CURRENT CLASSIFICATION OF MULTI CRITERIA DECISION ANALYSIS METHODS AND PUBLIC SECTOR IMPLEMENTATIONS

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Hakan Murat ARSLAN Düzce
Duzce University

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Hakan Murat Arslan

Abstract

Today, many scientific methods have been developed for the solution of different types of decision problems faced by businesses. It is observed that businesses that implement modern and scientific decision analysis methods in the face of increasingly complex business management decision problems provide an important competitive advantage in business life. Among these scientific methods, multi criteria decision making (MCDM) methods in the literature of operations research have attracted much interest in recent years. The main reason for this is thought to be the fact that the multi criteria decisions analyze MCDA methods contain the best or most appropriate solution that conflicts with each other in any decision problem and contains more than one criterion. The essence of this work is to introduce and classify the methods that have been studied in the field of MCDM also to emphasize the importance of the applicability of these scientific methods in the evaluation and resolution process, especially of the decision problems faced by public sector enterprises. In the study, the public sector enterprises are explained with examples of how they can solve many decision problems with the methods of MCDM. Moreover, in the application part of the study the analysis of AHP-PROMETHEE hybrid method has been included in determining the optimum location of the multi storey car park to be installed by a public administration. The results of the analysis are shared with the relevant public administration.

***Keywords**: Multiple Criteria Decision Making Methods, AHP-PROMETHEE Hybrid Method, Public Enterprises*

Introduction

People or organizations try a variety of methods to achieve different goals. The simplest way to select the most appropriate of these alternative methods is to say "decision". However, among the factors affecting the decision making process, it is very important to determine goals, criteria, alternatives and decision makers.

In general, individuals are influenced by their feelings in the face of decision problems they have in contemporary life. However, businesses have to use scientific decision-making methods because it means that they can destroy themselves if they make decisions with feelings in today's competitive conditions.

In MCDM problems, the definition of criteria and solution alternatives is essential. It is necessary to determine the most appropriate alternative by making a logical move in the scientific decision-making process. For this reason, this relationship between logic principles and decision problems has long attracted the attention of researchers.

In classical logic there is no other case except for the right or wrong probabilities for a decision. In these different possible situations, the mathematician Leibniz added the need-and-effect situation (Öner, 1969). With this addition, the existence of numerous decision points between 0, which expresses wrong and 1 which expresses truth are started to be thought and against these different decision ratios, there are numerous constraints and alternative solutions to the problem.

In order to solve decision problems known as multi-criteria decision making (MCDM) problems in the literature, researchers have developed many methods based on classical or heuristic. While it is essential to express and solve the problem of decision with mathematical formulas and concepts at the basis of classical approaches, heuristic approaches aim to determine the closest solution set of solution of multi-criterion decision problems in a short time.

This study was designed with the consideration of the necessity of classifying the MCDM problems according to recent developments. Today, when the studies on the methods of MCDM are examined, it is seen that new or hybrid studies are dominant. This brings to mind the question of which classification these current approaches applied in the literature will take. Due to this need in the literature, it is aimed to perform the current classification of the MCDM methods in the study.

In addition, an implementation has been made to demonstrate that current hybrid approaches can be easily applied, particularly in the public sector. Particular emphasis was put on the study because the social benefits of the implementation of the MCDM methods in decision problems in the public sector cannot be ignored and it is aimed to raise awareness on this issue.

For example (Arslan and Yıldız, 2015a), analysed the problem of determining the optimum facility location decision for an educational institution by using the fuzzy topsis method and shared the results of the study with the authorities. The use of MCDM methods based on scientific methods in decision-making problems encountered in such public-interest activities made it possible to make fewer mistakes in decisions and therefore, the public benefit is taken care of by the real benefit is saved.

In the application section of this study, it is aimed to solve the problem of urban parking in one of the provincial municipalities of Turkey, which is a public institution. For this purpose, it is necessary to determine the most convenient local parking place. Criteria and alternatives for this decision problem were identified by the decision makers scanning the relevant literature. Based on the obtained data, the most suitable parking location model was constructed and this model was analyzed by the AHP-PROMETHEE hybrid method of MCDM methods.

