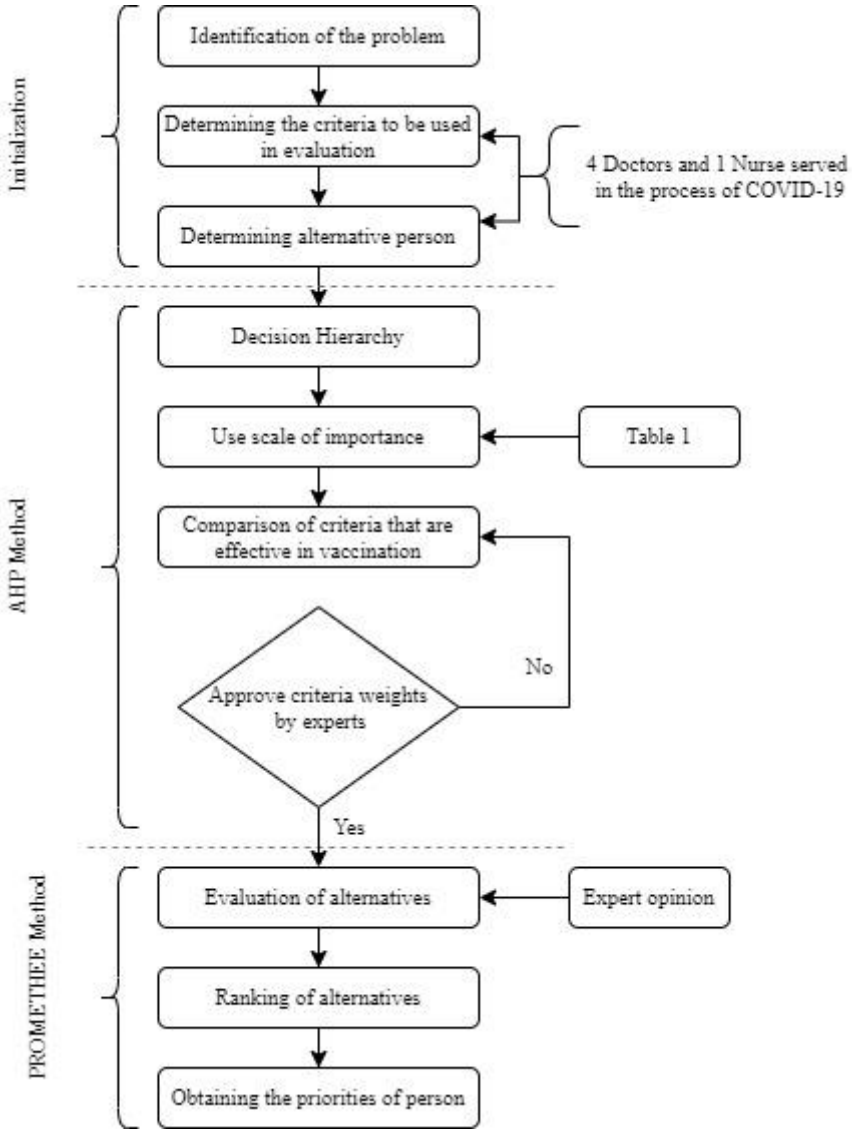

***Figure 1**. Application flow chart*

3.1. Determination of Criteria and Alternatives

With the emergence of the COVID-19 virus, each individual shows different symptoms. The individual's age, gender, chronic illnesses, routine medications, the region he lives in, his occupation, and exposure to COVID-19 constitute the study's criteria. Specialist doctors determined criteria and pairwise comparisons. Experts are experienced and knowledgeable in their fields by actively participating in diagnosing, and treating the disease in the COVID-19 process. The opinions of five experts were used in the study. Expert 1 is a 14-year-experienced physician as a general surgeon assigned to COVID-19 outpatient clinics. Expert 2 is intensive care specialist and is a doctor with 15 years of experience working in the COVID-19 intensive care unit. He is a specialist doctor with 2 years of experience working in the Expert 3 filiation team. Expert 4, is an academic with the title of professor and is also a doctor for 32 years. Expert 5 works as a cardiovascular surgery nurse in the pediatric intensive care unit and has 14 years of experience. Expert 5 has information for pediatric patients during the COVID-19 period.

Ten different candidates were selected to determine which individuals should be given the first vaccines during the COVID-19 process. In the selection of candidates, information was obtained from doctors who have experience in the COVID-19 process. In selecting candidates, individuals who are thought to have different effects of the COVID-19 virus have been included in the alternatives. Information on the determined candidates is summarized in Table 5.

