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A DECISION MODEL PROPOSAL IN CASE OF UNCERTAINTY: PHOTOCOPY MACHINE SELECTION WITH ENTROPY-BASED ELECTRE III METHOD

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Abstract

Decision making is getting more complex and difficult in our daily life and business life. However, correct and fast decision making is the first condition of managing and directing. The complexity and uncertainty in decision problems have increased as a result of technological developments and changes in consumer demands. Most of the decision problems encountered contain many criteria. Multi-Criteria Decision Making (MCDM) is to choose the most suitable alternative among many alternatives according to more than one determined criteria. Various methods have been developed for the solution of multi-criteria decision problems. ELECTRE III (ELimination Et Choice Translating REality) method, one of these methods, is one of the most widely used methods. The ELECTRE III method is a method used in the solution of decision problems involving uncertainty. In this study, the ELECTRE III method and its properties have been examined with an application. For this purpose, the problem of photocopy machine selection was examined with the ELECTRE III method in this study. The ENTROPY method was used to determine the weights of the criteria used in the decision problem and the ELECTRE III method was used to rank the copier machine options.

Keywords: Multi-Criteria Decision Making, ELECTRE III Method, Uncertainty, Copier Selection

BELİRSİZLİK DURUMUNDA KARAR MODELİ ÖNERİSİ: ENTROPİ TABANLI ELECTRE III YÖNTEMİYLE FOTOKOPİ MAKİNESİ SEÇİMİ

Özet

Karar verme günlük hayatımızda ve iş hayatımızda gittikçe karmaşıklaşmakta ve zorlaşmaktadır. Ancak doğru ve hızlı karar vermek, yönetmenin ve yönlendirmenin ilk şartıdır. Teknolojik gelişmeler ve tüketici taleplerindeki değişiklikler sonucunda karar problemlerindeki karmaşıklık ve belirsizlik artmıştır. Karşılaşılan karar sorunlarının çoğu birçok kriter içerir. Çok Kriterli Karar Verme (MCDM), belirlenen birden fazla kritere göre birçok alternatif arasından en uygun alternatifi seçmektir. Çok kriterli karar problemlerinin çözümü için çeşitli yöntemler geliştirilmiştir. Bu yöntemlerden biri olan ELECTRE III (Elimination Et Choice Translating Reality) yöntemi en yaygın kullanılan yöntemlerden biridir. ELECTRE III yöntemi, belirsizlik içeren karar problemlerinin çözümünde kullanılan bir yöntemdir. Bu çalışmada ELECTRE III yöntemi ve özellikleri bir uygulama ile incelenmiştir. Bu amaçla, bu çalışmada fotokopi makinesi seçimi problemi ELECTRE III yöntemi ile incelenmiştir. Karar probleminde kullanılan kriterlerin ağırlıklarını belirlemek için ENTROPİ yöntemi, fotokopi makinesi seçeneklerini sıralamak için ELECTRE III yöntemi kullanılmıştır.

Anahtar Kelimeler: Çok Kriterli Karar Verme, ELECTRE III, Belirsizlik, Fotokopi Makinesi Seçimi.

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1. INTRODUCTION

Decision making is the most basic managerial process. Decision making is difficult in decision problems with multiple conflicting criteria. However, uncertainty also makes it difficult for enterprises to decide on material and machine selection. Uncertainty is quantified with linguistic variables and participates in decision analysis. The issue of copy machine selection in businesses is a decision problem with uncertainty and conflicting criteria. In this study, the solution to this uncertainty has been examined with the ELECTRE III and ENTROPY method specifically for this decision problem.

The foundations of the ELimination Et Choice Translating REality (ELECTRE) method go back to the work of the SEMA consulting company in 1965. The method has been developed by Bernard Roy in 1968(Fıgueıra et al 2005:134). ELECTRE methods are based on binary superiority comparisons between alternatives. ELECTRE can include a large number of qualitative and quantitative criteria in the decision-making process. The ELECTRE III method is a sorting, selection, evaluation method based on binary comparisons. Comparisons are made according to preference, indifference, and veto threshold values. These values express the preference and thinking of the decision-maker about the decision problem. For this reason, the ELECTRE method is successfully applied to solving problems involving uncertainty. In this study, the ELECTRE III method was examined within the decision to choose a photocopy machine that contains uncertainty. The source of uncertainty has been defined as the qualitative decision criteria used. One of the most discussed topics in the ELECTRE III method is the determination of threshold values. Threshold values in the ELECTRE III method have critical importance in the superiority relationships of alternatives. The order of alternatives depends on the magnitude of these threshold values. In this study, the issue of determining the threshold values of qualitative decision criteria is examined and discussed.

