DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

CREDIT CARD AND POS DEVICE MARKETING PERSONNEL SELECTION IN BANKING SECTOR USING FUZZY MULTIPLE CRITERIA DECISION MAKING METHODS

by

İbrahim Emre SELÇUK

October, 2015

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We have read the thesis entitled "**CREDIT CARD AND POS DEVICE MARKETING PERSONNEL SELECTION IN BANKING SECTOR USING FUZZY MULTIPLE CRITERIA DECISION MAKING METHODS**" completed by **İBRAHİM EMRE SELÇUK** under supervision of **ASSOC. PROF. HASAN SELİM** and we certify in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

Personnel selection at human resources management can change drastically a company's current and/or future structure which may cause further growth or shrinkage of the company. The aim of this study is to select effectively the personnel for credit card and POS device marketing having great importance in banking sector. To support the related decision makers, the most suitable candidates are proposed to the decision makers by using multi criteria decision making methods namely Fuzzy AHP, Fuzzy ELECTRE I, Fuzzy TOPSIS, ELECTRE III and PROMETHEE II. A real world application is provided to validate the effectiveness of the proposed approach.

Keywords: Personnel selection, Banking sector, Fuzzy ELECTRE I, Fuzzy AHP, Fuzzy TOPSIS, multi criteria decision making.

BULANIK ÇOK KRİTERLİ KARAR VERME YÖNTEMLERİ KULLANILARAK BANKACILIK SEKTÖRÜNDE KREDİ KARTI VE POS CİHAZI PAZARLAMA PERSONELİNİN SEÇİMİ

ÖZ

İnsan kaynakları yönetiminde personel seçimi, bir firmanın mevcut ve/veya gelecekteki yapısını köklü bir şekilde değiştirebilir ve firmanın daha da büyümesine veya küçülmesine neden olabilir. Bu çalışmanın amacı; bankacılık sektöründe çok önemli bir alan olan kredi kartı ve POS cihazı pazarlamasında istihdam edilecek personelin etkin bir şekilde seçimini gerçekleştirmektir. İlgili karar vericileri desteklemek amacıyla, en uygun adaylar Bulanık AHP, Bulanık ELECTRE I, Bulanık TOPSIS, ELECTRE III ve PROMETHEE II gibi çok kriterli karar verme yöntemleri kullanılarak belirlenmiştir. Önerilen yaklaşımın etkinliğini göstermek amacıyla gerçek yaşam problemini ele alan bir uygulama sunulmuştur.

Anahtar kelimeler: Personel seçimi, Bulanık ELECTRE I, Bulanık AHP, Bulanık TOPSIS, çok kriterli karar verme

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INTRODUCTION

People throughout history have always faced a decision-making situation. Decision making can be described as determining the best described against a situation. If there is a single criterion in decision making process, the most suitable candidate / candidates can be selected easily. However, it is difficult to decide in multiple criteria cases.

One of the most important objectives of companies is getting profit. Companies are required to provide timely and correct decisions in all departments to get profit and survive in today’s highly competitive markets. A company chooses carefully not only the non-human factors such as raw materials, financial structure etc. but also people who manage these factors too. Companies should hire the staff that fits best to their purpose by assessing the applicants carefully according to the prespecified criteria for each position.

Staff selection is an important decision making problem, and multi criteria decision making methods are often employed for handling this problem.

In this study, we use the most widely used multi criteria decision making methods, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), The Elimination and Choice Translating Reality (ELECTRE), Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). To treat the inherent uncertainties of the real life problem more effectively, fuzzy logic is used in this thesis.

A real world application is provided in this study, to validate the effectiveness of the proposed approach. In the application, a commercial bank, Bank A, want to hire a female staff in one of its branch who will be responsible for marketing retail banking products. The Bank is decided to work with a consulting firm for the selection of the staff. The consulting firm reached a number of candidates and five of them are suggested to the Bank for its final decision.

In this study, eleven criteria are considered for the personnel selection problem under concern. Fuzzy AHP method is used to determine the weights of the criteria. In addition, for sorting the alternatives, Fuzzy TOPSIS and Fuzzy ELECTRE I methods are employed. DECISION LAB and LAMSADE software packages are also utilized in our application.

The remainder of this study is organized as follows. In Chapter 2, the literature about Fuzzy Multi Criteria Decision Making (MCDM) applications is overviewed. In Chapter 3, common MCDM methods are introduced. In Chapter 4, fuzzy logic, fuzzification and defuzzification terminology are explained. In Chapter 5, the Fuzzy MCDM methods that are employed in this study are explained. In Chapter 6, an application on personnel selection in banking sector is presented. Finally, concluding remarks are presented in Chapter 7.

CHAPTER TWO
RELATED LITERATURE

Decision making is often described as choosing an alternative which competes with each other for solving a particular problem. In other words, decision making is choosing an alternative from two or more alternatives.

People are all decision makers and they always try to find the best alternative for themselves. If there exists a few criteria and a few alternatives, people can choose the best one easily. However, they usually face complex problems including a lot of criteria and alternatives. When the purpose is determining the best alternative, people need some models, approaches or decision support systems.

Decision making is the study of identifying and choosing alternatives based on the values and preferences of decision makers. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on (Harris, 2012).

MCDM refers to making decisions in the presence of multiple, usually conflicting, criteria. MCDM problems are common in everyday life. In personal context, a house or a car one buys may be characterized in terms of price, size, style, safety, comfort, etc. In business context, MCDM problems are more complicated and usually of large scale (Xu & Yang, 2001).

Although MCDM problems are widespread all the time, MCDM as a discipline only has a relatively short history of about 30 years. The development of the MCDM discipline is closely related to the advancement of computer technology. In one hand, the rapid development of computer technology in recent years has made it possible to conduct systematic analysis of complex MCDM problems. On the other hand, the widespread use of computers and information technology has generated a huge amount of information, which makes MCDM increasingly important and useful in supporting business decision making. There are many methods available for solving MCDM problems. The most common methods are AHP, TOPSIS, ELECTRE and PROMETHEE.

Sometimes, MCDM methods are not sufficient to solve the real world problems exactly. For understanding and solving complicated real world problems that include uncertainties, fuzzy logic and MCDM methods are needed to be integrated.

The theory of decision making formed a basis for more systematic and rational decision making especially in the situation where multiple criteria need to be accounted. The decision theory does not take so much time to fully recognized with the four terms consolidated to be known as MCDM. The theory was further developed in line with the development of uncertainty and chaos theory. The uncertainty theory of fuzzy set theory which was introduced by Zadeh (1965) has been overwhelmingly accepted by MCDM enthusiast (Lazim, 2013).

There exists many studies using Fuzzy MCDM in the literature in different business areas. For instance, Meixner (2003) compared different energy production methods by using Fuzzy AHP. Göksu and Güngör (2008) studied on determining university preference rankings with Fuzzy AHP. Ayhan (2013) studied on selection of the best supplier under certain criteria for a gear motor company with Fuzzy AHP. Aydın (2009) used this method in order to determine the most suitable location for a hospital to be opened in Ankara, Turkey. In another paper, Vatansever (2013) studied on decisions regarding the purchase of various sets for use in ear, nose and throat surgeries in Gediz State Hospital with Fuzzy AHP. He compared the decisions taken with public procurement law and Fuzzy AHP method. Şengül, Eren and Shiraz (2012) evaluated five different busses for public transport to be planned to buy by Erzurum metropolitan municipality with Fuzzy AHP under eight criteria. Kazançoğlu and Ada (2010) applied this method on a supplier's selection process for a company from retail sector.

Ballı, Karasulu and Körükoğlu (2007) used another common Fuzzy MCDM method, Fuzzy PROMETHEE, for determining the best alternative among seven cars. Yuen and Ting (2012) used this method for selecting student textbook. In their study, they consider five criteria and four different textbooks. Yılmaz and Dağdeviren (2010) handled equipment selection problem by using PROMETHEE and Fuzzy PROMETHEE methods to find the best alternative among eleven alternatives under six criteria. Additionally, Alp, Demirtaş, Baraçli and Tuzkaya (2011) selected the best of three different parking locations for buses used in urban transport under six main criteria and 16 sub-criteria by using Fuzzy AHP and PROMETHEE methods.

One of the most common Fuzzy MCDM methods is Fuzzy TOPSIS. Among the studies that employs this method, Özdemir and Seçme (2009) evaluated suppliers of a furniture firm in Turkey. Çınar (2010) used Fuzzy TOPSIS method in selecting the best city among five alternatives for the new branch for a Bank in Southeastern Anatolia Region. Koca and Taşer (2014) used the method for evaluating the business customers of a bank while giving credits to small and medium sized enterprises. Başkaya and Öztürk (2011) used the method for the selection of salesperson for a store of a chain. Küçük and Ecer (2007) used Fuzzy TOPSIS method for evaluating suppliers that offers goods and services for a chain store in Erzurum, Turkey. Karaatlı, Ömürbek, Aksoy and Karakuzu (2014) used Fuzzy TOPSIS method for evaluating tour operators in Isparta province operating in the tourism sector. They used Fuzzy AHP method for determining the weight of criteria in the evaluation phase.

In another study, Aytaç, Işık and Kundakçı (2011) applied Fuzzy ELECTRE I method in handling catering firm selection problem in a textile company. Ertuğrul and Karakaşoğlu (2010) used ELECTRE and Fuzzy AHP methods for laptop selection problem in a company.

One of the most important decision problems in business administration is personnel selection. The success of enterprises depends directly on the staffs' efficiency. Choosing the right staff for a company plays a vital role in gaining sustainable competitive advantage in today's global markets. Personnel selection is a systematic determination of the employees among the candidates whose abilities, skills, attitudes, interests and experiences are suitable for the organization's requirement.

Human resources management plays a vital role in today's competitive world. As everybody wants highly distinguished persons, evaluation of the right staff / employee is a very difficult task. It is also necessary to choose a better person among the others, where the success of any industry / organization / institution heavily depends on (Kumar, Radhika & Suman, 2013).

Real world is different. Real world is not simple, sober, certain etc. All over the world nearly everything is inconsistent, uncertain, complex etc. People have to face this situation and puzzle over. Hence, fuzzy logic is evolved and uncertainty is taken into account in a better way. Because of the heavy competition between businesses and uncertainty in market conditions, attainment of complete and certain information flow becomes harder. Especially, in evaluations with linguistic variables, because of the uncertainty in language, there exists some fuzziness. In fuzzy environments like this, decision making with fuzzy numbers is rather important (Öztürk & Başkaya, 2012).

The necessity of dealing with uncertainty in real world problems has been a long term research challenge that has originated different methodologies and theories. Fuzzy decision making along with their extensions have provided a wide range of tools that are able to deal with uncertainty in different types of problems. Fuzzy decision making methods have also become increasingly popular in handling personnel selection problems. Various decision making approaches have been proposed to solve this problem (Afshari, Nikolic & Cockalo, 2014).

Personnel selection is a decision making process including uncertainty. Generally, the best candidate is tried to find with a compromise decision by a committee according to the predetermined attributes (Bali, 2013). Recently, the studies on human resources management have begun to contain fuzzy logic in handling personnel selection problems. There exist a number of studies that use Fuzzy MCDM methods in handling personnel selection problem. Among them, Dağdeviren (2007) proposed an algorithm for the solution of personnel selection problems with Fuzzy AHP method. For defuzzification of fuzzy weights he used α-cut and optimism index. In another study, Kabak and Kazançoğlu (2012) used Fuzzy AHP and absolute measurement methods for evaluating teacher candidates in military schools. They used Fuzzy AHP and absolute measurement methods to determine the weight of the criteria and rank the alternatives, respectively. Rouyendegh and Erkan (2012) used Fuzzy AHP method for selecting the most suitable academic staff, where five candidates under ten different sub-criteria were evaluated and prioritized. Karaçolak and Ünal (n.d.) studied on a hiring process for a public institution with Fuzzy AHP. Öztürk and Başkaya (2011) used Fuzzy TOPSIS for selecting the best alternative among the candidates for business salesperson. Şimşek, Catır and Ömürbek (2014) used Fuzzy AHP for personnel selection in the tourism sector. Çınar (2015) used Fuzzy TOPSIS method in his study. Six decision makers chose a staff from five candidates considering five criteria. Özbek (2014) studied for a non-governmental organization with Fuzzy AHP. It was advised the best candidate to the organization amongst seven candidates considering twelve criteria. Vatansever and Öncel (2014) used Fuzzy AHP in determining the weights of criteria and Fuzzy TOPSIS in evaluating the candidates according to the related weights of the criteria for selecting academic staff. Rouyendegh and Erkan (2012) studied on an application of academic staff selection using the opinion of experts to be applied into a model of group decision making called the Fuzzy ELECTRE method. There were ten qualitative criteria for selecting the best candidate amongst five prospective applicants.

The personnel selection process is occurred intensely in banking sector, too. The number of studies on personnel selection problems in banking sector with MCDM methods is scarce.

For instance, Polychroniou and Giannikos (2009) handle the employee selection problem in a private Greek bank. The bank selected a credit officer amongst seven candidates who were assessed with seven criteria. These are; annual salary request, personality profile, leadership ability, communication skills, educational background, age and knowledge of foreign languages. They used Fuzzy TOPSIS method for the selection process.

This study handles the personnel selection problem in banking sector by using Fuzzy MCDM methods namely Fuzzy AHP, Fuzzy ELECTRE I and Fuzzy TOPSIS. To validate the effectiveness of the proposed approach, a real world application is provided.

CHAPTER THREE
MULTI CRITERIA DECISION MAKING METHODS

In this chapter an introduction to MCDM and four different multi criteria decision making methods namely AHP, TOPSIS, ELECTRE and PROMETHEE are presented. Decision making processes of these four methods are explained step by step in the following subsections.

3.1 Multi Criteria Decision Making

Multi criteria decision making has been one of the fastest growing problem areas during at least the last two decades. In business, decision making has changed over the last decades. From a single person and a single criterion, decision environments have developed increasingly to become multi person and multi criteria situations. The awareness of this development is growing in practice. In theory, many methods have been proposed and developed since the sixties to solve this problem in numerous ways (Triantaphyllou, 2000).

MCDM is one of the most well-known branches of decision making. It concentrates on problems with discrete decision spaces. In these problems, the set of decision alternatives has been predetermined. MCDM methods provide a ranking of the available alternatives and thereby, decision of critical thinking become easier (Kumar, Radhika & Suman, 2013).

MCDM models do not try to compute an optimal solution, but they try to determine via various ranking procedures either a ranking of the relevant actions (decision alternatives) that is "optimal" with respect to several criteria, or they try to find the "optimal" actions amongst the existing solutions (decision alternatives). Even though this type of problem is much more relevant and frequent in practice, there are many new methods available and their quality is much harder to determine than in the continuous case.

The analysis of the way people make decisions (prescriptive theories) or the way people ought to make decisions (nonnative theories) is perhaps as old as the recorded history of mankind. Of course, not all these analyses were characterized by the rigorous scientific approaches we see in the literature today. Therefore, it is not surprising that the literature in decision making is humongous and continuously increasing. At the same time, however, the development of the perfect decision making method for rational real life decision making still remains an elusive goal. This contradiction between the extensiveness of the study on this subject and the elusiveness of the final goal of the real life applicability of the findings, constitutes in a way the ultimate decision making paradox.

In cases in which the number of criteria is large (e.g. more than a dozen), criteria may be arranged in a hierarchical manner. That is, some criteria may be major. Each major criterion may be associated with several sub criteria. Similarly, each sub criterion may be associated with several sub criteria and so on. Although some MCDM methods may explicitly consider a hierarchical structure in the criteria of a decision problem, most of them assume a single level of criteria (e.g. no hierarchies).

Although MCDM methods may be widely diverse, many of them have certain aspects in common. These are the notions of alternatives, attributes (also often called goals or decision criteria), weights and decision matrix as described next.

- Alternatives: Usually alternatives represent the different choices of action available to the decision maker. In MCDM, alternatives are assumed to be finite, ranging from several to hundreds. They are supposed to be screened, prioritized, and eventually ranked.

- Multiple Attributes: Each MCDM problem is associated with multiple attributes. Attributes are also referred to as "goals" or "decision criteria". Attributes represent the different dimensions from which the alternatives can be viewed.

- Conflict among Criteria: Since different criteria represent different dimensions of the alternatives, they may conflict with each other. For instance, cost may conflict with profit etc.

- Incommensurable Units: Different criteria may be associated with different units of measure. For instance, in the case of buying a used car, the criteria "cost" and "mileage" may be measured in terms of dollars and thousands of miles, respectively. It is this nature of having to consider different units makes MCDM problems intrinsically hard to solve.