Table 5. *Data on the problem in terms of alternatives and criteria*

Criteria / **Alternative**	Age	Gender	Risk of occupation	Chronic Illness	Pull Through the COVID-19 (Yes/No)	Population the of city of residence	Routine Drug Use
Person A	12	M	Student	✓	No	Downtown	Yes
Person B	23	W	Student	X	No	Downtown	No
Person C	25	M	Deliverer	✓	Yes	District	Yes
Person D	28	W	Housewife	X	No	Downtown	No
Person E	34	W	Civil Servant	✓	Yes	Downtown	Yes
Person F	38	W	Private Sector Employee	✓	Yes	District	Yes
Person G	45	M	Medical Personnel	✓	No	Downtown	Yes
Person H	47	M	Bus Driver	X	No	Downtown	No
Person I	50	M	Worker	✓	Yes	District	Yes
Person J	68	M	Retired	✓	No	District	Yes

3.2. Weighting the Criteria with AHP Method

The AHP method calculated the criteria determined in the prioritization for the COVID-19 vaccine. The hierarchical structure of our problem is shown in Figure 2.

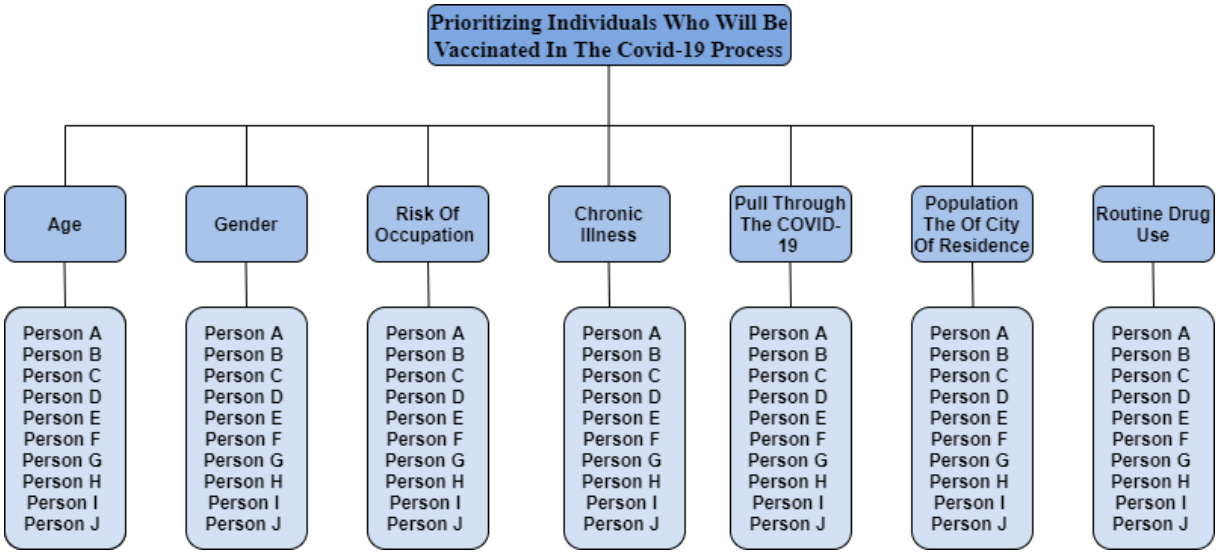

Figure 2. *Hierarchical structure*

Presented at the data in Table 5, the first criterion resulting from comparing the criteria was an occupational risk. Chronic disease criterion comes second. Then, age, routinely used medication, COVID-19 passing status, gender, and the city where the individual lives are followed in order of priority. The priority of the occupational risk criteria resulting from the comparison matrix confirms the information received by expert opinions. The comparison matrix is presented in Table 6.