In the first part, a short literatüre review is introduced. After given the algorithm and advantage of the ELECTRE III method have been explained in the second part, the copier selection problem was solved with the ELECTRE III method in the third part. It is also emphasized the benefits and features of the ELECTRE III method. In the conclusion part, the study was evaluated in general and suggestions were made to the researchers.

2. LITERATUR REVIEW

ELECTRE III methods have been used by many researchers to solve decision problems. Some studies in the literature can be given as examples; Rogers (2000) evaluated the residential site using the ELECTRE III method according to seven criteria varying based on workmanship, materials, and insulation. Li and Wang (2007) used the ELECTRE III method in the Dublin port highway route selection. Cavallaro (2010), Papadopoulos and Karagiannidis (2008) in the field of renewable energy resources; Giannoulis and Ishizaka (2010) used this method to rank British Universities according to performance and Karagiannidis and Moussiopoulos (1997) to evaluate the solid waste management of municipalities. Besides, many researchers have used this ranking method in various fields. Hodgett (2015) evaluated three multi-attribute decision-making methods for an equipment selection problem in the early stages ofa chemical manufactur- ing process with Analytical Hierarchy Process and ELECTRE III. Kılıç (2006) examined the estimation of an early warning model for predicting the financial failures of banks using the ELECTRE TRI method. Keleş (2019) examined the B segment car options of seven

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different brands with the ELECTRE III method using six technical specification criteria and price criteria. Buchanan, Sheppard, and Vanderpooten(2007) examined a project selection for a division of the Electricity Corporation of New Zealand using the ELECTRE III method. In this paper, it is expressed the concept of separating the objective and subjective components of a decision problem.

3. ELECTRE III METHOD

After developed by Bernard Roy, various ELECTRE models have been developed based on the structure of the problem to find a solution for a problem or to rank the alternatives, the degree of significance of the criteria to be taken into account, and the preferential information (Tzeng-Huang, 2011). New ELECTRE methods developed can be subdivided according to the types of problems they solve(Ishizaka-Nemery, 2013). ELECTRE II has been proposed to eliminate the inadequacy of ELECTRE I in the order of alternatives. Instead of finding a core solution, ELECTRE II can list the alternatives by addressing the strengths and weaknesses of superiority relationships(Huang, 2011). ELECTRE III method is a multi-criteria decision-making method that used a ranking approach. ELECTRE IV is similar to ELECTRE III in many ways. Performs alternative comparisons by considering the number of criteria that alternatives are superior, similar, and not superior. ELECTRE TRI assigns alternatives to predetermined categories as a result of the evaluation made according to the criteria. As can be seen, the ELECTRE method has different derivatives. These approach differences have emerged to solve the problems encountered in various application problems of ELECTRE. The different ELECTRE types are briefly shown in Table.1.

Table 3.1. Overview of the different ELECTRE Methods.

Decision Problem	**Method**
Choice problem	ELECTRE I ELECTRE Iv ELECTRE Is
Ranking problem	ELECTRE II ELECTRE III ELECTRE IV
Sorting problem	ELECTRE-Tri-B ELECTRE-Tri-C
Elicitation problem	Elicitation of the weights in ELECTRE Elicitation for ELECTRE-Tri: • IRIS method • other elicitation methods

Source: Ishizaka A., Nemery P., Multi-criteria Decision Analysis, 2013, p. 181.

The ELECTRE III method is not only suitable for individual decision-making but also for group decision making. ELECTRE III is non-compensatory. That means good scores on some criteria cannot compensate for bad scores on other criteria. Second, ELECTRE is not compensatory. That is, high scores on some criteria cannot make up for a project that scored too low on a particular benchmark(Buchanan -Vanderpooten, 2007:313). There is no need for

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independence of criteria. In this method, the qualitative criteria are converted into quantitative criteria(Alinezhad-Khalili, 2019).