- Decision Weights: Most of the MCDM methods require that the criteria be assigned weights of importance. Usually, these weights are normalized to add up to one.

- Decision Matrix: A MCDM problem can be easily expressed in a matrix format. A decision matrix A is an (mxn) matrix in which element a_{ij}, indicates the performance of alternative A_i, when it is evaluated in terms of decision criterion C_j (for i = 1, 2, 3, ..., m, and j = 1, 2, 3, ..., n). It is also assumed that the decision maker has determined the weights of relative performance of the decision criteria (denoted as w_j, for j = 1, 2, 3, ..., n). This information is best summarized in the following definition.

Let $A = \{A_i$, for i = 1, 2, 3, ..., $n\}$ be a (finite) set of decision alternatives and $G = \{g_j$, for j = 1, 2, 3, ..., $m\}$ a (finite) set of criteria according to which the desirability of an action is judged. Determine the optimal alternative A^* with the highest degree of desirability with respect to all relevant criteria g_j.

Criteria	C_1	C_2	C_3	...	C_n
Alts.	$(w_1$	w_2	w_3	...	$w_n)$
A_1	a_{11}	a_{12}	a_{13}	...	a_{1n}
A_2	a_{21}	a_{22}	a_{23}	...	a_{2n}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
A_m	a_{m1}	a_{m2}	a_{m3}	...	a_{mn}

Figure 3.1 Typical decision matrix

According to Baker (2001) a general decision making process can be divided into eight steps.

- Step 1. Define the problem

This process must, as a minimum, identify root causes, limiting assumptions, system and organizational boundaries and interfaces, and any stakeholder issues. The goal is to express the issue in a clear, one-sentence problem statement that describes both the initial conditions and the desired conditions. It is essential that the decision-maker(s) and support staff concur on a written problem statement to ensure that they all agree on what problem is going to be solved before proceeding to the next steps.

- Step 2. Determine requirements

Requirements are conditions that any acceptable solution to the problem must meet. Requirements spell out what the solution to the problem must do.

- Step 3. Establish goals

Goals are broad statements of intent and desirable programmatic values. Goals go beyond the minimum essential must have's (i.e. requirements) to wants and desires. Goals should be stated positively (i.e. what something should do, not what it shouldn't do). Because goals are useful in identifying superior alternatives (i.e., define in more detail the desired state of the problem), they are developed prior to alternative identification.

- Step 4. Identify alternatives

Alternatives offer different approaches for changing the initial condition into the desired condition. The decision team evaluates the requirements and goals and suggests alternatives that will meet the requirements and satisfy as many goals as possible. Generally, the alternatives vary in their ability to meet the requirements and goals. Those alternatives that do not meet the requirements must be screened out from further consideration. If an alternative does not meet the requirements, three actions are available:

1. The alternative is discarded
2. The requirement is changed or eliminated
3. The requirement is restated as a goal

- Step 5. Define criteria

Usually no one alternative will be the best for all goals, requiring alternatives to be compared with each other. The best alternative will be the one that most nearly achieves the goals. Decision criteria which will discriminate among alternatives must be based on the goals. It is necessary to define discriminating criteria as objective measures of the goals to measure how well each alternative achieves the project goals.

- Step 6. Select a decision making tool

The method selection needs to be based on the complexity of the problem and the experience of the team. Generally, the simpler the method, the better it is. More complex analyses can be added later if needed.

- Step 7. Evaluate alternatives against criteria

Alternatives can be evaluated with quantitative methods, qualitative methods, or any combination. Criteria can be weighted and used to rank the alternatives. Both sensitivity and uncertainty analyses can be used to improve the quality of the selection process. Experienced analysts can provide the necessary thorough understanding of the mechanics of the chosen decision-making methodology.

- Step 8. Validate solutions against problem statement

After the evaluation process has selected a preferred alternative, the solution should be checked to ensure that it truly solves the problem identified. Compare the original problem statement to the goals and requirements. A final solution should fulfill the desired state, meet requirements, and best achieve the goals within the values of the decision makers.

The following sections introduce the methods employed in this study.

3.2 AHP

One of the most popular analytical techniques for complex decision-making problems is AHP. Saaty (1980) developed AHP, which decomposes a decision-making problem into a system of hierarchies of objectives, attributes (or criteria), and alternatives. An AHP hierarchy can have as many levels as needed to fully characterize a particular decision situation. A number of functional characteristics make AHP a useful methodology. These include the ability to handle decision situations involving subjective judgments, multiple decision makers, and the ability to provide measures of consistency of preference. Designed to reflect the way people actually think, AHP continues to be the most highly regarded and widely used decision-making method. AHP can efficiently deal with tangible (i.e., objective) as well as non-tangible (i.e., subjective) attributes, especially where the subjective judgments of different individuals constitute an important part of the decision process. The main procedure of AHP using the radical root method (also called the geometric mean method) is as follows (Rao, 2007):

- Step 1. Determine the objective and the evaluation attributes. Develop a hierarchical structure with a goal or objective at the top level, the attributes at the second level and the alternatives at the third level.

- Step 2. Determine the relative importance of different attributes with respect to the goal or objective. Construct a pair-wise comparison matrix using a scale of relative importance. The judgments are entered using the fundamental scale of the analytic hierarchy process. Pair wise comparison values are shown in Table 3.1.

Table 3.1 Nine point scale for pair wise comparison

Intensity	Verbal scale of dominance
0	Independent
1	Equal dominance
3	Moderate dominance
5	Strong dominance
7	Very strong dominance
9	Absolute or extreme dominance
2,4,6 and 8	For compromise between the above two values

Assuming M attributes, the pair-wise comparison of attribute i with attribute j yields a square matrix B_{mxm} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, $b_{ij} = 1$ when $i = j$ and $b_{ji} = 1/b_{ij}$.

$$B_{mxm} = \begin{array}{c} \\ B_1 \\ B_2 \\ B_3 \\ \\ B_m \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 \ldots\ldots & & B_m \end{array} \\ \begin{pmatrix} 1 & b_{12} & b_{13} \ldots\ldots & b_{1m} \\ b_{21} & 1 & b_{23} \ldots\ldots & b_{2m} \\ b_{31} & b_{32} & 1 \ldots\ldots & b_{3m} \\ \ldots & & \ldots\ldots\ldots\ldots & \\ b_{m1} & b_{m2} & b_{m3} \ldots\ldots & 1 \end{pmatrix} \end{array}$$

Figure 3.2 Pair-wise comparison of attribute matrix

Find the relative normalized weight (w_j) of each attribute by calculating the geometric mean of the i^{th} row, and normalizing the geometric means of rows in the comparison matrix. This can be represented as:

$$GM_j = \left[\prod_{j=1}^{m} b_{ij} \right]^{1/m} \tag{3.1}$$

$$w_j = GM_j \Big/ \sum_{j=1}^{m} GM_j \tag{3.2}$$

The geometric mean method of AHP is commonly used to determine the relative normalized weights of the attributes, because of its simplicity, easy determination of the maximum Eigen value, and reduction in inconsistency of judgments.

Calculate matrices A_3 and A_4 such that $A_3 = A_1 * A_2$ and $A_4 = A_3 / A_2$, where

$$A_2 = [w_1, w_2, \ldots, w_j]^T \tag{3.3}$$

Determine the maximum Eigen value λ_{max} that is the average of matrix A_4.

Calculate the consistency index $CI = (\lambda_{max} - M) / (M - 1)$. The smaller the value of CI, the smaller is the deviation from the consistency.

Obtain the random index (RI) for the number of attributes used in decision making. The reader can refer to Table 3.2 for more details.

Calculate the consistency ratio $CR = CI / RI$. Usually, a CR of 0.1 or less is considered as acceptable, and it reflects an informed judgment attributable to the knowledge of the analyst regarding the problem under study.

- Step 3. The next step is to compare the alternatives pair-wise with respect to how much better (i.e., more dominant) they are in satisfying each of the attributes, i.e., to ascertain how well each alternative serves each attribute. If there is n number of alternatives, then there will be m number of nxn matrices of judgments, since there are m attributes. Construct pair-wise comparison matrices using a scale of relative importance. The judgments are entered using the fundamental scale of the AHP method. The steps are the same as those suggested under main step 2.

Table 3.2 Random index (*RI*) values

Attributes	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

In the AHP model, both the relative and absolute modes of comparison can be performed. The relative mode can be used when decision makers have prior knowledge of the attributes for different alternatives to be used, or when objective data of the attributes for different alternatives to be evaluated are not available. The absolute mode is used when data of the attributes for different alternatives to be evaluated are readily available. In the absolute mode, *CI* is always equal to 0, and complete consistency in judgments exists, since the exact values are used in the comparison matrices.

- Step 4. The next step is to obtain the overall or composite performance scores for the alternatives by multiplying the relative normalized weight (w_j) of each attribute (obtained in step 2) with its corresponding normalized weight value for each alternative (obtained in step 3), and summing over the attributes for each alternative.

Kwiesielewicz and Uden (2004) stated that even if the pair-wise comparison matrix B_{mxm} is of acceptable consistency, the matrix may still be contradictory. If a matrix is contradictory, then it is difficult to derive weights that satisfy all the judgments expressed in B_{mxm}. Hence, it is imperative to remove any such contradictory matrix from the decision-making process. For example, if b_{ij} = 1 and b_{ik} = 1, then b_{jk} must be equal to 1. If any judgment is made such that $b_{jk} > 1$, then contradiction is present in the matrix, and needs to be removed. Kwiesielewicz and Uden (2004) formulated an algorithm to check for the presence of any contradiction in B_{mxm}.

It may be added here that the AHP method can also be used for assigning the values of relative importance (a_{ij}) to the attributes in graph theory and the matrix approach (GTMA).

3.3 TOPSIS

Hwang and Yoon (1981) developed the TOPSIS method based on the concept that the chosen alternatives should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. Formally, for a MADM problem with m alternatives that are evaluated by n attributes (or called criteria), the positive ideal solution is denoted as (Zhang, Ruan & Wu, 2007):

$$A^* = (x^*_1, \ldots.x^*_j\ldots\ldots x^*_n) \tag{3.4}$$

where x^*_j is the best value for the j^{th} attribute among all available alternatives. Then the negative level solution is given as:

$$A^- = (x^-_1, \ldots.x^-_j\ldots\ldots x^-_n) \tag{3.5}$$

where x^-_j is the worst value for the j^{th} attribute among all available alternatives.

The method is presented in the following steps.

- Step 1. Calculate normalized ratings

The vector normalization is used for computing r_{ij} as:

$$r_{ij} = x_{ij} / (\sum_{i=1}^{m} x^2_{ij}\ )^{0,5} \qquad i=1,2,\ldots, m, j=1,2, \ldots, n \tag{3.6}$$

- Step 2. Calculate weighted normalized ratings

The weighted normalized value is calculated as:

$$v_{ij} = w_j \, r_{ij} \qquad (3.7)$$

where w_j is the weight of j^{th} attribute.

- Step 3. Identify positive-ideal and negative-ideal solutions

A^* and A^- are defined in terms of weighted normalized values as follows.

$$A^* = \{v^*_1, \; ....v^*_j......v^*_n\} = \{(\max_j v_{ij} \mid j=1, 2, \ldots, n) \mid i=1, 2, \ldots, m\} \quad (3.8)$$

$$A^- = \{v^-_1, \; ....v^-_j......v^-_n\} = \{(\min_j v_{ij} \mid j=1, 2, \ldots, n) \mid i=1, 2, \ldots, m\} \quad (3.9)$$

- Step 4. Calculate separation measure

The separation of each alternative from the positive ideal solution, A^*, is given by:

$$S^*_i = \left(\sum_{j=1}^{n} (v_{ij} - v^*_j)^2 \right)^{0,5} \qquad i=1, 2, \ldots, m \qquad (3.10)$$

Similarly, the separation from the negative ideal solution, A^- , is given by:

$$S^-_i = \left(\sum_{j=1}^{n} (v_{ij} - v^-_j)^2 \right)^{0,5} \qquad i=1,2, \ldots, m \qquad (3.11)$$

- Step 5. Calculate similarities to positive ideal solution

$$C^*_i = S^-_i / (S^*_i + S^-_i) \qquad i=1,2, ..., m \qquad (3.12)$$

Note that $0 \leq C^*_i \leq 1$, where $C^*_i = 0$ when $A_i = A^-$, $C^*_i = 1$ when $A_i = A^*$.

- Step 6. Rank preference order

Choose an alternative with the maximum C^*_i or rank alternatives according to C^*_i in descending order.

3.4 ELECTRE

The basic concept of ELECTRE method is to deal with "outranking relations" by using pairwise comparisons among alternatives under each one of the criteria separately. The outranking relationship of the two alternatives A_i and A_j, denoted as $A_i \rightarrow A_j$, describes that even when the i^{th} alternative does not dominate the j^{th} alternative quantitatively, then the decision maker may still take the risk of regarding A_i as almost surely better than A_j. Alternatives are said to be dominated, if there is another alternative which excels them in one or more criteria and equals in the remaining criteria (Triantaphyllou, 2000).

ELECTRE method begins with pairwise comparisons of alternatives under each criterion. Using physical or monetary values, denoted as $g_i(A_j)$ and $g_i(A_k)$ of the alternatives A_j and A_k, respectively, and by introducing threshold levels for the difference $g_i(A_j)$ - (A_k), the decision maker may declare that he/she is indifferent between the alternatives under consideration, that he/she has a weak or a strict preference for one of the two, or that he/she is unable to express any of these preference relations. Therefore, a set of binary relations of alternatives, the so-called outranking relations**,** may be complete or incomplete. Next, the decision maker is requested to assign weights or importance factors to the criteria in order to express their relative importance.

Through the consecutive assessments of the outranking relations of the alternatives, ELECTRE method elicits the so-called concordance index, defined as the amount of evidence to support the conclusion that alternative A_j outranks, or dominates, alternative A_k, as well as the discordance index, the counter-part of the concordance index.

Finally, the ELECTRE method yields a system of binary outranking relations between the alternatives. Because this system is not necessarily complete, ELECTRE method is sometimes unable to identify the most preferred alternative. It only produces a core of leading alternatives. This method has a clearer view of alternatives by eliminating less favorable ones. This method is especially convenient when there are decision problems that involve a few criteria with a large number of alternatives.

There are many variants of ELECTRE method. Organization of the original version of ELECTRE method is introduced in the following steps.

- Step 1. Normalizing the Decision Matrix

This procedure transforms the entries of the decision matrix into dimensionless comparable entries by using the following equation:

$$x_{ij} = a_{ij} / \left(\sum_{k=1}^{m} a^2_{kj} \right)^{0,5} \tag{3.13}$$

Therefore, the normalized matrix X is defined as follows:

$$X = \begin{pmatrix} x_{11} & x_{12} & \ldots\ldots & x_{1n} \\ x_{21} & x_{22} & \ldots\ldots & x_{2n} \\ . & . & . & . \\ . & . & . & . \\ x_{m1} & x_{m2} & \ldots\ldots & x_{mn} \end{pmatrix}$$

Figure 3.3 Normalized matrix

where m is the number of alternatives, n is the number of criteria, and x_{ij} is the normalized preference measure of the i^{th} alternative in terms of the j^{th} criterion.