Table 6. *The comparison matrix of criteria*

Criteria	Age	Gender	Risk of Occupation	Chronic Illness	Pull Through the COVID-19	Population the of city of residence	Routine Drug Use
Age	1	3	0,67	0,75	2	6	1,5

Gender	0,33	1	0,22	0,25	0,67	2	0,5
Risk of Occupation	1,5	4,5	1	1,13	3	9	2,25
Chronic Illness	1,33	4	0,89	1	2,67	8	2
Pull Through the COVID-19	0,5	1,5	0,33	0,38	1	3	0,75
Population the of city of residence	0,17	0,5	0,11	0,13	0,33	1	0,25
Routine Drug Use	0,67	2	0,44	0,5	1,33	4	1

As a result of the comparison matrix of the criteria created with the AHP method, the consistency rate was below 0.10. According to the results, it was seen that the criterion with the highest criterion weight was the occupational risk of the individual. The importance level of the occupational risk criterion, which has an importance degree of 27.3%, is found to be significant by the experts. It is believed that the mobility of individuals is an essential issue in the spread of the epidemic and that the most important reason for individuals' mobility in this process is their working life. Another important criterion is whether the individual has a chronic illness or not. According to experts, the high level of importance of individuals with chronic diseases is significant, as the level of exposure to the COVID-19 virus is higher than other individuals. These two criteria constitute more than 50% of the total criteria weight. Data on the criterion weights are summarized in Table 7.

Table 7. *Criterion weights*

Criteria	**Weights of Criteria**
Age	0,182
Gender	0,061
Risk of Occupation	0,273
Chronic Illness	0,242
Pull Through the COVID-19	0,091
Population the of city of residence	0,03
Routine Drug Use	0,121
Total	1

3.3. Prioritization of Individuals for COVID-19 Vaccine with PROMETHEE Method

Priorities have been determined for ten alternatives identified at this stage of the study. At this stage, a data matrix was created by ensuring that each alternative was evaluated according to the criteria with the experts. It is a critical issue to determine which type of function the criteria are suitable for in obtaining the priorities in the PROMETHEE method. PROMETHEE method has six different preference functions. The usual type preference function is a seldom-used function without any threshold value. [27]. The usual type preference function is generally used for criteria expressed as 0-1 or present/absent [28].

The U-type preference function is usually the function for which only indifference threshold value is determined for qualitative criteria. V-type preference function is a function whose preference threshold value used for quantitative criteria is determined. Level type preference function is usually used for qualitative criteria and unlike the U type preference function, the indifference threshold is determined in addition to the indifference threshold. Linear type preference function is used for quantitative criteria and its difference from the V type preference function is defined in addition to the indifference threshold value. Gaussion type preference function is a rarely used preference function [27]. The type and preference functions of the criteria taken into account in the solution of the problem are included in Table 8.

Table 8. *Preference functions used in solution of problem*

Criteria	**Type of criterion**	**Preference Functions**
Age	Quantitative	Linear
Gender	Qualitative	Level

Risk of Occupation	Qualitative	U-shape
Chronic Illness	Qualitative	Usual
Pull Through the COVID-19	Qualitative	Usual
Population the of city of residence	Qualitative	U-shape
Routine Drug Use	Qualitative	Usual

The visual PROMETHEE (2020) program was used in the solution of the PROMETHEE method. In the program, a data matrix was created for alternatives. A preference function was determined for each of our criteria, and min-max values were found for all criteria. Criteria weights obtained by the AHP method were entered into the PROMETHE method, and the interface in Figure 3 was created.

Visual PROMETHEE Academic - PROÖ.vpg (saved)

File Edit Model Control PROMETHEE-GAIA GDSS GIS Custom Assistants Snapshots Options Help

Scenario1	Age	Gender	Risk of occu…	Choronic Illn…	Pull Through	Population The	Routine Drug
Unit	unit	unit	unit	unit	unit	unit	unit
Cluster/Group	◆	◆	◆	◆	◆	◆	◆
Preferences							
Min/Max	max	max	max	max	max	max	max
Weight	0,18	0,06	0,27	0,24	0,09	0,03	0,12
Preference Fn.	Linear	Level	U-shape	Usual	Usual	V-shape	Usual
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	1,00	1,00	1,00	n/a	n/a	n/a	n/a
- P: Preference	2,00	2,00	n/a	n/a	n/a	2,00	n/a
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics							
Minimum	12,00	1,00	1,00	0,00	0,00	1,00	0,00
Maximum	68,00	3,00	10,00	1,00	1,00	3,00	1,00
Average	37,00	2,50	4,70	0,70	0,40	1,70	0,70
Standard Dev.	15,33	0,67	2,90	0,46	0,49	0,64	0,46
Evaluations							
Person A	12,00	3,00	2,00	1,00	0,00	2,00	1,00
Person B	23,00	2,00	2,00	0,00	0,00	2,00	0,00
Person C	25,00	3,00	7,00	1,00	1,00	1,00	1,00
Person D	28,00	1,00	1,00	0,00	0,00	2,00	0,00
Person E	34,00	2,00	6,00	1,00	1,00	2,00	1,00
Person F	38,00	2,00	6,00	1,00	1,00	1,00	1,00
Person G	45,00	3,00	10,00	1,00	0,00	3,00	1,00
Person H	47,00	3,00	5,00	0,00	0,00	2,00	0,00
Person I	50,00	3,00	7,00	1,00	1,00	1,00	1,00
Person J	68,00	3,00	1,00	1,00	0,00	1,00	1,00