In the second part of the study, a comprehensive literature search on the methods and classifications of the MCDM was made, in the third part, the public sector practices of MCDM problems and their social benefits were emphasized. In the fourth chapter, there is an implementation for the use of MCDM methods in determining the most suitable multi-storey car park place which is an important place for solving the urban traffic problem which is a common problem of public institutions. In the fifth and last section, the results of the analysis in the application section were expressed and recommendations were made for future studies, focusing on social benefits.

Literature Review

Multi-Criteria Decision Making (MCDM) methods can be defined as approaches that generate a set of solution or solutions that are the best in the solution process or that are closest to the best of different decision problems that conflict with one another and contain multiple criteria.

The MCDM methods can be basically examined in two main groups. These are multi qualified decision making (MQDM) methods and other multi-purpose decision making (MPDM) methods. However, since there is a lot of new or hybrid approaches related to the methods of MCDM, there is a need for the recent classification of MCDM methods. The study is expected to close this gap in the literature in this regard.

In the titles related to the literature review, firstly there is the historical part which includes the first emergence of the MCDM methods and historical development and then, in the course of this historical development, the heading of the MCDM methods, which describe how MCDM methods are classified, is included.

MCDM and History

The historical ties of the MCDM can be attributed to the contradiction of Petersburg between Nicolas Bernoulli (1687-1759) and Pierre Remond de Montmort (1678-1719). In the contradiction of St. Petersburg, it is firstly started with a heads or tails, and when it comes to heads for the first time, the game ends. The main thing in this vote is how much money the players will pay for this game? The expectation of the players is heads to arrive in the nearest time. But this time may not come at all. This problem cannot be resolved until Bernoulli's 1738 theory of utility. People tend to take risks as much as benefits they usually earn, not according to expectations. Obviously, individuals tend to choose the alternative that is most beneficial to decision problems.

In 1947, in Von Neumann and Morgenstern's famous books, "Theory of Games and Economic Behaviour," the theories of how games, benefits and society are related are explained. Undoubtedly, the pioneering work of these researchers has led to in-depth research and development of the MCDM (Tzeng and Huang, 2011: 2).

At the beginning of the 1950s, Kuhn and Tucker found a formula that contained the most appropriate solution for the problems of nonlinear programming. In fact, these researchers have done much more to solve decision problems. In 1955, scientists Charnes, Cooper and Ferguson published studies describing the basics of goal programming. However, the goal programming name first appeared in the Charnes and Cooper 'ın book in 1961 as the MCDM method. In 1968, Bruno Contini and Stan Zionts introduced the first consensus approach in solving decision problems with multi criteria. When it came to 1973, the scientists named Zionts and Jyrki Wallenius applied the Zionts-Wallenius method analysing multipurpose linear programming problems. Towards the end of the 1970s, since computers predominantly enter the scientific world Zionts, Wallenius and Korhonen have worked on decision support systems that can analyze multi-criteria mathematical programming problems (Ruiz, 2012).

Following the developments mentioned above, Bernard Roy and his colleagues implemented the ELECTRE method AHP and ANP for the first time in the 1970s by Thomas L. Saaty. Because of these studies, Saaty was accepted among the most successful scientists.

Although there have been continuous and different studies on MCDM, especially in the last twenty years, more progress has been made than in the past. The biggest reason for this development and enlargement can be considered too much progress of computer programming. Because of these developments in computer programming, MCDM problems can be solved in shorter time and with fewer errors (Xu and Yang, 2001: 3).

Below are some of the practical benefits of the MCDM methods in the public sector, and the optimal benefits they provide, especially those of study.

(Arslan and Yıldız, 2015b) determined the location of the disaster stations planned to be established in Düzce by using fuzzy topsis method. It is believed that maximum benefits are gained when the results are shared with the authorities and given the ease of reaching these stations that are set up at optimal locations for the community.

(Aydın et al., 2009) applied the AHP method for the selection of optimum hospital in Ankara. (Erden and Coşkun, 2010) determined the criteria to be taken into consideration in determining the optimum location for the fire stations and determined the weights of each criterion using the AHP method. They analyzed these data using Geographic Information Systems (GIS). (Arslan and Güler, 2011) determined the positive and negative factors regarding the operation of chemical tankers by SWOT analysis method. (Durak and Yıldız 2015) used a p-median facility location model in order to find the optimum numbers and locations of depots of a food company. They also shared the results of the study with the company authorities.