- Step 2. Weighting the Normalized Decision Matrix

Next, each one of the columns of the previous X matrix is multiplied by the associated weight of importance of the corresponding decision criterion. These weights, denoted as (w_1, w_2, w_3, ..., w_n), were determined by the decision maker. Therefore, the weighted matrix, denoted as Y, is:

$$Y=XW \tag{3.14}$$

$$Y = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ . & . & . & . \\ . & . & . & . \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{pmatrix}$$

$$= \begin{pmatrix} w_1x_{11} & w_2x_{12} & \cdots & w_nx_{1n} \\ w_1x_{21} & w_2x_{22} & \cdots & w_nx_{2n} \\ . & . & . & . \\ . & . & . & . \\ w_1x_{m1} & w_2x_{m2} & \cdots & w_nx_{mn} \end{pmatrix}$$

Figure 3.4 Weighted matrix

where:

$$W = \begin{pmatrix} w_1 & 0 & 0 & \cdots 0 \\ 0 & w_2 & & \cdots 0 \\ . & . & . & . \\ . & . & . & . \\ 0 & 0 & \cdots & wn \end{pmatrix}$$

Figure 3.5 Weight matrix

and

$$\sum_{i=1}^{n} w_i = 1 \tag{3.15}$$

- Step 3. Determine the Concordance and Discordance Sets:

The concordance set C_{kl} of two alternatives A_k and A_l, where $m \geq k,\ l \geq 1$, is defined as the set of all the criteria for which A_k is preferred to A_l. That is, the following is true:

$$C_{kl} = \{j,\ y_{kj} \geq y_{lj}\},\ for\ j = 1, 2, 3, \ldots, n. \tag{3.16}$$

The complementary subset is called the discordance set and it is described as follows:

$$D_{kl} = \{\ j,\ y_{kj} < y_{lj}\ \}\ ,\ for\ j = 1,2,3, \ldots, n. \tag{3.17}$$

- Step 4. Construct the Concordance and Discordance Matrices

The relative value of the elements in the concordance matrix C is calculated by means of the concordance index. The concordance index C_{kl} is the sum of the weights associated with the criteria contained in the concordance set. That is, the following is true:

$$C_{kl} = \sum w_j,\ \ for\ j = 1,2,3, \ldots, n.\ \ j \epsilon C_{kl} \tag{3.18}$$

The concordance index indicates the relative importance of alternative A_k with respect to alternative A_l. Apparently, $0 \leq C_{kl} \leq 1$. The concordance matrix C is defined as follows:

$$C = \begin{pmatrix} - & c_{12} & \ldots\ldots & c_{1m} \\ c_{21} & - & \ldots\ldots & c_{2m} \\ . & . & . & . \\ . & . & . & . \\ c_{m1} & c_{m2} & \ldots\ldots & - \end{pmatrix}$$

Figure 3.6 Concordance matrix

where the entries of matrix C are not defined when $k = l$

The discordance matrix D expresses the degree that a certain alternative A_k is worse than a competing alternative A_l. The elements d_{kl} of the discordance matrix are defined as follows:

$$d_{kl} = \frac{max_{j \epsilon C_{kl}} \mid y_{kj} - y_{lj} \mid}{max_j \mid y_{kj} - y_{lj} \mid} \tag{3.19}$$

The discordance matrix is defined as follows:

$$D = \begin{pmatrix} - & d_{12} & \ldots\ldots & d_{1m} \\ d_{21} & - & \ldots\ldots & d_{2m} \\ . & . & . & . \\ . & . & . & . \\ d_{m1} & d_{m2} & \ldots\ldots & - \end{pmatrix}$$

Figure 3.7 Discordance matrix

As with the C matrix, the entries of matrix D are not defined when $k = l$. Finally, it should be noted here that the previous two m x m matrices are symmetric.

- Step 5. Determine the Concordance and Discordance Dominance Matrices

The concordance dominance matrix is constructed by means of a threshold value for the concordance index. For example, alternative A_k will only have a chance to dominate alternative A_l, if its corresponding concordance index C_{kl} exceeds at least a certain threshold value $\underline{c}$. That is, this happens if the following condition is true:

$$C_{kl} \geq \underline{c} \tag{3.20}$$

The threshold value $\underline{c}$ can be determined as the average concordance index. That is, the following relation could be true:

$$\underline{c} = \frac{1}{m(m-1)} \sum_{\substack{k=1 \\ \text{and } k\neq l}}^{m} \sum_{\substack{l=1 \\ \text{and } l\neq k}}^{m} C_{kl} \tag{3.21}$$

Based on the threshold value, the elements of the concordance dominance matrix *F* are determined as follows:

$$f_{kl} = 1, \qquad \text{if } C_{kl} \geq \underline{c} \tag{3.22}$$

$$f_{kl} = 0, \qquad \text{if } C_{kl} < \underline{c} \tag{3.23}$$

Similarly, the discordance dominance matrix *G* is defined by using a threshold value *d*, where *d* could be defined as follows:

$$\underline{d} = \frac{1}{m(m-1)} \sum_{\substack{k=1 \\ \text{and } k\neq l}}^{m} \sum_{\substack{l=1 \\ \text{and } l\neq k}}^{m} D_{kl} \tag{3.24}$$

and

$$g_{kl} = 1, \qquad \text{if } D_{kl} \geq \underline{d} \tag{3.25}$$

$$g_{kl} = 0, \qquad \text{if } D_{kl} < \underline{d} \tag{3.26}$$

- Step 6. Determine the Aggregate Dominance Matrix

The elements of the aggregate dominance matrix *E* are defined as follows:

$$e_{kl} = f_{kl} \times g_{kl} \tag{3.27}$$

- Step 7. Eliminate the Less Favorable Alternatives

From the aggregate dominance matrix, one can derive a partial preference ordering of the alternatives. If e_{kl} = 1, then this means that alternative A_k is preferred to alternative A_l by using both the concordance and discordance criteria.

If any column of the aggregate dominance matrix has at least one element equal to 1, then this column is "ELECTREally" dominated by the corresponding row. Therefore, one can simply eliminate any column(s) which have an element equal to one. Then, the best alternative is the one which dominates all other alternatives in this manner.

TOPSIS algorithm has been developed over ELECTRE algorithm. The main difference of these methods is that while ELECTRE has pairwise comparisons, the results are obtained with calculating the distances to positive and negative ideal points by TOPSIS. ELECTRE I method has been subject to criticism because the method has not the ranking structure. Therefore, other versions of ELECTRE (ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE TRI and ELECTRE IS) method were developed to correct this deficiency.

3.5 PROMETHEE

PROMETHEE method is a multiple criteria priority assignment method that is developed by Brans (1985). PROMETHEE method is improved because of some difficulties at application phase among existent prioritization methods in literature (Gotze & Schuster, 2008).

The method is comprised by seven steps.

- Step 1. $A=(a, b, c, \ldots)$ data matrix is generated by k criteria $c=(f_1, f_2, \ldots, f_k)$ with $w=(w_1, w_2, \ldots, w_k)$ weight.

Table 3.3 Data matrix

Criteria	*a*	*b*	*c*	.....	*w*
f_1	$f_1(a)$	$f_1(b)$	$f_1(c)$	.....	w_1
f_2	$f_2(a)$	$f_2(b)$	$f_2(c)$	.....	w_2
.....	.....	.....	.....	.....	.....
f_k	$f_k(a)$	$f_k(b)$	$f_k(c)$	.....	w_k

- Step 2. Preference functions are determined for criteria.

Table 3.4 Preference Functions

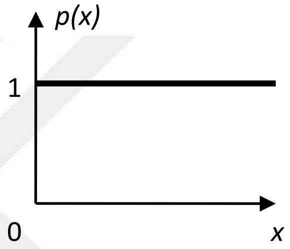
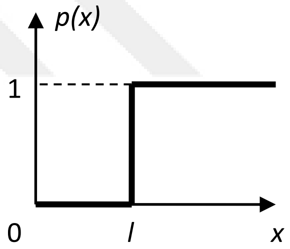
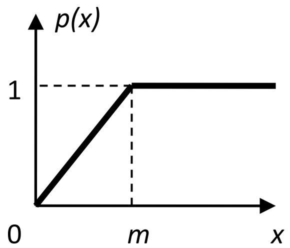
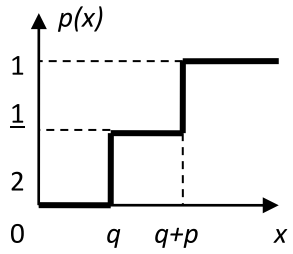
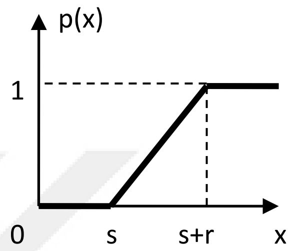
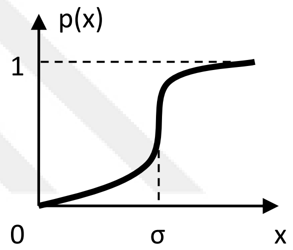
Type	Parameters	Functions	Graphic, *p(x)*
First Type (Ordinary Type)	-	$p(x)=\begin{cases}0, x\le 0\\ 1, x\ge 0\end{cases}$	
Second Type (U Type)	*l*	$p(x)=\begin{cases}0, x\le l\\ 1, x\ge l\end{cases}$	
Third Type (V Type)	*m*	$p(x)=\begin{cases}x/m, x\le m\\ 1, x\ge m\end{cases}$	

Table 3.4 Preference Functions (cont.)

Fourth Type (Level Type)	*q, p*	$p(x)=\begin{cases}0, x\le q\\1/2, q\le x\le p+q\\1, p+q\le x\end{cases}$	
Fifth Type (Linear Type)	*s, r*	$p(x)=\begin{cases}0, x\le s\\\dfrac{x-s}{r}, s\le x\le s+r\\1, s+r\le x\end{cases}$	
Sixth Type (Gaussian Type)	σ	$p(x)=\begin{cases}0, x\le 0\\1-e^{\frac{-x}{2\sigma^2}}, x^2\ge 0\end{cases}$	

- Step 3. Associate preference functions are determined for alternative pairs based on preference functions.

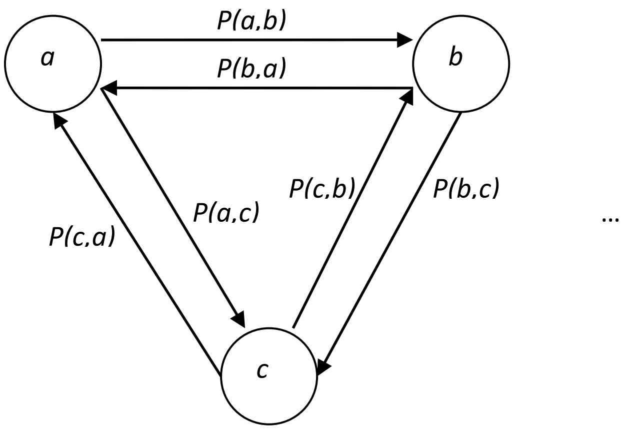


Figure 3.8 Schematic representation of the preference functions

Associate preference functions are determined for alternatives *a* and *b* with:

$$p(a,b) = \begin{cases} 0, \; f(a) \leq f(b) \\ p\left[f(a) - f(b)\right], \; f(a) > f(b) \end{cases} \tag{3.28}$$

- Step 4. Preference indexes are determined for each alternative pairs based on associate preference functions. Preference index, that alternatives *a* and *b* estimated by *k* criteria with w_i *(i = 1,2,….,k)* weights, is calculated.

$$\Pi(a,b) = \frac{\sum_{i=1}^{k} w_i \times P_i(a.b)}{\sum_{i=1}^{k} w_i} \tag{3.29}$$

- Step 5. Positive (Φ^{+}) and negative (Φ^{-}) priorities for alternatives are determined.

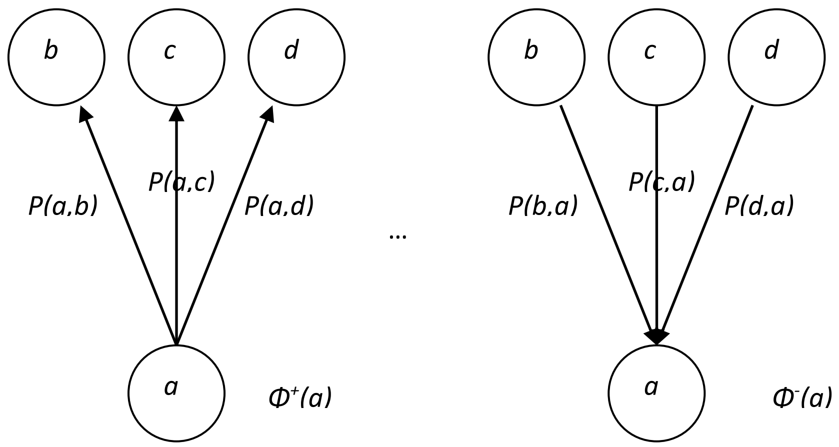


Figure 3.9 Positive and negative priorities for alternative a

$$\Phi^{+}(a) = \Sigma n(a, x), \quad x=(b,c,d,\ldots) \tag{3.30}$$

$$\Phi^{-}(a) = \Sigma n(x, a), \quad x=(b,c,d, \ldots) \tag{3.31}$$

- Step 6. Partial priorities are determined with PROMETHEE I. Partial priorities are provided alternatives' preference situations to each other's, and are determined indifferent alternatives and alternatives which are not compared each other's. For alternatives *a* and *b* the situations are given below about determining partial preferences.

- Alternative *a* is preferred to alternative *b* if:

  i. $\Phi^{+}(a) > \Phi^{+}(b) \text{ and } \Phi^{-}(a) < \Phi^{-}(b)$ (3.32)

  ii. $\Phi^{+}(a) > \Phi^{+}(b) \text{ and } \Phi^{-}(a) = \Phi^{-}(b)$ (3.33)

  iii. $\Phi^{+}(a) = \Phi^{+}(b) \text{ and } \Phi^{-}(a) < \Phi^{-}(b)$ (3.34)

- Alternative *a* and alternative *b* are indifferent if:

  i. $\Phi^{+}(a) = \Phi^{+}(b) \text{ and } \Phi^{-}(a) = \Phi^{-}(b)$ (3.35)

- Alternative *a* and alternative *b* are not compared if:

i. $\Phi^+(a) > \Phi^+(b) \text{ and } \Phi^-(a) > \Phi^-(b)$ (3.36)

ii. $\Phi^+(a) < \Phi^+(b) \text{ and } \Phi^-(a) < \Phi^-(b)$ (3.37)

- Step 7. Absolute priorities are determined with PROMETHEE II. With absolute priority values, entire alignment is determined for all alternatives evaluating same grade.

$$\Phi(a) = \Phi^+(a) - \Phi^-(a) \tag{3.38}$$

The decisions based on absolute priority value for alternatives *a* and *b* are taken as in thefollowing.

If $\Phi(a) > \Phi(b)$, alternative *a* is dominant.

If $\Phi(a) = \Phi(b)$, alternatives *a* and *b* are indifferent.

CHAPTER FOUR
FUZZY LOGIC, FUZZIFICATION AND DEFUZZIFICATION METHODS

In this chapter fuzzy logic, fuzzification and defuzzification concepts are introduced briefly and different fuzzification methods are defined. In this study, triangular fuzzy numbers are used and accordingly, a brief introduction to the idea of fuzzy membership functions is presented in this chapter.

4.1 Fuzzy Logic

Fuzzy logic is a form of many-valued logic that deals with approximate, rather than fixed and exact reasoning. Compared to traditional binary logic (where variables may take on true or false values), fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false (Novak, Perfilieva & Mockor, 1999).

Fuzzy logic can be conceptualized as a generalization of classical logic. Modern fuzzy logic was developed by Zadeh (1965) to model those problems in which imprecise data must be used or in which the rules of inference are formulated in a very general way making use of diffuse categories. In fuzzy logic, which is also sometimes called diffuse logic, there are not just two alternatives but a whole continuum of truth values for logical propositions. Fuzzy logic has a weak connection to probability theory. Probabilistic methods that deal with imprecise knowledge are formulated in the Bayesian framework, but fuzzy logic does not need to be justified using a probabilistic approach. The common route is to generalize the findings of multivalued logic in such a way as to preserve part of the algebraic structure (Rojas, 1996).

Fuzzy set approaches are suitable to use when the modeling of human knowledge is necessary and when human evaluations are needed. Fuzzy set theory is recognized as an important modeling and solution technique. It has been studied extensively over the past 40 years. Most of the early interest in fuzzy set theory pertained to representing uncertainty in human cognitive processes. The theory is now applied to problems in engineering, business, medical and related health sciences, and the natural sciences.

4.2 Fuzzification and Defuzzification Models

A fuzzy logic system can be defined as the nonlinear mapping of an input data set to a scalar output data. A fuzzy logic system consists of four main parts: fuzzier, rules, inference engine, and defuzzier. These components and the general architecture of a fuzzy logic system is shown in Figure 4.1 (Yıldız, 2010).

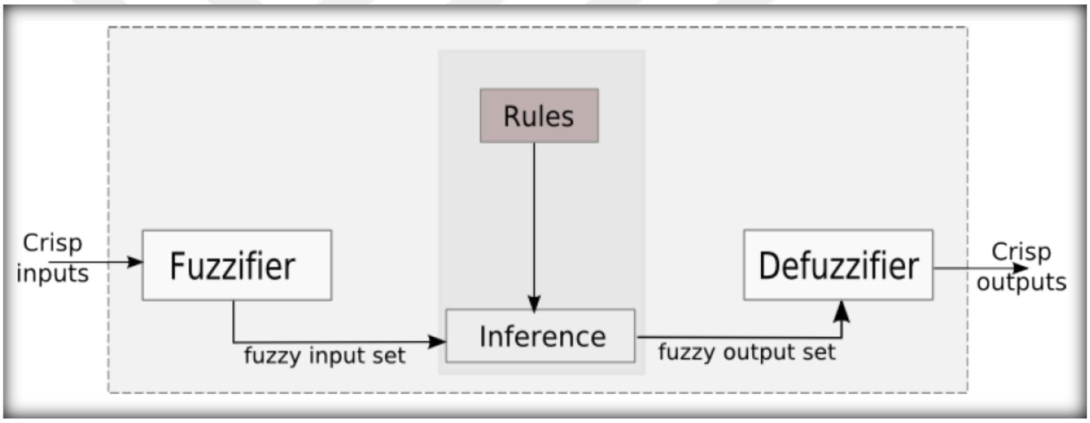


Figure 4.1 A fuzzy logic system

The process of fuzzy logic is explained in the following algorithm:

Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as fuzzification. Afterwards, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step. Fuzzy logic algorithm is defined as follows.