All Scenario 1

Actions: 10 (10 active) Criteria: 7 (7 active) Scenarios: 1 (1 active) Locale: Belgium [€/,] Saved

Figure 3. *Visual PROMETHEE program screenshot*

According to the PROMETHEE method, person priority ranking for the COVID-19 vaccine was obtained as in Figure 4.

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	Person G	0,4427	0,5438	0,1011
2	Person I	0,4397	0,5019	0,0622
3	Person F	0,2812	0,4041	0,1229
4	Person E	0,2574	0,3906	0,1331
5	Person C	0,1970	0,3806	0,1836
6	Person J	0,0757	0,3098	0,2341
7	Person H	-0,1796	0,2763	0,4559
8	Person A	-0,2717	0,1344	0,4061
9	Person D	-0,6011	0,0673	0,6684
10	Person B	-0,6413	0,0269	0,6682

Figure 4. *PROMETHEE method results*

According to this result, the primary individual in vaccination was G individual. Considering the characteristics of the G individual, it is seen that he is a 45-year-old male and is a health worker. However, the individual has a chronic disease using routine medication and lives in a metropolitan area. It is seen that the second priority individual is the I individual. I is a 50-year-old male individual who lives in the district and uses routine medication due to his chronic illness and works permanently. It is seen that G and I individuals have high occupational risks. These individuals are followed by F, E, C, J, H, A, D and B individuals. Among the individuals in the last rank in the priority order, D individual is; 28 years old, housewife, pregnant woman living in a metropolitan city. Individual B is a 23-year-old student who does not have chronic discomfort and does not use routine medication. In the light of the results obtained, it is recommended that health managers prioritize individuals by taking into account the occupational risks and chronic diseases of the individuals. In addition, it has been observed that the age of the individual is an important factor according to the results obtained. Our recommendation to managers is that instead of giving priority to a single standard, the current situation of the individuals should be evaluated and vaccination priorities should be given accordingly.

4. CONCLUSION

The world has been battling the COVID-19 pandemic for over two year. There have been significant developments in vaccine studies in the treatment of the epidemic recently in this fight, and some countries have started to vaccinate individuals. However, it is impossible to produce, supply, and apply enough vaccines for everyone in the current situation. For this reason, it is necessary to determine effective and efficient policies in vaccination of individuals to prevent the spread of the epidemic and reduce deaths. One of these policies is to apply vaccines to individuals first.

In this study, identifying individuals with priority in vaccination was addressed, and the individuals who need to receive the COVID-19 vaccine were investigated using MCDM methods. The essential criteria for vaccination were determined, and the importance levels of these criteria were calculated with the AHP method. Then, the priorities of individuals in vaccination were obtained in an integrated manner by considering the importance levels obtained from the AHP method in the PROMETHEE method. According to the results obtained, it was determined that the importance levels of occupational risk, chronic disease, age, and routine drug use criteria in vaccination of individuals are high. In addition, it has been observed that the individual's COVID-19 exposure, gender, and the region where he lives are effective in vaccination. As a result of the evaluation of the determined alternative individuals according to the criteria, it was seen that the individual selected primarily according to the PROMETHEE method was a health worker and an individual with chronic diseases. It has been observed that the second priority individual is a 50-year-old worker. According to the results, it was seen that the individual' occupation, chronic illness, and age criteria came to the fore. The results are suggestions to the managers. In subsequent studies, it is suggested to increase the number of criteria, diversify the solution methods, and compare the results.

In this study, alternative individuals were determined by taking expert opinions, and analytical methods can be used to identify individuals in future studies. The study has prioritized individuals in the use of vaccine resources for the COVID-19 period and provides a decision model for possible pandemics that may arise in the future. At the same time, the application is not only for the pandemic period but also for earthquakes, floods, etc. in extraordinary situations. It can be taken into account as an example in determining the course of action in situations that require search and rescue and intervention in disaster situations.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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