Classification of MCDM Methods

Some of the methods of MCDM which are applied until today and the historical development of the decision making science have been expressed in the previous section. However, these methods, which are quite numerous, require a comprehensive classification. When the related literature is examined; The MCDM methods are classified according to the characteristics of the criteria, alternatives, or solution set in the structure of the decision problem. Examples of these classification schemes are listed below.

The MCDM problems can be divided into four basic classifications. These are (Ishizaka and Nemery, 2013: 5);

- Selection between alternatives: Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), MAUT, UTA, MACBETH, PROMETHEE, ELECTRE I, TOPSIS, Objective Programming, Data Envelopment Analysis

- Alternatives Rating: AHS, AAS, MAUT, UTA, MACBETH, PROMETHEE, ELECTRE III, TOPSIS

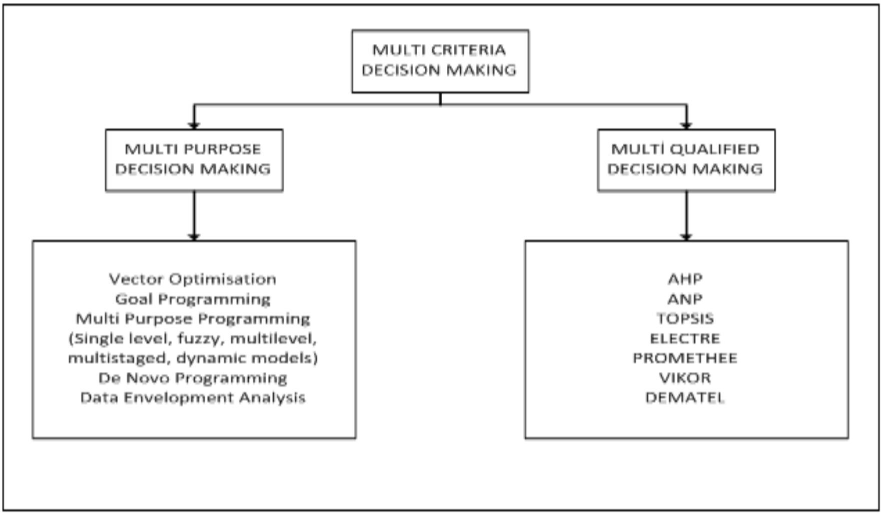
- Alternatives Classification: AHSSort, UTADIS, Flowsort, ELECTRE-Tri;

- Identifying Alternatives: GAIA and FS-Gaia

In a process where there are many factors, such as contradictory criteria, alternatives and solutions, naturally, the solution of the MCDM problems will be both more difficult and longer. Here are a number of methods developed by researchers to solve such decision problems. These methods generally evaluate the solution alternatives of the problem within certain criteria and help to determine the most suitable alternative.

The MCDM methods can be classified in many different ways. In 1981, a basic classification was made by Hwang and Yoon. Hwang and Yoon (1981) collect the MCDM methods in two groups as multi-purpose decision making (MPDM) and multi-quality decision making (MQDM) methods based on different purpose and different data groups. This classification style is expressed in Figure 1.

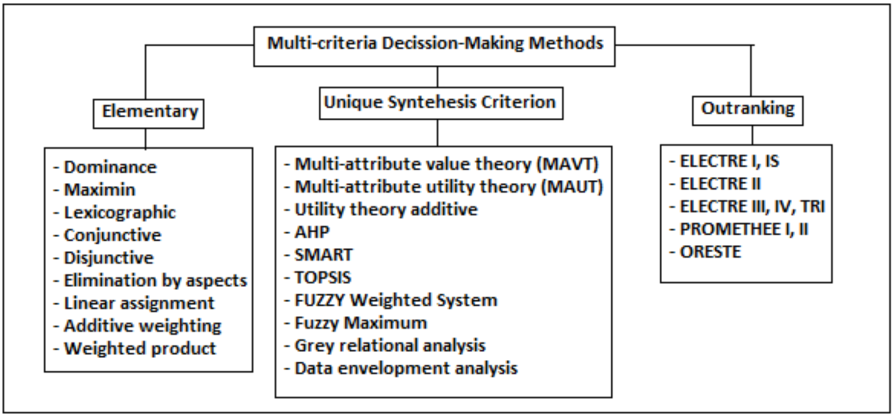
Figure 1: Classification of MCDM methods (Tzeng and Huang, 2011: 3)