Fuzzy logic algorithm:

- Define the linguistic variables and terms (initialization)
- Construct the membership functions (initialization)
- Construct the rule base (initialization)
- Convert crisp input data to fuzzy values using the membership functions (fuzzification)
- Evaluate the rules in the rule base (inference)
- Combine the results of each rule (inference)
- Convert the output data to non-fuzzy values (defuzzification)

After the inference step, the overall result is a fuzzy value. This result should be defuzzified to obtain a final crisp output. This is the purpose of the defuzzier component of a fuzzy logic system. Defuzzification is performed according to the membership function of the output variable.

4.2.1 Fuzzy Membership Functions

Fuzzy logic's philosophy is based on the number of neighborhood. If a case being expressed by a number at the decision-making process, acceptance of the admissibility of the case will be the realization of that number. But numbers close to the number in question will not be detected as part of the decision process. However, member of different populations of these numbers in a certain trust factor will also be wrong to suggest statistically significant (Yaralıoğlu, n.d.).

The following are the most frequently used fuzzy membership functions (Yılmaz, n.d.).

1- Triangular membership functions

These are partially - linear functions. Graphical representations, creations and calculations are quite easy to create.

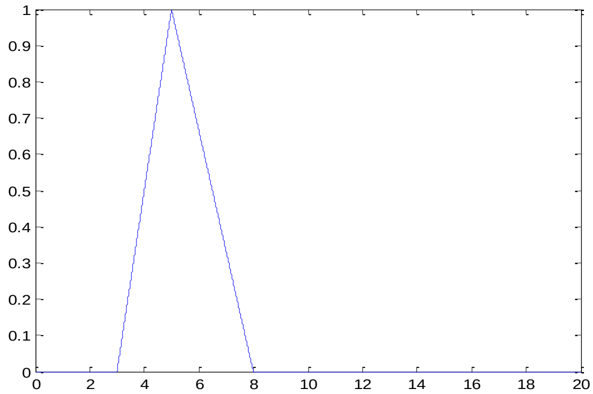


Figure 4.2 Triangular membership function

Triangular membership functions are defined by the beginning point (*a*,*0*), top point (*c*,*0*) and end point (*b*,*0*).

$$\mu_A(x) = \begin{cases} \alpha\left(\dfrac{x-a}{c-a}\right), a \le x \le c \\ \alpha\left(\dfrac{x-b}{c-b}\right), c \le x \le b \\ 0, \text{other points} \end{cases} \tag{4.1}$$

2- Trapezoid membership function

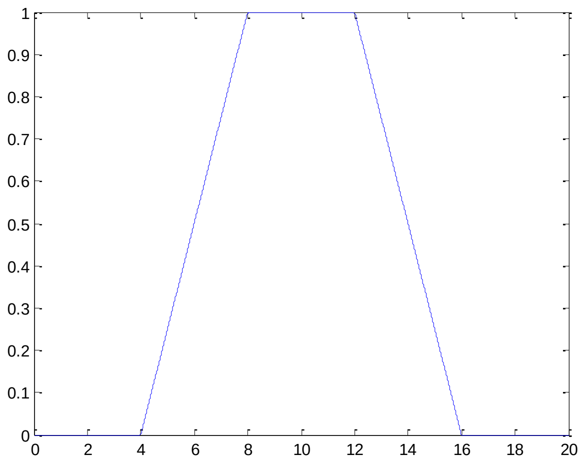


Figure 4.3 Trapezoid membership function

Trapezoid membership functions are defined by the beginning point (*a*,*0*), top point (*c*,*0*) and (*d*,*0*) and end point (*b*,*0*).

$$\mu_A(x) = \begin{cases} \alpha\left(\dfrac{x-a}{c-a}\right), a \le x \le c \\ \alpha, c \le x \le d \\ \alpha\left(\dfrac{x-b}{c-b}\right), d \le x \le b \\ 0, \text{other points} \end{cases} \tag{4.2}$$

3- Gauss membership function

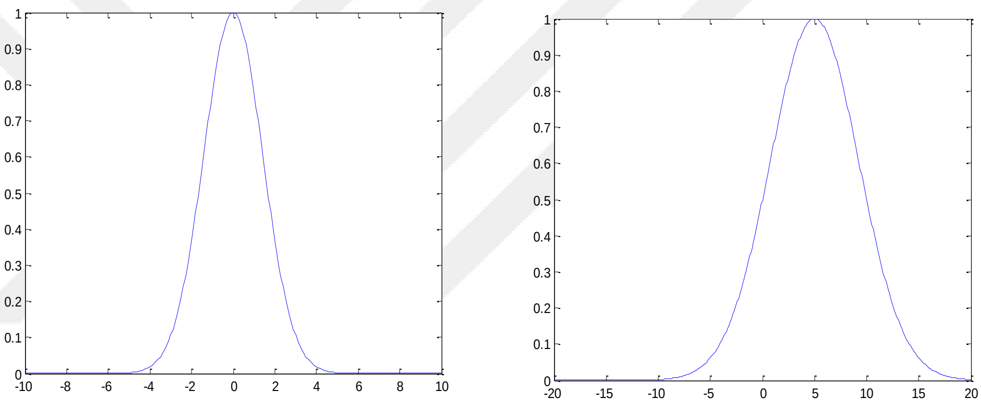


Figure 4.4 Gauss membership functions

Left figure is standard gauss $e^{\frac{-x^2}{2}}$ and right figure is Gauss $e^{\frac{-(x-5)^2}{2(3)^2}}$ functions curves.

Here c represents the center of Gauss curve; σ represents the width of Gauss curve.

$$\mu_A(x) = e^{\frac{-(x-c)^2}{2\sigma^2}} \tag{4.3}$$

4- Cauchy membership function

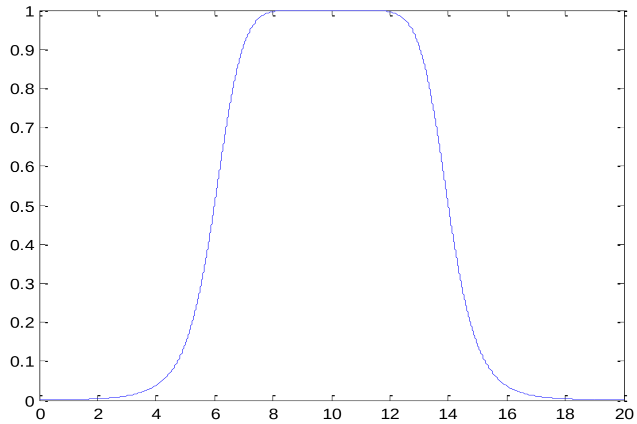


Figure 4.5 Cauchy membership function

Also known as generalized bell curve. Here c represents the center of Gauss curve, σ represents the base width of Gauss curve and n represents the ceiling width of Gauss curve:

$$\mu_A(x) = \frac{1}{\left(1 + \left|\frac{x-c}{\sigma}\right|^{2n}\right)} \tag{4.4}$$

5- *S* and *Z* shaped sigmoid membership functions

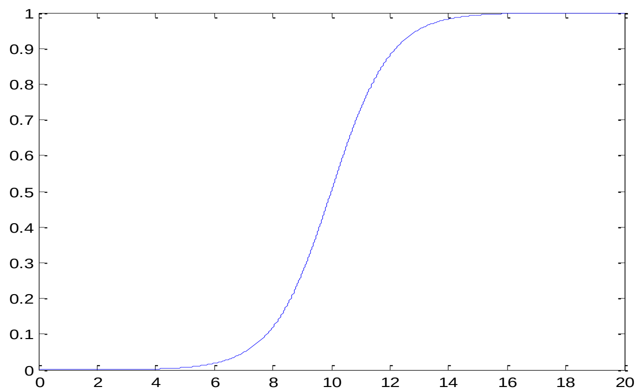


Figure 4.6 S shaped membership function

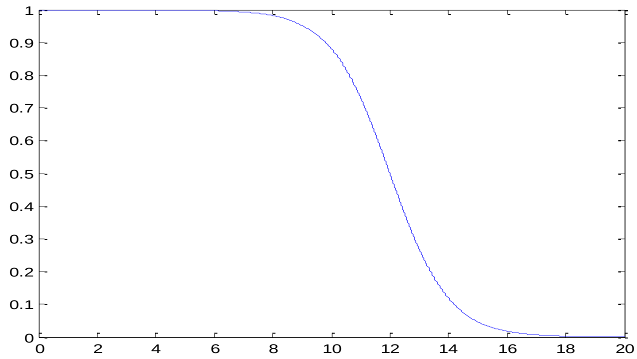


Figure 4.7 Z shaped membership function

The symbol of σ represents that the function is increasing (S) or decreasing (Z), the value of σ represents increasing or decreasing shape. m represents the center of the function in other words the midpoint of the curved portion.

$$\mu_A(x) = \frac{1}{\left(1 + e^{-(x-m)\sigma}\right)} \tag{4.5}$$

6- Single impact membership functions

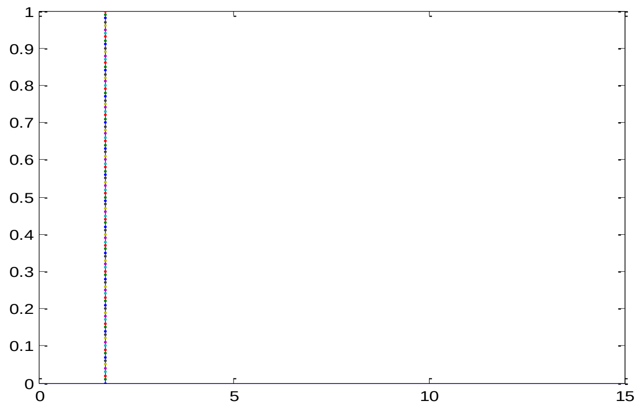


Figure 4.8 Single impact membership function

Set A consists of one element. At $x=a$ point, membership value is 1, at other points membership value is 0.

$$\mu_A(x) = \begin{cases} 1, x = a \\ 0, x \neq a \end{cases} \tag{4.6}$$

4.2.2 Defuzzification Methods

As mentioned in the Introduction Section of this study, there may be situations where the output of a fuzzy process needs to be a single scalar quantity as opposed to a fuzzy set. Defuzzification is the conversion of a fuzzy quantity to a precise quantity, just as fuzzification is the conversion of a precise quantity to a fuzzy quantity. The output of a fuzzy process can be the logical union of two or more fuzzy membership functions defined on the universe of discourse of the output variable (Ross, 2010).

Scientists have developed several methods for defuzzification. The most commonly used methods are presented in the following (Şen, 2001).

1. The biggest membership method

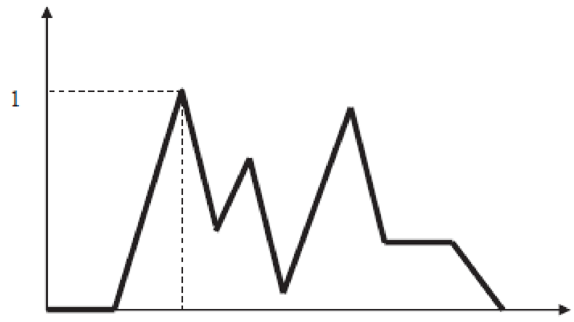


Figure 4.9 Defuzzification with the biggest method: One biggest value case

You need a set of inference which is tops in order to use this method. Another name of this method is the height method. Basically, the highest peak which is considered as the degree of membership is accepted as the membership degree of the system.

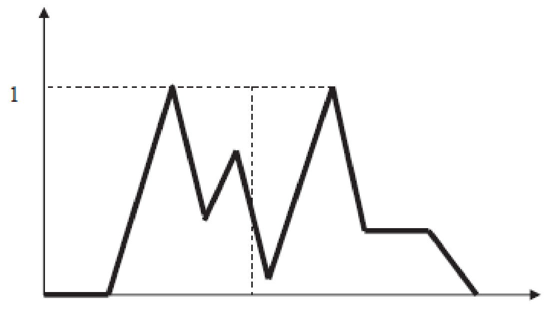


Figure 4.10 Defuzzification with the biggest method: Two biggest values case

Herein, the membership degree of the system is the average of two locations corresponding to the highest point.

2. Center of gravity method

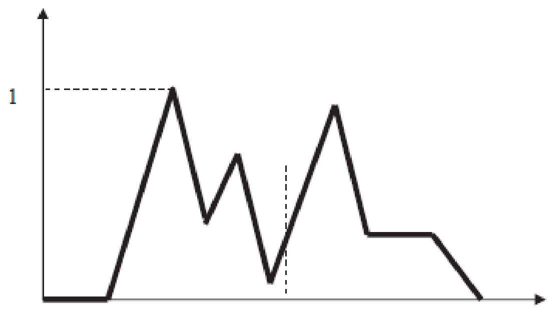


Figure 4.11 Defuzzification with center of gravity method

The center of gravity method is one of the most widely used method. The weight of the shape of the cluster formed by inference method is centrally located and taken as sharp values corresponding to the center value.

3. Weighted average method

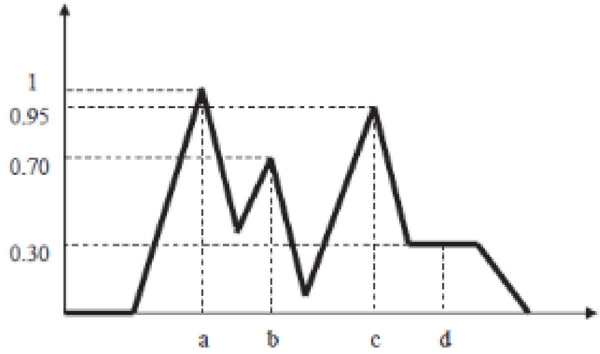


Figure 4.12 Defuzzification with weighted average method

A prerequisite for the method is the use of symmetrical membership functions. Largest membership degree of each set of membership functions constituting the mining has reached the point where this value is multiplied by and is expressed as the following equation.

$$x = \frac{a(1.0) + b(0.70) + c(0.95) + d(0.30)}{a + b + c + d} \tag{4.7}$$

4. Average biggest membership method

This method is also known as the middle of the biggest. It is similar to the biggest membership method. Unlike the biggest membership method that if the biggest value is more than one value set. And also at the largest area if there is a flat area which is a conjunction of trapezoid, bells and sigma functions, the method are used mostly, too.

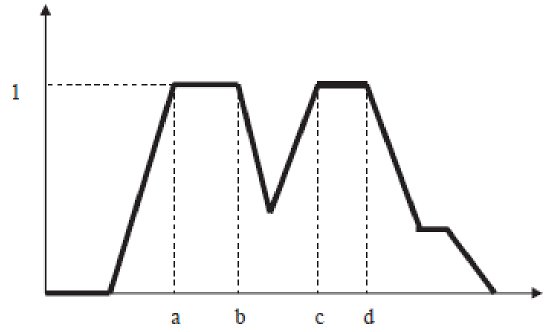


Figure 4.13 Defuzzification with average biggest membership method

The defuzzification is calculated with average biggest membership method by the following equation.

$$x = \frac{a+b+c+d}{4} \tag{4.8}$$

5. Total of center

Total of center method is the fastest one of all methods. Instead of adding two different fuzzy sets, taking the algebraic sum provides. Because of the duplication of data there may cause some errors. Basically, it works as weighted average method. Weights of the membership functions and center of functions are multiplied. In one aspect, the method is a mixture of weighted average method and center of gravity method.

6. The Biggest Space Center

This method is similar to center of gravity method. Method, if the interests of all convex sets are the same as the center of gravity method. The lack of interest of all convex sets and convex when at least two sub set of fuzzy inference is clarifying values are considered as the center of gravity, which has the largest area.