The method is based on comparing the options according to the concordance and discordance of the criteria. These comparisons are made by considering the threshold values determined. There are uncertainties when converting qualitative criteria to quantitative criteria. It is seen that this uncertainty generally occurs in MCDM problems where qualitative criteria are used. This means that the decision-maker makes comparisons using uncertain or fuzzy information in comparisons made according to qualitative criteria. This feature states that the ELECTRE III method is a method that tries to provide the solution to the problem by taking into account the uncertainties(Roy et al,(2014). This uncertainty has two important sources. The first source of uncertainty is the decision maker's evaluation of the judgments, and the second is the uncertainties carried by the interval scale used in the evaluation(Hokkanen-Salminen, 1997).

ELECTRE III was designed to improve ELEC- TRE II and thus deal with imprecise, uncertain, or ill-determination of data. The novelty of this method is the introduction of pseudo-criteria instead of true-criteria(Karagiannidis-Zopounidis1997) In ELECTRE III the outranking relation can be interpreted as a fuzzy relation. The construction of this relationship requires the definition of a credibility index, which characterizes the credibility of the assertion outranks let denote this index(Fıgueıra et al 2005, p. 145; López-González, 2003, p. 22). The ELECTRE I and ELECTRE II methods were designed to involve only true criteria, while ELECTRE III and ELECTRE IV methods were designed to involve pseudo-criteria and they take into account indifference and preference thresholds. ELECTRE III method provides an ordering of the alternatives from the best to the worst based on the comparisons of them(Pardalos-Hearn 1998).

ELECTRE III method is based on the binary comparison of the criteria that are effective in the selection and ranking of the alternatives. The criteria that affect the decision problem and their importance and weights should be determined before these comparisons. It is also necessary to determine the preference, indifference, and veto thresholds for each criterion. In other words, before the method is applied, a good definition of the problem should be made and the structuring of the problem should be done correctly. Concordance and discordance matrix is used to sort the alternatives in ELECTRE III. The concordance index C (a, b) measures how well a is to b. The discordance index D (a, b) measures the degree to which b is definitely preferable to a(Tzeng-Huang, 2011:81).

Three different threshold values are used in the ELECTRE III method: preference threshold $p_j(g_j(*))$, indifference threshold $q_j(g_j(*))$ and veto threshold $v_j(g_j(*))$. It takes account clearly of indifference, preference, and veto associated with each criterion. For the criterion being considered these thresholds may be simple numerical constants or they may be functions of the level of performance g_j (*) of one of the options being compared. They produce outranking relations while making allowances for uncertainty in the data. To use the model these thresholds must be defined by the decision-makers for all criteria (v>q>p), and importance ratings (weights) w_j for each of the criteria also must be determined(Rogers, 2000:334; Buchanan-Vanderpooten, 2007:313) While creating the model, the threshold values required for the creation of concordance and discordance matrices are determined.

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Short definitions of Thresholds can be given as follows:

✓ Indifference thresholds q_j: when the difference between criterion values of two alternative in a criterion is not more that is alternatives are considered indifferent from each other.

✓ Preference threshold p_j: when the difference between values of two alternative in a criterion is more than p_j, that is, that is as large as the preferred threshold is preferred to the other.

✓ Veto threshold: If the difference between the two alternatives is between the preference threshold and the veto threshold values, the alternative with the higher value is strongly preferred to the alternative with the lower value in terms of that criterion. If the difference of the values of the alternatives is greater than the preference threshold, the alternative with the higher value vetoes the alternative with the lower value in terms of that criterion(Liu-Zhang, 2011;Atıcı-Ulucan, 2009).