The most obvious difference between the two groups expressed in Figure 1 is the number of alternatives included in the appropriate solution of the decision problem. In other words, if a decision problem contains an infinite number of continuous alternatives, it can be considered as a MPDM method, if it contains limited and discrete alternatives it can be considered as MPDM method (Mendoza and Martins, 2006: 2).

A different classification of the solution methods of the MCDM problems can be made according to the data types, that is to say problems involving deterministic, stochastic and fuzzy data should be grouped separately. In fact, some researchers seem to classify MCDM problems according to the number of decision makers (Chen and Hwang, 1992).

Figure 2: Classifications of MCDM Methods (Zardari et al., 2015: 11)

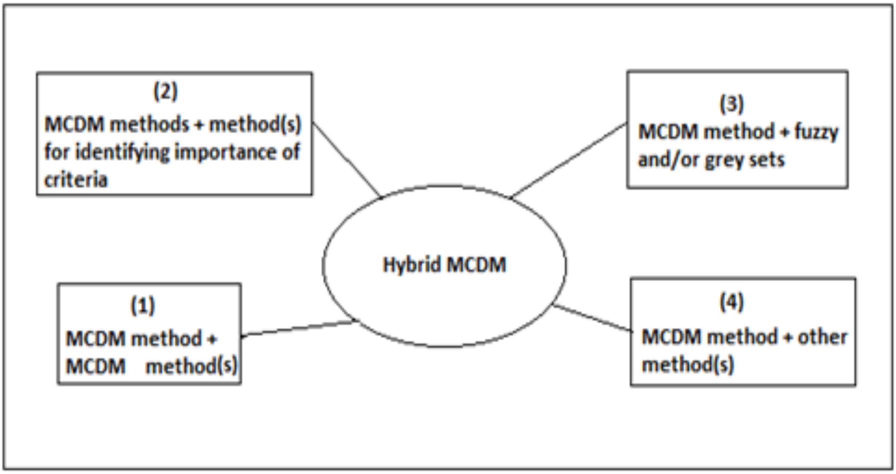


When Figure 2 is examined carefully, it is seen that Zardari et al. have distinguished three main groups of the MCDM methods. They have expressed these groups as simple, original and distinguished methods. This classification can be seen as the form of an up-to-date classification as it was made in 2015. However, in the last few years, hybrid methods have also been used in the analysis of the MCDM problems. It would be appropriate to consider these versatile approaches in a different group, as it would be contrary to the basic principle of classification of data to include in the groups in the classification schemes expressed in Figures 1 and 2. In Figure 3, Zavadkas and colleagues show detailed information about the formation of hybrid MCDM methods. According to this formation, Hybrid methods come together in four different ways. These;

- Combined use of single analysis method and single analysis method of MCDM (s)

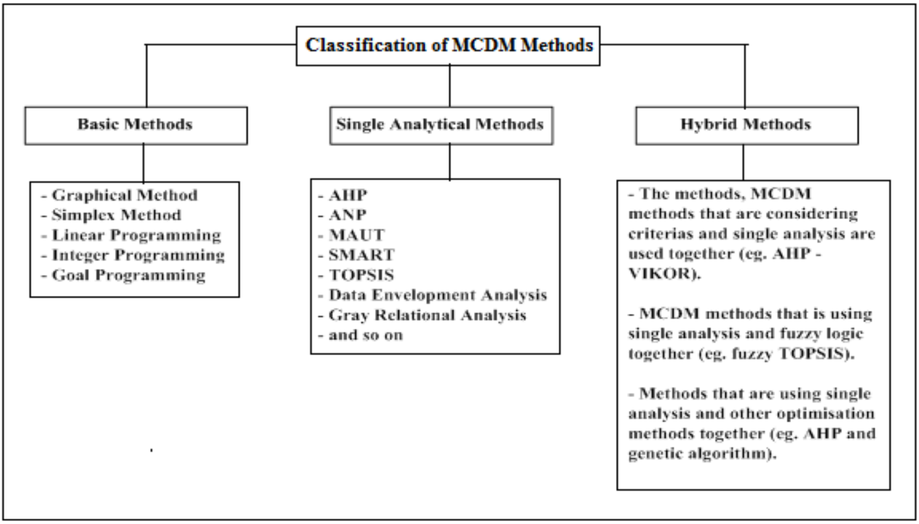
- Combined use of CRC method (s) taking into account the importance of criteria and single analytical method
- Use of fuzzy logic based method (s) and single analysis
- The combined use of single analysis and other optimization method (s) together.