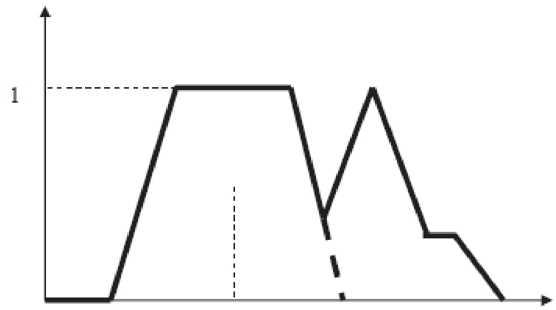


Figure 4.14 Defuzzification with center of the largest area

7. The center of the biggest ones and first biggest method

The first biggest value is taken as the defuzzification value. Moreover, if the same logic that the biggest value is consistently continuing the middle of this continuum that is taken as the biggest value in the middle of clarifying values.

CHAPTER FIVE
FUZZY MULTI CRITERIA DECISION MAKING METHODS

After elaborating decision making methods and fuzzy logic concepts in previous chapters, fuzzy decision making methods employed in this study are described in this chapter. In addition, a demonstration of AHP application performed by Excel is presented.

5.1 Fuzzy Multi Criteria Decision Making

Decision makers face many problems with incomplete and vague information in MCDM problems since the characteristics of these problems often require this kind of information. In a real-world decision situation, application of the classic MCDM methods may face serious practical constraints, because of the criteria containing imprecision or vagueness inherent in the information. Fuzzy logic provides a useful way to approach a MCDM problem. Over the years, there have been successful applications and implementations of fuzzy set theory in MCDM (Kahraman, 2008).

5.2 Fuzzy AHP

Fuzzy AHP embeds the fuzzy set theory to basic AHP. Since basic AHP does not include vagueness for personal judgments, it has been improved by using fuzzy logic approach. In Fuzzy AHP, the pair wise comparisons of both criteria and the alternatives are performed through the linguistic variables, which are represented by triangular numbers. One of the first Fuzzy AHP applications was performed by Laarhoven and Pedrycz (1983). They defined the triangular membership functions for the pair wise comparisons. Afterwards, Buckley (1985) has contributed to the subject by determining the fuzzy priorities of comparison ratios having triangular membership functions. Although there exists some more techniques embedded in Fuzzy AHP, Buckley (1985)'s method is implemented in this study to determine the relative importance weights for both the criteria and alternatives. Steps of the procedure are presented in the following (Laarhoven & Pedrycz, 1983).

- Step 1. Decision Maker compares the criteria or alternatives via linguistic terms shown in Table 5.1.

Table 5.1 Linguistic terms and the corresponding triangular fuzzy numbers

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally Important	(1.000, 1.000, 1.000)
2	Intermittent Value	(1.000, 2.000, 3.000)
3	Weakly Important	(2.000, 3.000, 4.000)
4	Intermittent Value	(3.000, 4.000, 5.000)
5	Fairly Important	(4.000, 5.000, 6.000)
6	Intermittent Value	(5.000, 6.000, 7.000)
7	Strongly Important	(6.000, 7.000, 8.000)
8	Intermittent Value	(7.000, 8.000, 9.000)
9	Absolutely Important	(9.000, 9.000, 9.000)

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example if the decision maker states "Criterion 1 (*C1*) is Weakly Important than Criterion 2 (*C2*)", then it takes the fuzzy triangular scale as (2, 3, 4). On the contrary, in the pair wise contribution matrix of the criteria, comparison of *C2* to *C1* will take the fuzzy triangular scale as (1/4, 1/3, 1/2).

The pair wise contribution matrix is shown below, where $\tilde{d}_{ij}^{k}$ indicates the k^{th} decision maker's preference of i^{th} criterion over j^{th} criterion, via fuzzy triangular numbers. Here, "tilde" represents the triangular number demonstration and for the example case, $\tilde{d}_{12}^{1}$ represents the first decision maker's preference of first criterion over second criterion, and equals to $\tilde{d}_{12}^{1}$ = (2, 3, 4).

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \dots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \dots & \dots & \tilde{d}_{2n}^k \\ \dots & \dots & \dots & \dots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \dots & \tilde{d}_{nn}^k \end{bmatrix}$$

Figure 5.1 The pair wise contribution matrix

- Step 2. If there is more than one decision maker, preferences of each decision maker ($\tilde{d}_{ij}^k$) are averaged and ($\tilde{d}_{ij}$) is calculated as follows.

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^k}{K} \tag{5.1}$$

- Step 3. According to averaged preferences, pair wise contribution matrix is updated as follows.

$$\tilde{A} = \begin{bmatrix} \tilde{d}_{11} & \dots & \tilde{d}_{1n} \\ \dots & \dots & \dots \\ \tilde{d}_{n1} & \dots & \tilde{d}_{nn} \end{bmatrix}$$

Figure 5.2 Averaged pair wise contribution matrix

- Step 4. According to Buckley (1985), the geometric mean of fuzzy comparison values of each criterion is calculated as follows. Here, $\tilde{r}_i$ still represents triangular values.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij} \right)^{1/n}, \; i=1, 2, \dots, n \tag{5.2}$$

- Step 5. Fuzzy weights of each criterion can be found by equation (5.3), by incorporating next three sub steps.

- Step 5a. Find the vector summation of each $\tilde{r}_i$.
- Step 5b. Find the (-1) power of summation vector. Replace the fuzzy triangular number to make it in an increasing order.
- Step 5c. To find the fuzzy weight of criterion *i* ($\tilde{w}_i$), multiply each $\tilde{r}_i$ with this reverse vector.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1} \tag{5.3}$$
$$= (lw_i, mw_i, uw_i)$$

- Step 6. Since $\tilde{w}_i$ are still fuzzy triangular numbers, they need to defuzzified

by Centre of Area method proposed by Chou and Chang (2008), via applying the equation below.

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \tag{5.4}$$

- Step 7. M_i is a non-fuzzy number. However, it needs to be normalized by

following Equation.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{5.5}$$

These seven steps are performed to find the normalized weights of both the criteria and alternatives. Then, by multiplying each alternative weight with related criteria, the score for each alternative is calculated. According to these results, the alternative with the highest score is suggested to the decision maker.

In our application, firstly, the decision makers make pairwise comparisons for the criteria. For determining the fuzzy triangular scale, Saaty (1980)'s numbers are used.

Table 5.2 Fuzzy triangular scale

Scale	Definitions	Abbreviations	Fuzzy Triangular Scale
1	Equally Important	EI	(1.000, 1.000, 1.000)
3	Weakly Important	WI	(2.000, 3.000, 4.000)
5	Fairly Important	FI	(4.000, 5. 000, 6.000)
7	Strongly Important	SI	(6.000, 7.000, 8.000)
9	Absolutely Important	AI	(9.000, 9.000, 9.000)

The following are the examples for the pairwise comparisons.

If Decision Maker 1 fills the "*A*" value as "*WI*" than Decision Maker cannot fill the "*a*" value. If "*A*" value defines as "*WI*" than it's equivalent of fuzzy value is (2.000, 3.000, 4.000). And the "*a*" value is calculated with (1/4.000, 1/3.000, 1/2.000) and the result is (0.250, 0.333, 0.500). The "*A*" value represents moderate dominance about criterion 2 to criterion 4 for Decision Maker 1.

If Decision Maker 2 fills the "*B*" value as "*AI*" than Decision Maker cannot fill the "*b*" value. If "*B*" value defines as "*AI*" than it's equivalent of fuzzy value is (9.000, 9.000, 9.000). And the "*b*" value is calculated with (1/9.000, 1/9.000, 1/9.000) and the result is (0.111, 0.111, 0.111). The "*B*" value represents absolute dominance about criteria 5 to criteria 1 for Decision Maker 2.

"-" represents (1.000, 1.000, 1.000).

Table 5.3 An example pairwise comparison table

CRITERIA NO	DECISION MAKER	C 1	C 2	C 3	C 4	C 5
C 1	DM 1	-				
C 2			-		A	
C 3		K	L	-	M	N
C 4			a		-	C
C 5						-
C 1	DM 2	-				b
C 2			-			
C 3		K	L	-	M	N
C 4					-	D
C 5		B				-

Under the multiple Decision Maker circumstance, their assessments about the criteria weights are calculated with weighted arithmetic average method.

Fuzzy value of each criterion is calculated in the next stage.

For example, in calculation of the fuzzy value of *K3* criterion, Buckley (1985)'s geometric mean method is used.

In the above table, geometric mean of *K* (1.000, 1.000, 1.000), *L* (2.000, 3.000, 4.000), *M* (9.000, 9.000, 9.000) and *N* (4.000, 5.000, 6.000) is taken. Then, value of *K3* can be:

$K3 = ((1.000 * 2.000 * 1.000 * 9.000 * 4.000)^{1/k}, (1.000 * 3.000 * 1.000 * 9.000 * 5.000)^{1/k}, (1.000 * 4.000 * 1.000 * 9.000 * 6.000)^{1/k}) = (2.352, 2.667, 2.930)$.

Herein, *k* represents the number of criteria.

In the next stage, values of the criteria are summed up. Then, *r* values of the criteria are multiplied by new "above", "middle" and "below" values. For defuzzification of these values, Chou and Chang (2008)'s centroid method is used. The weight of each criterion is calculated by normalizing the weights. In the next stage, consistency of the weights are evaluated.

Sometimes Decision Makers may wish to determine criteria weights manually. In this case, "MANUAL" option is selected on the "Criteria Weight Type" list.

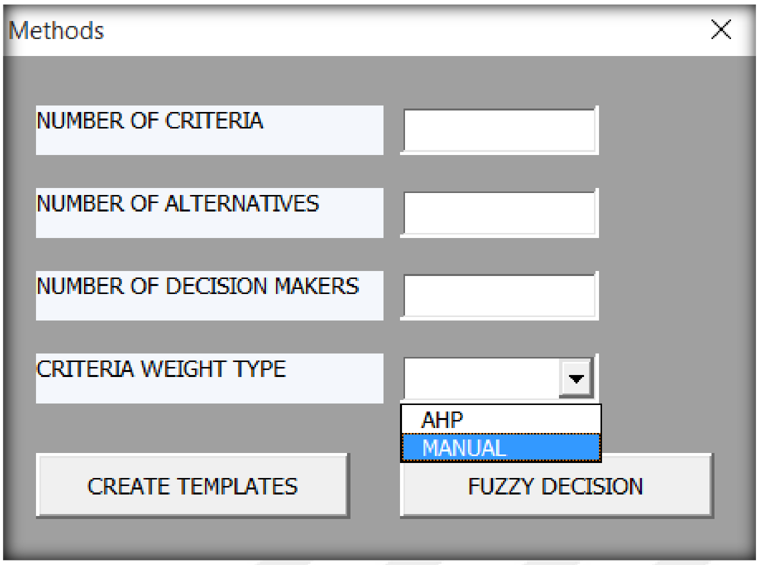


Figure 5.3 Excel macro user form screenshot

Table 5.4 Initial table of the example

Definitions	Abbreviations	Criteria Weight	Criteria Name	Slope Rate	Difference Between Above-Below Value	Max /Min
Equally Important	EI	0.5	AAA	2	10	MAX
Weakly Important	WI	0.8	BBB	1	20	MIN
Fairly Important	FI	0.4	CCC	0.5	20	MAX
Strongly Important	SI	0.2	DDD	4	10	MIN
Absolutely Important	AI					

The above table is filled when the "Criteria Weight Type" is selected as "MANUAL".

A study is carried out in the following for the fuzzy values of the alternatives. For example, for the criteria AAA, the value of the first alternative is 100. Fuzzy value of this value is calculated as follows.

m value is 100.

Slope rate represents (*m*-*l*) to (*u*-*m*). If this value is bigger than 1, then the triangular structure lies to the right. If it is between 0 and 1, then the triangular structure lies to the left. If the value is 1, then the triangular structure becomes isosceles.

(u-l) represents Difference Between Above-Below Value. The value of l is calculated as follows.

Alternative value for the relevant criteria * Difference Between Above-Below Value / 100 = 100*10/100= 10 ((u-l) value)

Difference Between Above-Below Value / (slope rate + 1) = 10/ (2+1) = 3.333

l = Alternative value for the relevant criteria – 3.333*slope rate = 93.333

u = Alternative value for the relevant criteria + ((u-l) value – 3.333*slope rate)
= 100+ (10-6.667) = 100.333

For AAA criterion, the first alternative's fuzzy value is (93.333, 100.000, 103.333).

If Fuzzy AHP method is employed in determining the criteria weights, consistency analysis is performed. In case of meeting the consistency criteria, Fuzzy TOPSIS and Fuzzy ELECTRE I methods are applied in the preceding stage. As illustrated below, a message appear if criteria's comparison values are not consistent.

Figure 5.4 An error screen about fuzzy AHP calculations

5.3 Fuzzy TOPSIS

In real life, because of incompleteness and obtaining information difficulty, the data are not deterministic but fuzzy. Usually judgments contain preferences that are uncertain and judgments cannot be expressed with a precise numerical value. Fuzzy TOPSIS is a method which helps to give the correct decision for the election under uncertainty to decision makers (Öztürk, Ertuğrul & Karakaşoğlu, 2008).

In the first step of Fuzzy TOPSIS method, a committee of decision makers is constituted. The cluster of N decision makers is expressed as $E= \{KV_1, KV_2, \ldots, KV_N\}$. After decision makers are constituted, alternatives $A= \{A_1, A_2, \ldots, A_m\}$ and criteria $K= \{K_1, K_2, \ldots, K_n\}$ are defined. Then linguistic variables are determined for both the alternatives and importance weight of the criteria by decision makers. Then, these linguistic variables are expressed as fuzzy numbers. Decision makers assessments for the alternatives and criteria reduce to a single value as described below (Chen, 2000).

$$x_{ij} = \frac{1}{N}\left[\tilde{x}_{ij}^{1} \oplus \tilde{x}_{ij}^{2} \oplus \ldots \oplus \tilde{x}_{ij}^{N}\right] \qquad (5.6)$$

where $\tilde{x}_{ij}^{N}$ denotes the assessment *of* N^{th} decision makers.

Criteria weights ($\tilde{w}_j$) are calculated by equation (5.7).

$$\tilde{w}_j = \frac{1}{N}\left[\tilde{w}_{j}^{1} \oplus \tilde{w}_{j}^{2} \oplus \ldots \oplus \tilde{w}_{j}^{N}\right] \qquad (5.7)$$

where $\tilde{w}_j^{N}$ denotes the importance weight of N^{th} decision maker.

After obtaining a single value for all criteria and alternatives, the decision matrix is formed as follows.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots & \tilde{x}_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{bmatrix}$$

Figure 5.5 The decision matrix

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n] \tag{5.8}$$

where $\tilde{x}_{ij}^1$ =(a_{ij}, b_{ij}, c_{ij}) and $\tilde{w}_j$ = (w_{j1}, w_{j2}, w_{j3}) can be approximated by positive triangular fuzzy numbers. $\tilde{D}$ is the fuzzy decision matrix and $\tilde{W}$ is the fuzzy weight matrix.

The normalized fuzzy decision matrix can be represented by equations (5.10) and (5.11):

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \tag{5.9}$$

where B and C are the sets of benefit and cost criteria, respectively:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \quad j \in B \ , \quad c_j^* = \max_i c_{ij}, \quad j \in B \tag{5.10}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right) \quad j \in C \ , \quad a_j^- = \min_i a_{ij}, \quad j \in C \tag{5.11}$$

The normalization method mentioned above is designed to preserve the property in which the elements $\tilde{r}_{ij}$ are standardized (normalized) fuzzy numbers.

Considering the different importance level of the criteria, the weighted normalized fuzzy decision matrix is constructed as follows.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \qquad i=1, 2,\ldots, m, \quad j=1, 2,\ldots, n \tag{5.12}$$

where

$$\tilde{v}_{ij} = \tilde{r}_{ij}\,(.)\,\tilde{w}_j \tag{5.13}$$

Then, the fuzzy positive ideal solution (*FPIS*, A^*) and fuzzy negative ideal solution (*FNIS*, A^-) can be defined.

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\right) \tag{5.14}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right) \tag{5.15}$$

where $\tilde{v}_j^* = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$ $j=1, 2, \ldots, n$.

The distance of each alternative from A^* and A^- can be calculated as follows.

$$d_i^* = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) \qquad i=1, 2, \ldots, m \tag{5.16}$$

$$d_i^- = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \qquad i=1, 2, \ldots, m \tag{5.17}$$

where d_v is the distance measurement between two fuzzy numbers.