In the ELECTRE III method, the construction of relation requires a credibility index. The steps of the ELECTRE III model contain; determination of concordance index, determination of discordance index, determination of credibility index, performing distillation procedure, and performing the complete ranking. The following algorithm is followed while applying the method. A = (a, b, c,…., n) expresses options, C=($g_1, g_2, g_3, ...g_m$) shows criteria and the $g_j(a_i)$ expresses the performance of option an according to g_j criterion (Hokkanen-Salminen, 1997:215; Roy 1991). Concordance index is created for each criterion of each option pair (a, b). The concordance index shown in Equation (1) is obtained by using the concordance function.

$$C_j(a,b) = \begin{cases} 1, & if \quad g_j(a) + q_j(g_j(a)) \geq g_j(b) \\ 0, & if \quad g_j(a) + p_j(g_j(a)) \leq g_j(b) \\ other, & \dfrac{g_j(a) - g_j(b) + p_j(g_j(a))}{p_j(g_j(a)) - q_j(g_j(a))} \end{cases} \tag{3.1}$$

By using Equation (2), the cumulative concordance index is obtained from the concordance matrices obtained by Equation (1).

$$C(a,b) = \frac{1}{W}\sum_{j=1}^{n} w_j c_j(a,b) \tag{3.2}$$

W is the sum of the weights of all criteria expressed by Equation (3).

$$W = \sum_{j=1}^{n} w_j \tag{3.3}$$

The cumulative concordance index consists of values between 0 and 1. The value of 0 indicates that option b is better than option a for all criteria, and a value of 1 indicates that option b is worse than option a for any criteria.

By comparing the options according to each criterion in pairs, the discordance index is obtained according to the rules in Equation (4). When creating the discordance index, it is used preference and veto threshold values.

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$$D_j(a,b)=\begin{cases} 0, & if \quad g_j(b)\le g_j(a)+p_j(g_j(a)) \\ 1, & if \quad g_j(b)\ge g_j(a)+v_j(g_j(a)) \\ other, & \dfrac{g_j(b)-g_j(a)+p_j(g_j(a))}{v_j(g_j(a))-p_j(g_j(a))} \end{cases} \tag{3.4}$$

When the function has taken the value of 1, that indicates the option b is better than the option a in terms of based on the criteria.

The set of J (a, b) represents the criteria that satisfy the condition C (a, b) ≥Dj (a, b). The credibility matrix is an nxn size matrix created by comparing the values in the cumulative concordance matrix with the values in the discordance matrix created for each criterion. If the value of the concordance index is greater than all values in discordance matrices for an (a. b) pair, the value of the credibility matrix of this pair is equal to the cumulative concordance index value. Otherwise, the credibility matrix value is calculated with the formula shown in Equation (5).

$$S(a,b)=\begin{cases} C(a,b), & if \quad D_j(a,b)\le C(a,b), \quad \forall j \\ C(a,b), & other \quad \prod_{j\in j(a,b)} \dfrac{1-D_j(a,b)}{1-C(a,b)} \end{cases} \tag{3.5}$$

In the classification of options and the distillation process, two different option transitions are obtained, ascending and descending. The final ranking is formed by the intersection of both obtained passes. The distillation process starts with finding the largest value (λ_{max}) of the credibility matrix, the threshold of discrimination $(s(\lambda_{max}))$, maximum cutting level (λ^*), and cutting level (λ). The distillation process is performed with the formulas below(Marzouk, 2011:598).

$$\lambda_{max}=\max S(a,b) \tag{3.6}$$

$$s(\lambda_{max})=0,3-0,15*\lambda_{max} \tag{3.7}$$

$$\lambda^*=\lambda_{max}-s(\lambda_{max}) \tag{3.8}$$

$$\lambda=\max\ S(a,b) \tag{3.9}$$

After calculating λ; the options are compared with each other. If S(a,b)> λ and S(a, b)- S(b, a)> $S(\lambda_{max})$ conditions are met, option a is preferred to b. In this case, +1 is given to the stronger a and -1 to the weaker b. Priority points are achieved by collecting strength and weakness values for each option (Atıcı-Ulucan, 2009; Rogers, 2000).

3.1.Determination of Criteria weight based on Entropy Method

In Multi-Criteria Decision problems, there are many methods for determining the importance weights of criteria. Some of these methods are AHP, DEMATEL, SMART, sorting method, standard deviation, binary comparison, statistical variance procedure, CRITIC methods. Weighting methods are divided into subjective and objective methods. Subjective methods take into account the opinions of decision-makers or experts. Objective methods use mathematical methods to determine criterion weights, and decision-makers do not influence

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them. Entropy, standard deviation, statistical variance procedure are the most commonly used objective methods.