Figure 3: Formation of Hybrid MCDM Methods (Zavadskas et al., 2016)



In the current classification of MCDM methods that the study would like to emphasize and see as a gap in the literature; it is considered necessary to classify the methods developed considering the feature of the solution path. Up to this day, the methods of MCDM are classified according to data, criteria, alternatives or the number of decision makers. However, the methods of analysis including the solution methods of the MCDM problems also vary within themselves. These differentiations should definitely take place in current classifications. For this purpose, the current classification scheme shown in Figure. 4 is proposed.

Figure. 4 Classification of MCDM Methods by Analysis Types



Implementations the Placement of Multi Storey Parking Facility with AHP-PROMETHE Hybrid Method

AHP and PROMETHEE Methods

The AHP method is based on the rationale of determining the priority weight of each decision criterion by comparing the alternatives according to the criteria and assessing the performance of all alternatives according to the criteria (Triantaphyllou, 1995).

The steps of the method firstly implemented by Saaty in 1986 are listed below (Kamal and Harbi, 2001).

a. The data of the problem are presented completely and the targets are determined.

b. From the goal, criteria and alternatives should be expressed in a certain hierarchy.

c. The scale shown in Table 2 should be used in order to determine the priorities of alternatives and the criteria. (Saaty, 1986).

d. In the comparison of the criteria, columns are added for column normalization. Thus, normalization is performed by dividing the elements by the total value.

e. The rows of the normalization matrix of the alternatives are added together to find the priority vector matrix.

f. There is a resultant weighted matrix by which the priority vector matrix is multiplied by the priority values.

g. The priority values of the criteria and alternatives are found by dividing the sum of the rows of the weighted matrices by the values of the rows of the priority vector matrix.

h. A consistency index should be calculated to determine whether there is consistency in the comparison of the criteria (Saaty, 1990). However, the first priority in finding this index is to find the CI value.

i. $CI = (\lambda\ max - n)/(n-1)$ CI: Consistency Index

j. Table values and consistency index shown in Table 1 can be calculated together to determine the consistency ratio (Saaty, 1980: 21).

CR: Consistency Indicator RI: Randomness Indicator

The consistency rate in the AHP method should be less than 0.10. The priorities of the alternatives determined according to the criteria, the criterion priorities are calculated for each alternative and the desired priority values are determined.

Table 1: Mean Random Consistency (RI) Table (Saaty, 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 2: Binary Benchmarking Scale (Saaty, 1986)

Value	Description	Explanation
1	Equally Significant	Equality of binary comparison
3	Too little Significant	A value is slightly more preferred than the other
5	High Significant	One value is much more preferred than the other
7	Very High	The value of one value is strongly preferred than the
9	Absolute Significant	One value is preferred over the other
2,4,6,8	Intermediate Value	Values between 1-3,3-5,5-7,7-9
Reverses	Reverse Comparison	

Promethee Method

Recently, the MCDM method has been developed based on the selection of the most appropriate one among alternatives in the framework of certain criteria. One of these methods is PROMETHEE (The Preference Ranking Organization Method for Enrichment Evaluation). It was modelled by Jean-Pierre Brans in 1982.

It is an appropriate approach for problems where a certain number of alternatives can be sorted according to multiple and contradictory criteria (Goumas and Lygerou, 2000). The basis for the frequent and successful implementation of the PROMETHEE method is being based on simple mathematical expressions and ease of use.