The distance between two triangular fuzzy numbers can be calculated by Vertex Method (Chen, 2000).

$$d_v = \sqrt{\frac{1}{3}\left[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2\right]} \tag{5.18}$$

A closeness coefficient is defined to determine the ranking order of all possible alternatives once d_i^* and d_i^- of each alternative A_i *(i=1,2, ..., m)* has been calculated. The closeness coefficient represents the distances to the fuzzy positive ideal solution (A^*) and the fuzzy negative ideal solution (A^-) simultaneously by taking the relative closeness to the fuzzy positive ideal solution. The closeness coefficient (CC_i) of each alternative is calculated as follows.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \qquad i=1, 2, \ldots, m \tag{5.19}$$

It is clear that CC_i =1 if Ai = A^* and CC_i =0 if Ai = A^- . In other words, alternative A_i is closer to the *FPIS* (A^*) and farther from *FNIS* (A^-) as CC_i approaches to 1. According to the descending order of CC_i, we can determine the ranking order of all alternatives and select the best one from among a set of feasible alternatives. Although we can determine the ranking order of all feasible alternatives, a more realistic approach may be to use a linguistic variable to describe the current assessment status of each alternative in accordance with its closeness coefficient. In order to describe the assessment status of each alternative, we divide the interval [0, 1] into five sub-intervals. Five linguistic variables with respect to the sub-intervals are defined to divide the assessment status of alternatives into five classes. The decision rules of the five classes are presented in Table 5.5.

Table 5.5 Decision rules about the classes

Closeness coefficient (CCi)	Assessment status
CCi ϵ [0.0, 0.2)	Do not recommend
CCi ϵ [0.2, 0.4)	Recommend with high risk
CCi ϵ [0.4, 0.6)	Recommend with low risk
CCi ϵ [0.6, 0.8)	Approved
CCi ϵ [0.8, 1.0]	Approved and preferred

5.4 Fuzzy ELECTRE

Fuzzy ELECTRE I is one of the fuzzy multi criteria decision making methods used to solve the uncertain values about decision makers' decisions (Aytaç, Işık & Kundakçı, 2011). Similar to Fuzzy TOPSIS, a committee of decision makers is constituted. Cluster of N decision makers is expressed as $E=\{KV_1,KV_2,\ldots,KV_N\}$. After decision makers are constituted, alternatives $A=\{A_1, A_2,\ldots, A_m\}$ and criteria $K=\{K_1, K_2,\ldots, K_n\}$ are defined. Then linguistic variables are determined for both the alternatives and importance weights of the criteria by decision makers. After that, these linguistic variables are expressed as fuzzy numbers. Decision makers' assessments of alternatives and criteria is reduced to a single value as described below.

$$x_{ij}=\frac{1}{N}\left[\tilde{x}_{ij}^{1}\oplus\tilde{x}_{ij}^{2}\oplus\ldots\oplus\tilde{x}_{ij}^{N}\right] \tag{5.20}$$

where $\tilde{x}_{ij}^{N}$ denotes N^{th} decision makers assessment.

The weights for the criteria ($\tilde{w}_j$) are calculated with equation (5.19).

$$\tilde{w}_j=\frac{1}{N}\left[\tilde{w}_{j}^{1}\oplus\tilde{w}_{j}^{2}\oplus\ldots\oplus\tilde{w}_{j}^{N}\right] \tag{5.21}$$

where $\tilde{w}_{j}^{N}$ denotes N^{th} decision makers importance weight.

After obtaining a single value for all criteria and alternatives, the decision matrix is formed as follows.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix}$$

Figure 5.6 Fuzzy decision matrix

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n] \tag{5.22}$$

where $\tilde{x}_{ij}^1 = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ can be approximated by positive triangular fuzzy numbers. $\tilde{D}$ is the fuzzy decision matrix and, $\tilde{W}$ is the fuzzy weight matrix.

The normalized fuzzy decision matrix can be represented as follows by equations (5.24) and (5.25).

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \tag{5.23}$$

where B and C are the sets of benefit and cost criteria, respectively.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \quad j \in B \ , \quad c_j^* = \max_i c_{ij}, \quad j \in B \tag{5.24}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right) \quad j \in C \ , \quad a_j^- = \min_i a_{ij}, \quad j \in C \tag{5.25}$$

The normalization method mentioned above is designed to preserve the property in which the elements $\tilde{r}_{ij}$ are standardized (normalized) fuzzy numbers.

Considering the different importance level of each criterion, the weighted normalized fuzzy decision matrix is constructed as follows.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \quad i=1, 2, \ldots, m, \quad j=1, 2, \ldots, n \tag{5.26}$$

where

$$\tilde{v}_{ij} = \tilde{r}_{ij} (.) \tilde{w}_j \tag{5.27}$$

Concordance and discordance sets are determined by the weighted normalized fuzzy decision matrix. For each criteria, a pairwise comparison is made with alternatives. For comparing the alternatives, the weighted normalized fuzzy decision matrix is defuzzified. For defuzzification, centroid method can be used.

Concordance and discordance matrices are calculated by using the weighted normalized fuzzy decision matrix ($\tilde{V}$) and the pairwise comparison among the alternatives.

Considering two alternatives, the concordance set can be defined as:

$$C_{kl} = \{j, v_{kj} \geq v_{lj}\} \tag{5.28}$$

The discordance set can be defined as:

$$D_{kl} = \{j, v_{kj} < v_{lj}\} \tag{5.29}$$

The concordance matrix for each pair wise comparison of the alternatives can be defined as *C*, and the elements of the concordance matrix are determined as summation of the weights of all criteria in the concordance set.

$$c_{kl} = \sum_{j \in C_{kl}} w_j \tag{5.30}$$

$$C = \begin{bmatrix} - & c_{12} & c_{13} & \dots & c_{1m} \\ c_{21} & - & c_{23} & \dots & c_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ c_{m1} & c_{m2} & c_{m3} & \dots & - \end{bmatrix}$$

Figure 5.7 The concordance matrix

The discordance matrix can be defined as D and the elements of the discordance matrix are calculated as follows.

$$d_{kl} = \frac{\max\limits_{j \in D_{kl}} \left| v_{kj} - v_{lj} \right|}{\max\limits_{j} \left| v_{kj} - v_{lj} \right|} \tag{5.31}$$

$$D = \begin{bmatrix} - & d_{12} & d_{13} & \dots & d_{1m} \\ d_{21} & - & d_{23} & \dots & d_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ d_{m1} & d_{m2} & d_{m3} & \dots & - \end{bmatrix}$$

Figure 5.8 The discordance matrix

According to the concordance level, the value of the concordance matrix elements are evaluated. The concordance level can be defined as the average of the elements in the concordance matrix represented by:

$$\underline{c} = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} c_{kl} \tag{5.32}$$

Boolean matrix F is formed according to the minimum concordance level. If $c_{kl} \geq \underline{c} \implies f_{kl} = 1$, else if $c_{kl} < \underline{c} \implies f_{kl} = 0$.

The elements of the discordance matrix are measured by a discordance level. The discordance level can be defined as the average of the elements in the discordance matrix.

$$\underline{d} = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} d_{kl} \tag{5.33}$$

Boolean matrix G is measured by the minimum discordance level. If $d_{kl} \leq \underline{d} \implies g_{kl} = 1$, else if $d_{kl} > \underline{d} \implies g_{kl} = 0$.

The global matrix E is calculated by peer to peer multiplication of the elements of the matrices F and G as follows:

$$E = F \otimes G \tag{5.34}$$

CHAPTER SIX
APPLICATION

In this study, a real world personnel selection problem is examined in banking sector. In the application, a commercial bank, Bank A, want to hire a female staff in one of its branch who will be responsible for marketing retail banking products.

Commercial banks pay attention to all their human and non-human compounds very carefully to make more profit. They aim to hire the most efficient stuff to achieve the objectives in enterprise level. One of the important revenue channels of commercial banks is selling credit card and POS (Point Of Sales Terminal) device. The revenues gathered from these channels are introduced briefly in the following.

The biggest benefit of the card payment system belongs to issuer and operating banks without doubt. Issuer banks earn income, fee and commission income. Some of these revenues listed below.

1- Fees received from customers

Annual Card Usage Fee: The cardholders are liable annual card usage fee for each credit main and additional cards.

Renewal Fee: Renewal fee will be charged according that require reprinted card within a year.

Cash Withdrawal Fee: Cash withdrawal fee is calculated on determined the rate and/or by applying cash over the amount from the points can be made cash withdrawal authorized by the Bank.

Limit Excess Charge Fee: When exceeding the allocated limit, limit excess charge fee is charged.

Transaction Fee: The issuer bank charge transaction fee to cardholder if the contracted firms' bills are paid by credit card.

Credit Card Statements Fee: If previous periods' credit card statements are demanded, the credit card statements fees are charged.

2- Interest Income

Interest of Delayed: If the minimum payment amount in the Account Summary is not paid amount until the payment deadline, the interest of delayed is charged until the payment date.

Cash Advance Interest: The cash advance interest is calculated daily from the withdrew cash day from the card account.

Contractual Interest: The cash advance interest is calculated daily from the withdrew cash day from the card account if the minimum amount is paid.

3- Clearing Commissions

The banks earn clearing commissions from cardholders' shopping with other bank POS devices either in the country or abroad.

4- Other Income

Foreign Exchange Gains: Between cardholder's abroad shopping registration date and the payment date to the bank because of the increasing exchange rates, the difference reflect to cardholders.

Demand Deposits: If the cardholders pay the bets before the last payment date, the bank earns demand deposit advantages.

5- POS Devices

Usage Price: POS device owner bank earn usage price if the member businesses used the device below determined limit.

Commission income: POS device owner bank earn commission income each transaction through POS.

Credit cards and POS devices also allow the banks to increase the volume of demand savings deposits and marketing other retail banking products with cross selling. The banks can gather more interest income because of credit cards have higher interest rates compared to interest rates of the other instruments. The credit card on the market bearing the bank's logo and name provide an important prestige and promotion.

In our application, Bank A will hire a female staff who will study full time and sales retail banking products for Konak branch. Bank A decides to work together Pi2 Organizations Company for the staff selection. The Bank chooses Pi2 Company because of the company's experience, making preliminary studies and ability to provide easy contact to candidates.

Pi2 Organizations Company contacts 178 female candidates with announcements and its own data warehouse. 92 of the candidates accept to participate in the pre-interview. Pi2 preselects 5 candidates to Bank A by eliminating major number of candidates whose pre-interviews results successfully. The Bank A will give the final decision regarding hiring among these 5 candidates.

Pi2 Company decides to use multi criteria decision making methods for pre-interview process. While using these methods, the analysis is presented to Pi2's decision maker/management, and the decision maker use these data for finalizing the pre-interview process.

Decision Maker wants to use the fuzzy numbers for the criteria because of the following conditions:

1-Age: Any of the candidate’s age that in the last days of 26 years may be evaluated as the candidate's age is partly 27. Likewise, any of the candidate’s age that in the early days of 26 years may be evaluated as the candidate's age is partly 25.

2- Marital Status: Single candidate is preferred for the position under concern. However, it is possible that a married candidate can reveal a better performance than a single candidate.

3- Distance to Branch: The Bank prefers a candidate who lives near the relevant branch. However, due to the lack of regular structure of the district boundaries, the distances cannot be measured only by district’s name.

4- Driver License: The candidate having driver license is more preferred with a small margin.

5- English Level: A candidate’s English level who specifies her English level as “medium” can be better than another candidate’s English level who specifies her English level as “good” in the case of candidates states their English levels.

6- Second Foreign Language Level: The decision makers prefer a candidate whose second language is German with “medium” level to a candidate whose second language is Russian with the level of “good”.

7- Educational Status: It can be preferred for instance that a candidate whose educational level is associate degree and having graduated from the Banking Department to another candidate whose educational level is license degree and having graduated from the Public Administration.

8-9- Experience / In-Other Sector (Year): Because of two reasons, the fuzzy numbers are chosen for these criteria. First, it can be acceptable that a candidate’s experience is four years whose real experience is three years and eleven months.

Second, a candidate’s sales experience who works in other sectors may be better than another candidate’s sales experience who works in banking sector.

10- Reference Status: Because of two reasons, the fuzzy numbers are chosen for this criterion. First, it can be considered that a reference working as an officer at a Bank than a reference working as a general manager at a company in another sector. Second, a candidate whose reference number is five but all of them from other sectors may be chosen instead of a candidate whose reference number is one who is from banking sector. However, generally, a candidate whose reference is from banking sector is preferred to another candidate whose reference is from other sectors.

11- Presentation Ability: It is an important criteria in marketing sector. However, presentation ability is a subjective factor defined by “good” or “bad” or “very good”.

Some assessments / comparisons have been asked for the Decision Maker to perform the analyses. The Decision Maker’s assessments about the criteria, pairwise comparison table of the criteria and the criteria weights table are presented below. Because of covering a lot of space, most of the calculation steps and detailed results are presented in the appendix.

In our application, Excel software is employed for the calculations in Fuzzy AHP, Fuzzy TOPSIS and Fuzzy ELECTRE I methods. Some details about these calculations are presented in the following.

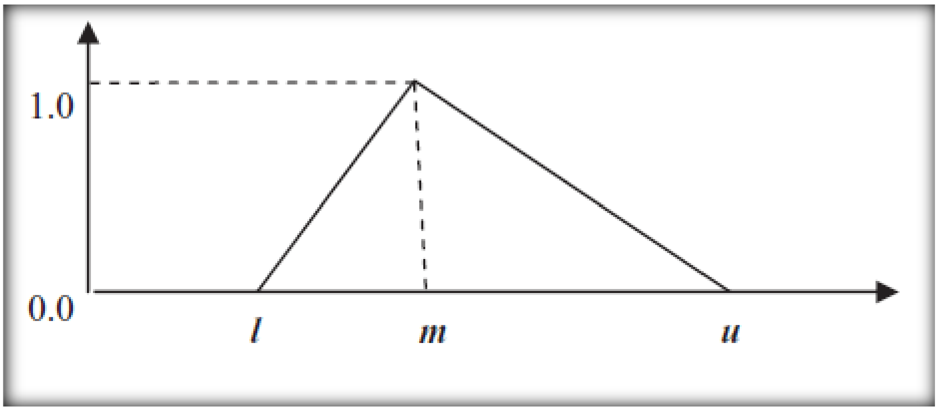


Figure 6.1 Triangular fuzzy number

Determining Slope Rate and Difference between Above-Below Value is reported in the following.

Table 6.1 Initial table example

Definitions	Abbrev.	Criteria Weight	Criteria Name	Slope Rate	Difference Between Above-Below Value	Max /Min
Equally Important	EI	1	Criteria 1	1	0	MAX
Weakly Important	WI	1	Criteria 2	1	0	MAX
Fairly Important	FI	1	Criteria 3	1	0	MAX
Strongly Important	SI					
Absolutely Important	AI					

While the difference between above-below values increases, the candidate's rated value becomes more fuzzified for each criterion. For example, if a candidate's English level is "good" and given 5 point (*m* value) to "good" term and the difference between above-below values is 20, the difference between above value (*u*) and *l* is 1 (For instance, (4.5, 5.0, 5.5)). If the difference between above-below value is 40, then the difference between *u* and *l* is 2 (For instance, (4.0, 5.0, 6.0)).

The slope rate serves the purpose by making more emphasis on above value or below value. Thus, decision makers can create an optimistic or abstaining structure about the criteria.

For example, if a candidate's English level is "good" and given 5 point (m value) to "good" term and difference between above-below values is 40, the difference between u value and l value is 2. If the slope rate is 3, then the candidate's value is (3.5, 5.0, 5.5). If the slope rate is 0.333, then candidate's value is (4.5, 5.0, 6.5).

In the real world application conducted in this study, Fuzzy AHP is employed for determining the criteria weights, while Fuzzy TOPSIS and Fuzzy ELECTRE I methods are used for determining the best candidate among the alternatives.

Table 6.2 Initial table for the application

Criteria Name	Slope Rate	Difference Between Above-Below Value	MAX /MIN
Age	0.50	20	MAX
Marital Status	0.80	10	MAX
Distance to Branch	4.00	30	MIN
Driver License	1.00	0	MAX
English Level	0.40	20	MAX
Second Foreign Language Level	0.80	20	MAX
Educational Status	0.70	10	MAX
Experience / Other Sector (Year)	0.75	20	MAX
Experience / In Sector (Year)	0.75	20	MAX
Reference Status	0.50	30	MAX
Presentation Ability	0.40	40	MAX

Table 6.3 Pairwise comparison for the criteria

Criteria No	Decision Maker	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11
C 1	DM 1	-	FI	WI	AI	AI	AI	FI	WI	WI	FI	
C 2			-		WI	WI	WI				EI	
C 3			FI	-	FI	SI	SI	FI	WI	WI	FI	
C 4					-		WI					
C 5					EI	-						
C 6						EI	-					
C 7			EI		WI	WI	FI	-			EI	
C 8			WI		FI	FI	FI	EI	-		WI	
C 9			WI		FI	FI	FI	WI	WI	-	FI	
C 10					WI	EI	EI				-	
C 11		EI	FI	WI	SI	AI	AI	FI	WI	WI	FI	-

Once the macro is executed, the Fuzzy AHP calculations are made and the criteria weights are determined as in the following.