The weights of the criteria are effective in the results of the analysis. If the criterion weights change, so will the results of the analysis. In this study, the Entropy method, one of the objective weighting methods, was used to determine the criterion weights. The entropy method is a measure of uncertainty for calculating the weights of criteria by the entropy method. Here the decision matrix is normalized first, and then the following equations are used (Liu-Zhang, 2011).

$$x^* = \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m} \tilde{x}_{ij}^2}}, \qquad 1 \le i \le m, \quad 1 \le j \le n, \tag{3.10}$$

$$\tilde{x}_{ij} = \begin{cases} x_{ij,} & if\ x_{ij}\ \ is\ a\ benefit\ criteria \\ 1/x_{ij}, & if\ x_{ij}\ \ is\ a\ \mathrm{cos}t\ criteria \end{cases} \tag{3.11}$$

Then the entropy value is calculated as follows:

$$E_j = -K\sum_{i=1}^{m} x^* \ln x^*, \quad 1 \le i \le m, \quad 1 \le j \le n \quad 0 \ln 0 \equiv 0. \tag{3.12}$$

E_j it shows the uncertainty measure of the criterion and the entropy value. Here, m is the number of evaluations and K=1/ln m. The different degree is calculated as follows:

$$G_j = 1 - E_j, \qquad 1 \le j \le n. \tag{3.13}$$

Entropy weight calculated as follows:

$$w_j = G_j / \sum_{J=1}^{n} G_j \qquad 1 \le j \le n. \tag{3.14}$$

4. PHOTOCOPY MACHİNE SELECTION

Office equipment is an important technological tool for employees to do their work quickly and efficiently. The most commonly used of these tools are copiers, printers, scanners, telephones, and faxes. Within the scope of technological developments, these tools can be produced in such a way as to perform all functions. In the same way, thanks to developing production infrastructures, many companies produce different brands and different characteristics. When purchasing office equipment for use in offices, decision-makers evaluate machines by looking at many features. Photocopy machines one of the office equipment have started to be developed as multi-functional today. Copiers are also used as printers, scanners, and faxes. Decision analysis begins with determining the decision criteria and creating the decision matrix. Later, the weights of the decision criteria are calculated and enumeration and selection is made. The steps followed in the decision process are shown in Figure 1.

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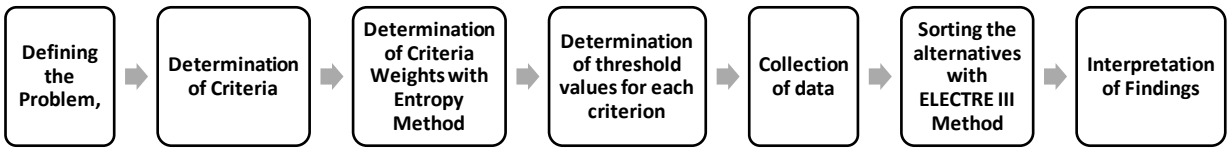

Figure 4.1. The decision process.

Many features are taken into consideration when choosing a copier. These characteristics represent the selection criteria in the study. Price, maximum copy speed, resolution, service possibilities, first copy speed were determined as effective criteria for copying machine selection. In practice, 6 different machines were evaluated according to 5 criteria. The criteria set by user experts are shown in Table 2.

Table 4.1. Decision criteria used in the analysis.

Criteria Code	Criteria	Unit	Description
C_1	Maximum Copy Speed/per minute	Pages	Maximum copy page duplicated in one minute
C_2	Price($)	Dollars	The sale price of the copier
C_3	Service possibilities	Qualitative Judgment	Service quality, speed, and service satisfaction
C_4	Copier Noise Level(db)	Quantitative	The measured noise level of the copier
C_5	First page out (Copying Speed)	Second	Copier's first print out time

The decision matrix and the values of the criteria are shown in Table 3. The service facilities criterion, which is one of the effective criteria in the selection of copiers, is qualitative and the other criteria are quantitative. This criterion was evaluated by users with a Likert scale of 5. The number 5 on this scale is best defined as. The analysis includes 6 copy brands. The values obtained by the alternatives according to the criteria were obtained from the manufacturing companies.

Tablo 4.2. Decision matrix for photocopy machine selection.