There are 7 steps in the implementation of the PROMETHEE method (Dağdeviren and Eraslan, 2008: 70-72, Kücü, 2007: 25-29):

Step 1: Expressing the matrices where the performances of the criteria, weights, possible alternatives and determined alternatives according to the criteria that are determined are shown according to the decision problem.

Step 2: The preference function type for each criterion is determined. There are 6 preference functions that are different from each other. These; First Type (Ordinary), Second Type: (U) type, Third Type: (V) type, Fourth Type (Level), Fifth Type (Linear), Sixth Type (Gaussian).

Step 3: Based on each criterion, preference functions are defined for the alternatives included in the solution set.

Step 4: Preference indices are determined on the basis of the determined preference functions.

Step 5: Positive (Φ^{+}) and negative (Φ^{-}) superiorities are determined for each alternative.

Step 6: Partial priorities are determined using the PROMETHEE I method.

Step 7: The net priority of each alternative is calculated using the PROMETHEE II method.

Methodology

The study was designed on the basis of the AHP-PROMETHEE Hybrid method to provide optimum benefits to the authorities in determining the location of the multi-storey car park, which is necessary for relieving the intra-city traffic of a provincial municipality in Turkey.

The criterial weights of the optimal parking layout model were determined by the AHP method. The analysis steps of the PROMETHEE method are then switched. The model for the determination of the multi-storey car park facility of the municipality operation was analyzed through the decision-making Lab 2000 package program.

Criteria of related decision problem are; traffic density, transportation convenience, physical structure of the land, closeness to fire department, suitability of ground structure and other activities. The alternatives are; A1 (Şerefiye Nbh.), A2 (Camiikebir Nbh.), A3 (Cedidiye Nbh.), A4 (Nusreddin Nbh.), A5 (Uzun Mustafa Nbh.) and A6 (Kültür Nbh.), (Nbh: Neighbourhood). The decision makers are the authorities of the relevant municipality. The performances of the alternatives according to the criteria mentioned above are stated in Table 3.

Table 3: First Data Matrix

	K1 (max) Pcs.	**K2 (min.) m**	**K3 (max.) m^2**	**K4 (min.) m**	**K5 (max.) Parameter**	**K6 (max.) Pcs.**
A1	325	1050	8500	550	4	43
A2	346	1100	4600	600	3	23
A3	423	850	5400	350	4	27
A4	406	1150	6200	650	4	31
A5	412	1400	7300	800	4	36
A6	307	1600	6500	900	4	32

When Table 3 is examined, it can be said that K1 is the number of cars passing in front of alternative places in relation to the traffic intensity and at certain time intervals. The K2 criterion is the bus termination distances where alternatives relieve urban traffic. The K3 criterion is the area size of alternative sites. K4 is the closeness of the alternatives to the fire station. K5 is the number of story permits allowed by the authorities in the region where the alternatives are located. The K6 criterion is the number of businesses that can be established for different purposes on alternatives. Table 3 also shows the maximum or minimum of each criterion according to the feature of the decision problem.

In the direction of the above-mentioned data, after the determination of the criterial weights of the most suitable multi-storey car park model by the AHP method it is determined by PROMETHEE method in seven steps. Decision makers' alternative evaluations by criteria were analyzed separately by the AHP method and the geometric mean of these evaluations were calculated to reach real weight values (Zakarian and Kusiak, 1999). As a result of the analysis carried out by the AHP method, the consistency ratio was 0.0309. Since this result is less than 0.1, it can be said that decision makers' evaluations for the criteria are consistent. As a result of the calculations made by the AHP method, the weights of the criteria are; 0.394, 0.221, 0.174, 0.095, 0.074 and 0.042.

Findings and Comments

Step 1: The first data matrix is expressed. As indicated in Table 3, the performances of the alternatives are shown in the framework of the criteria.

Step 2: Determine weights for each criterion. The weight of the criterion was determined by considering the analysis stages of the AHP method in the light of the opinions of the decision makers as explained in the previous section.

Step 3: The preference function of each alternate is determined and the preference functions are calculated one by one. As the preference function of the alternatives, the usual type preference function was accepted and all calculations were made using this type of formula.