Table 6.4 Criteria weights

Criteria No	M	N
C 1	0.241	0.231
C 2	0.047	0.045
C 3	0.166	0.159
C 4	0.024	0.023
C 5	0.022	0.021
C 6	0.019	0.018
C 7	0.053	0.051
C 8	0.084	0.080
C 9	0.118	0.113
C 10	0.036	0.034
C 11	0.236	0.226

After the consistency analysis (consistency ratio is obtained as 0.059) Fuzzy TOPSIS and Fuzzy ELECTRE I calculations are made. It was also used for evaluation of the results with DECISION LAB and LAMSADE software packages.

Because of not entering slope rate and differences between above-below values at DECISION LAB and LAMSADE programs, the macros executed with slope rates of 1 for all criteria and differences between above-below values of 0 for all criteria.

The results are found by the Excel, DECISION LAB and LAMSADE software. While comparing the results, the values obtained by Excel macro are taken as the base. The results of the application are reported in Table 7.1.

In Table 7.1, two different Fuzzy TOPSIS and Fuzzy ELECTRE I results are presented. The first ones obtained by utilizing the Decision Maker’s assessments about slope rate and difference between above-below values. The second ones obtained by using slope rate values of 1 and difference between above-below values of 0.

Table 7.1 The results of the application

	FUZZY ELECTRE I	FUZZY TOPSIS	FUZZY ELECTRE I	FUZZY TOPSIS	LAMSADE (ELECTRE III)	DECISION LAB (PROMETHEE II)
CAND 19	KERNEL	1	KERNEL	1	1	1
CAND 43	KERNEL	2	KERNEL	3	12	6
CAND 60	KERNEL	3	KERNEL	4	6	3
CAND 68		4		2	7	4
CAND 27		5		5	10	8
CAND 86					2	2
CAND 25					3	
CAND 47					4	7
CAND 66					5	5
CAND 08					8	
CANDI 45					9	
CANDI 52					11	

The Bank under concern wants five candidates to be preselected for the available position. After reviewing these five candidates, the Bank will give the final decision about hiring. According to the results obtained in this study, Pi2 company select candidates 19, 43, 60, 68 and 27 for recommending to the Bank. Particularly, candidate 19 is determined as the best option by all the methods. Since ranking is not take place in Fuzzy ELECTRE I method, candidates 43 and 60 are determined as the best options. In Figure 7.1, the Kernel results of Fuzzy ELECTRE I method are presented. This case illustrates the disadvantage of Fuzzy ELECTRE I method. In the result, totally 2738 dominance vector emerged for the 92 alternatives.

Since there exist a lot of alternatives and none them is superior to another one, considering only the first three digits of the decimal part and the values of criteria weights, the results presented in Appendix 22 reveal that all of the TOPSIS assessments are conclude the outcome of “Not Recommended”.

It should be stated that while applying fuzzy decision making methods we should be very careful in selecting experts for comparison and setting the logic of the algorithms. In addition, slop rate and difference between above and below values should be determined judiciously.

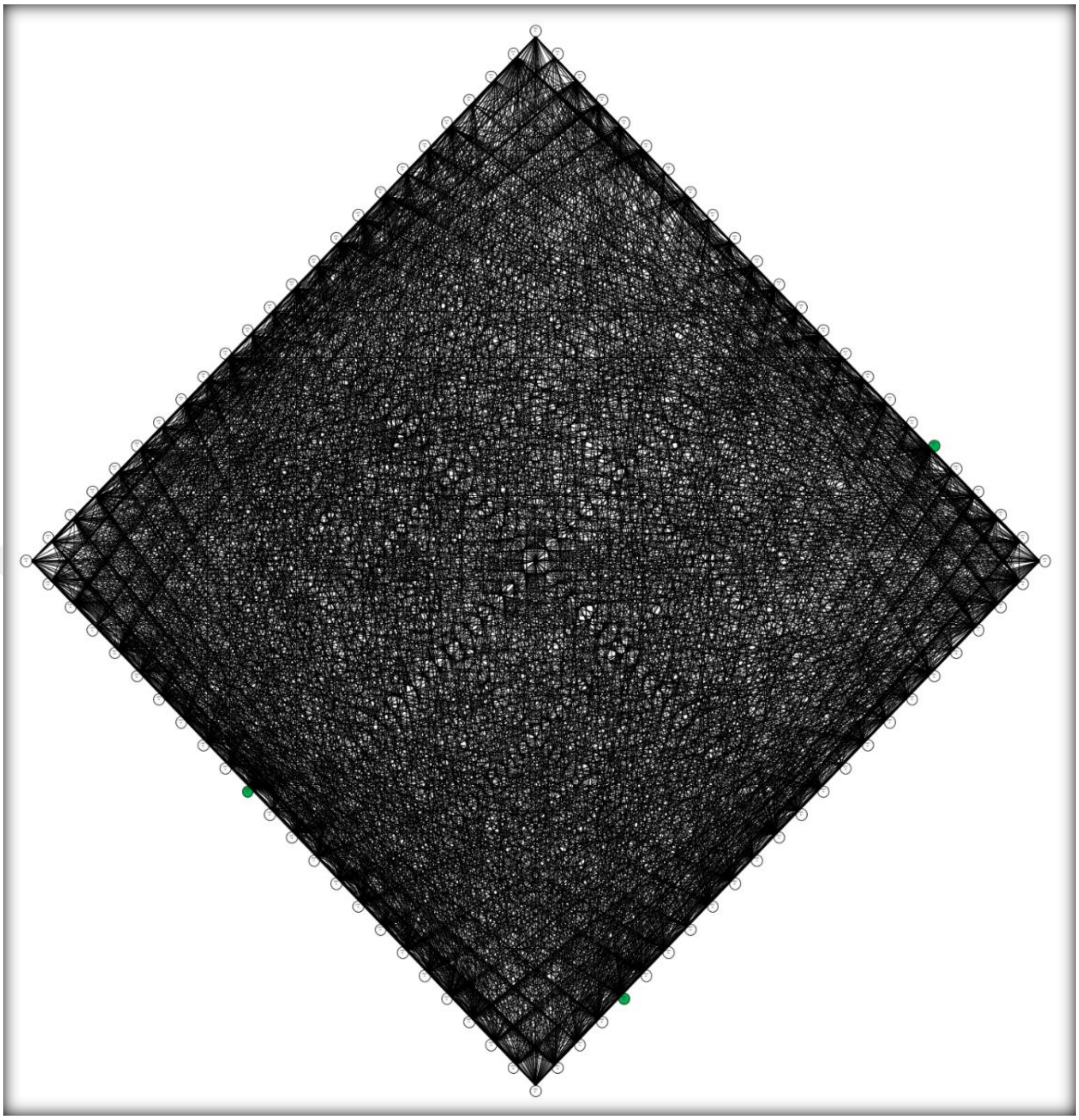


Figure 7.1 Application kernel structure

CHAPTER SEVEN
CONCLUSION

Staff selection is an important decision making problem, and multi criteria decision making methods are often employed for handling this problem. In this study, we use the most widely used multi criteria decision making methods, TOPSIS, ELECTRE, AHP and PROMETHEE. To treat the inherent uncertainties of the real life problem more effectively, fuzzy logic is used in this thesis.

A real world application is provided in this study, to validate the effectiveness of the proposed approach. In the application, a commercial bank want to hire a staff in one of its branch who will be responsible for marketing retail banking products. The Bank is decided to work with a consulting firm for the selection of the staff. The consulting firm reached a number of candidates and five of them are suggested to the Bank for its final decision.

In this study, eleven criteria are considered for the personnel selection problem under concern. Fuzzy AHP method is used to determine the weights of the criteria. In addition, for sorting the alternatives, Fuzzy TOPSIS and Fuzzy ELECTRE I methods are employed. DECISION LAB and LAMSADE software packages are also utilized in the application.

The application presented in this study reveals that personnel selection problem in banking sector can effectively be handled by treating the inherent uncertainties with Fuzzy MCDM methods.

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APPENDICES

Appendix 1: Job application form

Pi2 Organisations

JOB APPLICATION FORM

PHOTOGRAPHY

UPLOAD

Name and Surname	:		
Place and Date of Birth	:	/	
T.C. Identification No / Nationality	:	/ TC ☐	Other :
Phone Number	: GSM :		Home :
E-mail	:		
Gender	: Female ☐	/ Male ☐	
Marital Status	: Single ☐	/ Married☐	Child :
Mother's Name and Job	:	/	
Father's Name and Job		/	
Number of Siblings			
Military Service	: ☐ Complete	☐ Postponed	☐ Exempt
Home Address	:		
Contact Person in Emergency	:	/ Degree of Relation :	GSM :
Driver's License	: Yes ☐	No ☐	Class :
Foreign Language Knowledge	: English	: Poor ☐ Intermediate☐ Good ☐	
	Other :	: Poor ☐ Intermediate☐ Good ☐	

Educational Background:	High School / Year :
	1.University / Department / Year :
	2.University / Department / Year :
	Graduate / Department / Year :

Work Experience (Write in Order From the Last Company...)	Company	Job / Task	Job Period / Date Range { E.g.: 1,5 year, February 2013 - August 2014 }
1. :			
Definition of Job / Task :			
2. :			
Definition of Job / Task :			
3. :			
Definition of Job / Task :			

Last Payment Date of SGK :		
Iskur Registration Status :	Yes ☐	No ☐
Filling CV Form Date		

Your references (It is important that they work for your previous companies.)	Name and Surname	GSM	Company	Title
:				
:				
:				

Opinions (Filled by Pi2 Employee)	: Applied Position :
	: Applied Location :
	:
	:
	:

In case your interview result is negative, you will be notified by e-mail.

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Appendix 2: Decision Maker’s pairwise comparisons about the criteria

Absolutely Important	Strongly Important	Fairly Important	Weakly Important	Criteria 1	Equally Important	Criteria 2	Weakly Important	Fairly Important	Strongly Important	Absolutely Important
		X		Age		Marital Status				
			X	Age		Distance To Branch				
X				Age		Driver License				
X				Age		English Level				
X				Age		Second Foreign Language Level				
		X		Age		Educational Status				
			X	Age		Experience / Other Sector (Year)				
			X	Age		Experience / In Sector (Year)				
		X		Age		Reference Status				
				Age	X	Presentation Ability				
				Marital Status		Distance To Branch		X		
			X	Marital Status		Driver License				
			X	Marital Status		English Level				
			X	Marital Status		Second Foreign Language Level				
				Marital Status	X	Educational Status				
				Marital Status		Experience / Other Sector (Year)	X			
				Marital Status		Experience / In Sector (Year)	X			
				Marital Status	X	Reference Status				
				Marital Status		Presentation Ability		X		
		X		Distance To Branch		Driver License				

	X			Distance To Branch		English Level				
	X			Distance To Branch		Second Foreign Language Level				
		X		Distance To Branch		Educational Status				
			X	Distance To Branch		Experience / Other Sector (Year)				
			X	Distance To Branch		Experience / In Sector (Year)				
		X		Distance To Branch		Reference Status				
				Distance To Branch		Presentation Ability	X			
				Driver License	X	English Level				
			X	Driver License		Second Foreign Language Level				
				Driver License		Educational Status	X			
				Driver License		Experience / Other Sector (Year)		X		
				Driver License		Experience / In Sector (Year)		X		
				Driver License		Reference Status	X			
				Driver License		Presentation Ability			X	
				English Level	X	Second Foreign Language Level				
				English Level		Educational Status	X			
				English Level		Experience / Other Sector (Year)		X		
				English Level		Experience / In Sector (Year)		X		
				English Level	X	Reference Status				
				English Level		Presentation Ability				X
				Second Foreign Language Level		Educational Status		X		

				Second Foreign Language Level		Experience / Other Sector (Year)		X		
				Second Foreign Language Level		Experience / In Sector (Year)		X		
				Second Foreign Language Level	X	Reference Status				
				Second Foreign Language Level		Presentation Ability				X
				Educational Status	X	Experience / Other Sector (Year)				
				Educational Status		Experience / In Sector (Year)	X			
				Educational Status	X	Reference Status				
				Educational Status		Presentation Ability		X		
				Experience / Other Sector (Year)		Experience / In Sector (Year)	X			
			X	Experience / Other Sector (Year)		Reference Status				
				Experience / Other Sector (Year)		Presentation Ability	X			
		X		Experience / In Sector (Year)		Reference Status				
				Experience / In Sector (Year)		Presentation Ability	X			
				Reference Status		Presentation Ability		X		

The assessments are passed to excel as follows.

Criteria Name	Slope Rate	Difference Between Above-Below Value	Max /Min	Criteria No	Decision Maker	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11
Age	0.5	20	MAX	C 1		-	FI	WI	AI	AI	AI	FI	WI	WI	FI	
Marital Status	0.8	10	MAX	C 2			-		WI	WI	WI				EI	
Distance To Branch	4	30	MIN	C 3			FI	-	FI	SI	SI	FI	WI	WI	FI	
Driver License	1	0	MAX	C 4					-		WI					
English Level	0.4	20	MAX	C 5					EI	-						
Second Foreign Language Level	0.8	20	MAX	C 6	DM 1					EI	-					
Educational Status	0.7	10	MAX	C 7			EI		WI	WI	FI	-			EI	
Experience / Other Sector (Year)	0.75	20	MAX	C 8			WI		FI	FI	FI	EI	-		WI	
Experience / In Sector (Year)	0.75	20	MAX	C 9			WI		FI	FI	FI	WI	WI	-	FI	
Reference Status	0.5	30	MAX	C 10					WI	EI	EI				-	
Presentation Ability	0.4	40	MAX	C 11		EI	FI	WI	SI	AI	AI	FI	WI	WI	FI	-

Appendix 3: Decision Maker’s evaluations about the criteria

Objective Function	Criteria No	Criteria Name	Options	Point	Slope Rate	Difference Between Above-Below Value
Maximize	1	Age	20 And Below	6	0.5	20
			21	8		
			22	9		
			23	10		
			24	10		
			25	10		
			26	9		
			27	8		
			28 And Above	6		
Maximize	2	Marital Status	Married	3	0.8	10
			Single	5		
Minimize	3	Distance To Branch	Aliağa/Izmir	59	4	30
			Balçova/Izmir	7		
			Bayrakli/Izmir	13		
			Bornova/Izmir	11		
			Buca/Izmir	5		
			Çiğli/Izmir	19		
			Gaziemir/Izmir	12		
			Karabağlar/Izmir	6		
			Karşiyaka/Izmir	14		
			Kemalpaşa/Izmir	31		
			Konak/Izmir	2		
			Menemen/Izmir	34		
			Narlidere/Izmir	16		
			Ödemiş/Izmir	115		
			Tire/Izmir	95		
			Torbali/Izmir	53		
			Urla/Izmir	49		
			Turgutlu/Manisa	56		
Maximize	4	Driver Licence	Yes	5	1	0
			No	4		
Maximize	5	English Level	Absent	1	0.4	20
			Poor	2		
			Medium	3		
			Good	5		

Maximize	6	Second Foreign Language Level	Absent	1	0.8	20
			Poor	2		
			Medium	3		
			Good	5		
Maximize	7	Educational Status	High School	1	0.7	10
			Associate Degree	4		
			Undergraduate	6		
			Graduate	2		
			Doctorate	1		
Maximize	8	Experience / Other Sector (Year)	0 Year	1	0.75	20
			1-2 Year	3		
			3-4 Year	4		
			5-6 Year	5		
			7 Year And Above	6		
Maximize	9	Experience / In Sector (Year)	0 Year	1	0.75	20
			1-2 Year	3		
			3-4 Year	4		
			5-6 Year	5		
			7 Year And Above	6		
Maximize	10	Reference Status	In Sector	6	0.5	30
			Other Sector	4		
			Absent	1		
Maximize	11	Presentation Ability	Very Good	10	0.4	40
			Good	7		
			Medium	4		
			Not Enough For Sector	1		