Copier Code	Maximum Copy Speed/per minute	Price($)	Service possibilities	Copier Noise level(db)	First page out (Copying Speed)
M_1	40	554	3	48,3	6,4
M_2	35	628	3	63,2	6,9
M_3	23	329	4	51	9
M_4	22	342	3	54	6
M_5	24	400	4	47	8
M_6	45	666	3	57	8

After creating the decision matrix, thresholds were determined by experts. The threshold values and weights of the criteria are shown in Table 4. The entropy method was used to determine the importance weights of the criteria. The threshold value of the service facilities qualitative criterion was determined as 1 because the evaluation ranges on the Likert

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scale was equal to the minimum value of 1, so the threshold value was taken as 1. In other words, the smallest difference between the performance of alternatives for the service facilities criterion was determined as a threshold value.

Tablo 4.3. Threshold and weights values of criteria for ELECTRE III.

Parameter	Maximum Copy Speed/per minute	Price($)	Service possibilities	Copier Noise level(db)	First page out (Copying Speed)
P	0,2	0,2	1	0,2	0,2
q	0,1	0,1	0	0,1	0,1
v	0,286	0,271	0,25	0,25	0,25
Weights	0,217	0,208	0,165	0,207	0,203

The cumulative compatibility matrix consists of values between 0 and 1. The value of 0 indicates that option a is worse than option b for all criteria, the value of 1 indicates that option b is not better than option a for any criteria. Table 5 shows that the concordance matrix calculated using formulas (1) and (2).

Tablo 4.5. Concordance matrix

	M_1	M_2	M_3	M_4	M_5	M_6
M_1	-	1	0,686	0,797	0,932	1
M_2	0,989	-	0,741	0,791	0,819	0,946
M_3	0,782	0,892	-	1	1	0,782
M_4	0,782	0,865	0,849	-	0,960	0,763
M_5	0,783	0,919	1	1	-	0,782
M_6	1	1	0,771	0,791	1	-

The credibility matrix has been calculated using formula (5). If the value of the concordance matrix for a (a, b) pair is greater than the values in all discordance matrices, the value of the credibility matrix of this pair is equal to the cumulative concordance matrix value.

Tablo 4.6. Credibility matrix.

	M_1	M_2	M_3	M_4	M_5	M_6
M_1	-	1	0,686	0,797	0,932	1
M_2	0,989	-	0,741	0,791	0,819	0,946
M_3	0,782	0,892	-	1	1	0,782
M_4	0,782	0,865	0,849	-	0,960	0,763
M_5	0,783	0,919	1	1	-	0,782
M_6	1	1	0,771	0,791	1	-

The ascending and descending distillation procedures lead to the complete ranking represented below. The final ranking of alternatives is as follows;

$M_6 > M_5, M_3, M_1 > M_2 > M_4$

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Six alternatives were evaluated and sorted according to 5 criteria. In the assessment, thresholds were determined by using the literature. In practice, price, the maximum number of copies, service possibilities, the noise level of the copier, first-page copy speed were used. The value of the service facilities criterion is determined by asking users. The values of quantitative criteria were obtained from the promotional catalogs of the companies. The importance weights of the criteria were determined by the entropy method. As a result of the analysis, the M6 brand was the best, while the M2 and M4 brands took last place. The M5, M3, and M1 brands were the preferred brands at the same level.

CONCLUSIONS

Criteria expressed with linguistic variables contain uncertainties due to their nature. When the results are evaluated, the method can be used effectively in the solution of decision problems in which the method has quantitative and qualitative criteria. In addition, in the ELECTRE III method, the group decision can be reflected in the analysis and the analysis results of the investigated question are evaluated as easily understandable.

The threshold values determined by the decision maker are used in the solution of uncertainty in the ELECTRE III method. The size of the difference between the threshold values in the method enables the decision maker to reflect his thoughts to the solution. Decision-makers reflected their preferences for uncertain qualitative criteria in the decision analysis. In the analysis threshold values were determined subjectively and used to express the uncertainty inherent in the criteria. Six photocopy machine exzamined in analysis. Sixth machine the best photocopy machine selected among other machine.

When different criteria are taken into account in the method and the criteria weights change, the results will change. Likewise, if the threshold values are determined differently, the result will change. It is thought that determining the threshold values and criterion weights appropriately are effective in the success of the method. Supporting this process with computer software helps decision-makers to make the right decision in decision problems.

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