Step 4: Determine preference indices. The index table is used to express all of the alternatives as a table after the preference functions have been calculated separately. The index table of the decision problem of the study is shown in Table 4.

Table 4: Index Table

	A1	A2	A3	A4	A5	A6
A1	0	0.606	0.216	0.532	0.532	0.926
A2	0.394	0	0	0.316	0.316	0.710
A3	0.710	1.000	0	0.710	0.710	0.710
A4	0.394	0.684	0.216	0	0.316	0.710
A5	0.394	0.684	0.216	0.610	0	0.926
A6	0	0.290	0.216	0.216	0	0

Step 5: Calculation of positive and negative superiority values. Positive and negative superiority values were found using the formulas (1) and (2) given below, respectively.

$$\varphi^{+}(A_1) = \frac{1}{n-1}\sum \pi(A_1, x) \qquad (1)$$

$$\varphi^{-}(A_1) = \frac{1}{n-1}\sum \pi(x, A_1) \qquad (2)$$

Step 6: Determine the positive and negative superiority values as a table. Positive and negative superiorities are calculated separately using the formulas described in Step 5 and the superiority values of all alternatives are shown collectively in Table 5.

Table 5: Positive and Negative Superiorities Table

	Pos. Super. ($\boldsymbol{\varphi}^{+}$)	Neg. Super. ($\boldsymbol{\varphi}^{-}$)
A1	0.562	0.378
A2	0.347	0.652
A3	0.768	0.172
A4	0.464	0.476
A5	0.566	0.374
A6	0.144	0.796

Step 7: Determine the final ranking of the alternatives by the PROMETHEE II method. By using this method, the final order can be determined by subtracting the negative advantage value from the positive advantage value of each alternative in ordering of alternatives. This is expressed by formula (3).

$$\varphi(A_1) = \varphi^+(A_1) - \varphi^-(A_1) \qquad (3)$$

The final dominance values of each alternative were calculated using formula (3) and the relevant results are presented in Table 6.

Table 6: Table of the Final Dominance Values of Each Alternative

	Dominance Values of Alternatives	**Rank**
φ(A1)	0.184	3
φ(A2)	-0.305	5
φ(A3)	0.596	1
φ(A4)	-0.012	4
φ(A5)	0.192	2
φ(A6)	-0.652	6

When seven steps of the PROMETHEE method were applied, the results shown in Table 6 were found. According to these results, when alternatives are listed taking their priorities into account;

- Cedidiye Nbh.
- Uzun Mustafa Nbh.
- Şerefiye Nbh.
- Nusreddin Nbh.
- Camiikebir Nbh.

- Kültür Nbh.

Conclusions and Suggestions

In the face of increasingly complex decision problems, organizations have tended to apply modern and scientific decision analysis methods. Otherwise it is obvious that they will have difficulty in maintaining their lives. The enormous number of modern and scientific methods make operators controversial. Essentially a decision problem can be solved using many different decision analysis methods but the most appropriate method for that decision problem must be explicitly stated in the literature.

In this respect, it is the major problem to study the current classification of the disorganized MCDM methods in the literature as a need. Related literature has been searched in this issue and the need for a classification according to the nature of the solution path and a classification scheme as described in Figure 4 is proposed.

It has been stated in the study that many different public enterprises have solved many decision problems in a way that will provide them optimum benefit by using the MCDM methods.

In the application section, the utility of the AHP-PROMETHEE hybrid method has been demonstrated in the determination of the optimum location of a multi-storey car park building that a public enterprise needs. Possible plant locations for multi-storey car parks have been accepted as alternatives and analyzed with the AHP-PROMETHEE hybrid method in the framework of six criteria that were determined together with the decision makers and alternatives are ranked according to their superiority. According to this order, the municipal administration has determined that it is appropriate to establish the multi-storey car park primarily on the Cedidiye Neighbourhood, secondly on the Uzun Mustafa Neighbourhood and thirdly on the Şerefiye Neighbourhood.

The work has many different aspects that can be developed or changed by researchers. Particularly, studies can be carried out on updating the classification schemes which take into account the qualifications of the decision makers on the current classification of the MCDM methods.

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