Appendix 4: Information on the Candidates

Candidate No	Birth Date	Marital Status	Residence Address	Driver License	English Level	Second Foreign Language Level	Educational Status	Experience / Other Sector (Year)	Experience / In Sector (Year)	Reference Status	Presentation Ability
01	06.02.1990	Single	Bayrakli /İzmir	No	Good	Poor	Undergraduate	0	0	In Sector	Medium
02	04.03.1986	Married	Torbali /İzmir	Yes	Medium	Absent	Undergraduate	8	0	Other Sector	Good
03	01.09.1993	Single	Buca /İzmir	No	Medium	Absent	Associate Degree	0	0	Other Sector	Not Enough For Sector
04	03.07.1989	Single	Ödemiş /İzmir	Yes	Poor	Absent	Undergraduate	0	0	Other Sector	Good
05	29.04.1991	Single	Buca /İzmir	No	Poor	Absent	Undergraduate	2	0	Absent	Medium
06	16.08.1992	Single	Konak /İzmir	No	Good	Absent	Associate Degree	3	0	Other Sector	Good
07	01.03.1988	Single	Karabağlar /İzmir	No	Absent	Absent	Undergraduate	0	1	In Sector	Not Enough For Sector
08	07.06.1991	Single	Buca /İzmir	Yes	Poor	Absent	Undergraduate	1	1	In Sector	Medium
09	11.11.1987	Married	Buca /İzmir	No	Medium	Absent	Associate Degree	0	2	Other Sector	Medium
10	06.06.1985	Married	Bornova /İzmir	Yes	Medium	Absent	Undergraduate	5	0	Other Sector	Good
11	29.06.1992	Single	Buca /İzmir	Yes	Medium	Poor	Undergraduate	1	0	Absent	Medium
12	02.12.1991	Single	Buca /İzmir	No	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
13	19.04.1995	Single	Bornova /İzmir	No	Medium	Absent	High School	0	0	Absent	Good
14	21.10.1992	Single	Buca /İzmir	No	Poor	Absent	Associate Degree	0	0	Other Sector	Not Enough For Sector
15	03.03.1989	Single	Buca /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
16	14.09.1991	Married	Kemalpaşa /İzmir	No	Poor	Absent	Undergraduate	0	0	Absent	Good
17	21.06.1988	Single	Aliağa /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
18	17.08.1986	Single	Bornova /İzmir	Yes	Medium	Absent	Undergraduate	3	1	Other Sector	Good
19	03.10.1989	Single	Konak /İzmir	Yes	Medium	Absent	Undergraduate	1	1	Absent	Good
20	17.01.1987	Single	Karabağlar /İzmir	Yes	Absent	Absent	High School	9	0	Other Sector	Good
21	01.06.1989	Single	Buca /İzmir	Yes	Medium	Absent	Undergraduate	2	0	Absent	Medium
22	23.10.1992	Single	Gaziemir /İzmir	No	Medium	Absent	Associate Degree	0	0	Other Sector	Not Enough For Sector
23	05.12.1989	Single	Bornova /İzmir	No	Good	Absent	Undergraduate	0	0	Other Sector	Medium
24	09.07.1993	Single	Buca /İzmir	No	Absent	Absent	Associate Degree	0	0	Other Sector	Medium
25	26.08.1990	Single	Bornova /İzmir	Yes	Good	Absent	Undergraduate	0	0	Absent	Very Good
26	10.07.1990	Single	Gaziemir /İzmir	No	Absent	Absent	Undergraduate	0	0	Other Sector	Medium
27	17.04.1992	Single	Konak /İzmir	Yes	Medium	Absent	Undergraduate	0	0	In Sector	Very Good
28	29.03.1986	Single	Karşiyaka /İzmir	No	Medium	Absent	Undergraduate	0	1	In Sector	Good
29	25.04.1989	Single	Çiğli /İzmir	No	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
30	31.12.1987	Single	Karabağlar /İzmir	No	Medium	Absent	Undergraduate	2	0	Absent	Good
31	25.12.1987	Single	Buca /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
32	07.02.1991	Single	Turgutlu/Manisa	No	Poor	Absent	Undergraduate	1	0	Absent	Medium
33	07.01.1986	Married	Buca /İzmir	Yes	Medium	Absent	Undergraduate	0	2	In Sector	Medium

34	23.04.1989	Single	Bayrakli /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
35	14.01.1986	Single	Bornova /İzmir	Yes	Poor	Absent	Associate Degree	7	0	Other Sector	Medium
36	22.07.1989	Single	Gaziemir /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Absent	Very Good
37	18.03.1986	Single	Bayrakli /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Good
38	05.05.1993	Single	Çiğli /İzmir	No	Medium	Medium	Associate Degree	0	0	Other Sector	Medium
39	25.04.1989	Single	Çiğli /İzmir	No	Medium	Absent	Associate Degree	0	0	Other Sector	Medium
40	09.10.1992	Single	Balçova /İzmir	Yes	Poor	Poor	Associate Degree	1	0	Other Sector	Good
41	09.05.1989	Single	Bayrakli /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
42	22.10.1991	Single	Bornova /İzmir	No	Medium	Absent	Undergraduate	0	0	Other Sector	Good
43	01.04.1988	Single	Konak /İzmir	No	Poor	Poor	Undergraduate	2	0	In Sector	Very Good
44	21.12.1993	Single	Bayrakli /İzmir	No	Medium	Absent	Undergraduate	1	0	Other Sector	Not Enough For Sector
45	03.04.1989	Single	Buca /İzmir	No	Medium	Absent	Undergraduate	1	1	Other Sector	Medium
46	17.09.1993	Married	Buca /İzmir	No	Poor	Absent	Associate Degree	2	0	Other Sector	Not Enough For Sector
47	31.07.1990	Single	Konak /İzmir	Yes	Good	Absent	Undergraduate	0	0	Absent	Good
48	07.01.1989	Married	Menemen /İzmir	Yes	Good	Poor	Undergraduate	0	0	Other Sector	Medium
49	19.08.1990	Married	Karabağlar /İzmir	Yes	Good	Poor	Undergraduate	1	0	Other Sector	Medium
50	24.09.1994	Single	Buca /İzmir	No	Medium	Absent	Associate Degree	0	0	Other Sector	Medium
51	03.11.1991	Single	Bayrakli /İzmir	Yes	Absent	Absent	Associate Degree	1	0	Other Sector	Very Good
52	25.10.1989	Single	Buca /İzmir	No	Good	Absent	Undergraduate	0	1	In Sector	Medium
53	01.12.1991	Single	Buca /İzmir	No	Poor	Absent	Undergraduate	0	0	Absent	Good
54	19.06.1991	Single	Karabağlar /İzmir	Yes	Good	Good	Associate Degree	0	0	Other Sector	Medium
55	20.08.1991	Single	Bornova /İzmir	No	Medium	Absent	Associate Degree	0	0	Absent	Good
56	11.07.1993	Single	Karabağlar /İzmir	Yes	Medium	Absent	Associate Degree	1	1	Other Sector	Very Good
57	24.10.1991	Single	Karşiyaka /İzmir	Yes	Poor	Absent	Associate Degree	0	0	Absent	Good
58	22.06.1988	Married	Narlidere /İzmir	No	Poor	Absent	Undergraduate	0	0	Other Sector	Medium
59	17.07.1993	Single	Bayrakli /İzmir	No	Medium	Absent	Associate Degree	1	0	Other Sector	Good
60	25.05.1988	Single	Konak /İzmir	Yes	Medium	Absent	Undergraduate	4	0	Other Sector	Very Good
61	31.07.1990	Single	Tire /İzmir	Yes	Good	Absent	Undergraduate	1	0	In Sector	Good
62	01.05.1986	Married	Karşiyaka /İzmir	Yes	Medium	Absent	Undergraduate	3	0	Other Sector	Medium
63	11.07.1990	Single	Çiğli /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
64	01.01.1988	Single	Karşiyaka /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
65	25.12.1988	Single	Karabağlar /İzmir	Yes	Poor	Absent	Undergraduate	2	0	Other Sector	Not Enough For Sector
66	06.08.1991	Single	Karabağlar /İzmir	No	Medium	Absent	Undergraduate	1	1	Absent	Good
67	01.01.1991	Single	Çiğli /İzmir	No	Medium	Absent	High School	3	0	Other Sector	Medium
68	16.09.1988	Single	Konak /İzmir	Yes	Good	Medium	Undergraduate	1	0	Other Sector	Very Good
69	14.09.1990	Single	Bornova /İzmir	No	Medium	Absent	Undergraduate	0	1	Other Sector	Medium
70	03.05.1991	Single	Karabağlar /İzmir	No	Medium	Absent	Undergraduate	0	0	In Sector	Medium
71	09.08.1989	Married	Aliağa /İzmir	No	Poor	Absent	Undergraduate	0	0	In Sector	Good
72	26.06.1988	Single	Bornova /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Absent	Medium
73	30.03.1989	Married	Çiğli /İzmir	No	Medium	Absent	Undergraduate	1	0	Other Sector	Good

74	01.08.1989	Single	Konak /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Other Sector	Medium
75	05.06.1986	Single	Balçova /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
76	24.08.1992	Single	Karabağlar /İzmir	Yes	Poor	Poor	High School	0	1	In Sector	Medium
77	15.08.1989	Single	Bornova /İzmir	No	Medium	Absent	Undergraduate	1	0	Other Sector	Good
78	25.08.1988	Single	Menemen /İzmir	Yes	Medium	Absent	Undergraduate	0	0	In Sector	Medium
79	03.05.1987	Married	Urla /İzmir	No	Medium	Absent	Graduate	4	0	Other Sector	Not Enough For Sector
80	06.04.1986	Single	Bayrakli /İzmir	Yes	Medium	Absent	High School	1	0	Other Sector	Good
81	01.01.1987	Single	Bornova /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Good
82	25.01.1990	Single	Turgutlu/Manisa	No	Medium	Absent	Associate Degree	1	0	Other Sector	Good
83	20.08.1988	Single	Bornova /İzmir	Yes	Medium	Absent	Undergraduate	1	0	Other Sector	Medium
84	06.05.1989	Married	Çiğli /İzmir	Yes	Good	Good	Undergraduate	1	0	Other Sector	Good
85	17.02.1990	Single	Bornova /İzmir	No	Medium	Absent	Associate Degree	0	0	In Sector	Medium
86	19.11.1989	Single	Konak /İzmir	Yes	Medium	Medium	Undergraduate	1	0	In Sector	Good
87	31.01.1993	Single	Balçova /İzmir	No	Poor	Absent	High School	0	0	Other Sector	Good
88	02.06.1994	Single	Çiğli /İzmir	No	Poor	Absent	Associate Degree	0	0	Other Sector	Good
89	16.04.1991	Single	Buca /İzmir	No	Poor	Absent	Undergraduate	4	0	Absent	Medium
90	01.05.1991	Married	Çiğli /İzmir	No	Medium	Absent	Undergraduate	0	1	In Sector	Not Enough For Sector
91	30.08.1986	Single	Karabağlar /İzmir	No	Medium	Absent	Undergraduate	0	1	In Sector	Medium
92	11.09.1991	Single	Çiğli /İzmir	Yes	Medium	Absent	Undergraduate	0	0	Other Sector	Good

The data are replaced into the following digital form.

Candidate No	Birth Date	Marital Status	Residence Address	Driver License	English Level	Second Foreign Language Level	Educational Status	Experience / Other Sector (Year)	Experience / In Sector (Year)	Reference Status	Presentation Ability
01	10	5	13	4	5	2	6	1	1	6	4
02	6	3	53	5	3	1	6	6	1	4	7
03	8	5	5	4	3	1	4	1	1	4	1
04	10	5	115	5	2	1	6	1	1	4	7
05	10	5	5	4	2	1	6	3	1	1	4
06	9	5	2	4	5	1	4	4	1	4	7
07	9	5	6	4	1	1	6	1	3	6	1
08	10	5	5	5	2	1	6	3	3	6	4
09	8	3	5	4	3	1	4	1	3	4	4
10	6	3	11	5	3	1	6	5	1	4	7
11	9	5	5	5	3	2	6	3	1	1	4
12	10	5	5	4	3	1	6	1	1	4	4
13	6	5	11	4	3	1	1	1	1	1	7
14	9	5	5	4	2	1	4	1	1	4	1
15	10	5	5	5	3	1	6	1	1	4	4
16	10	3	31	4	2	1	6	1	1	1	7
17	9	5	59	5	3	1	6	3	1	4	4
18	6	5	11	5	3	1	6	4	3	4	7
19	10	5	2	5	3	1	6	3	3	1	7
20	8	5	6	5	1	1	1	6	1	4	7
21	10	5	5	5	3	1	6	3	1	1	4
22	9	5	12	4	3	1	4	1	1	4	1
23	10	5	11	4	5	1	6	1	1	4	4
24	8	5	5	4	1	1	4	1	1	4	4
25	10	5	11	5	5	1	6	1	1	1	10
26	10	5	12	4	1	1	6	1	1	4	4
27	9	5	2	5	3	1	6	1	1	6	10
28	6	5	14	4	3	1	6	1	3	6	7
29	10	5	19	4	3	1	6	1	1	4	4
30	8	5	6	4	3	1	6	3	1	1	7
31	8	5	5	5	3	1	6	1	1	4	4
32	10	5	56	4	2	1	6	3	1	1	4
33	6	3	5	5	3	1	6	1	3	6	4
34	10	5	13	5	3	1	6	3	1	4	4
35	6	5	11	5	2	1	4	6	1	4	4
36	10	5	12	5	3	1	6	3	1	1	10
37	6	5	13	5	3	1	6	3	1	4	7
38	8	5	19	4	3	3	4	1	1	4	4

39	10	5	19	4	3	1	4	1	1	4	4
40	9	5	7	5	2	2	4	3	1	4	7
41	10	5	13	5	3	1	6	3	1	4	4
42	10	5	11	4	3	1	6	1	1	4	7
43	9	5	2	4	2	2	6	3	1	6	10
44	8	5	13	4	3	1	6	3	1	4	1
45	10	5	5	4	3	1	6	3	3	4	4
46	8	3	5	4	2	1	4	3	1	4	1
47	10	5	2	5	5	1	6	1	1	1	7
48	10	3	34	5	5	2	6	1	1	4	4
49	10	3	6	5	5	2	6	3	1	4	4
50	6	5	5	4	3	1	4	1	1	4	4
51	10	5	13	5	1	1	4	3	1	4	10
52	10	5	5	4	5	1	6	1	3	6	4
53	10	5	5	4	2	1	6	1	1	1	7
54	10	5	6	5	5	5	4	1	1	4	4
55	10	5	11	4	3	1	4	1	1	1	7
56	8	5	6	5	3	1	4	3	3	4	10
57	10	5	14	5	2	1	4	1	1	1	7
58	9	3	16	4	2	1	6	1	1	4	4
59	8	5	13	4	3	1	4	3	1	4	7
60	9	5	2	5	3	1	6	4	1	4	10
61	10	5	95	5	5	1	6	3	1	6	7
62	6	3	14	5	3	1	6	4	1	4	4
63	10	5	19	5	3	1	6	1	1	4	4
64	9	5	14	5	3	1	6	3	1	4	4
65	9	5	6	5	2	1	6	3	1	4	1
66	10	5	6	4	3	1	6	3	3	1	7
67	10	5	19	4	3	1	1	4	1	4	4
68	9	5	2	5	5	3	6	3	1	4	10
69	10	5	11	4	3	1	6	1	3	4	4
70	10	5	6	4	3	1	6	1	1	6	4
71	10	3	59	4	2	1	6	1	1	6	7
72	9	5	11	5	3	1	6	1	1	1	4
73	10	3	19	4	3	1	6	3	1	4	7
74	10	5	2	5	3	1	6	1	1	4	4
75	6	5	7	5	3	1	6	3	1	4	4
76	9	5	6	5	2	2	1	1	3	6	4
77	10	5	11	4	3	1	6	3	1	4	7
78	9	5	34	5	3	1	6	1	1	6	4
79	8	3	49	4	3	1	2	4	1	4	1
80	6	5	13	5	3	1	1	3	1	4	7
81	8	5	11	5	3	1	6	3	1	4	7
82	10	5	56	4	3	1	4	3	1	4	7
83	9	5	11	5	3	1	6	3	1	4	4
84	10	3	19	5	5	5	6	3	1	4	7

85	10	5	11	4	3	1	4	1	1	6	4
86	10	5	2	5	3	3	6	3	1	6	7
87	8	5	7	4	2	1	1	1	1	4	7
88	6	5	19	4	2	1	4	1	1	4	7
89	10	5	5	4	2	1	6	4	1	1	4
90	10	3	19	4	3	1	6	1	3	6	1
91	6	5	6	4	3	1	6	1	3	6	4
92	10	5	19	5	3	1	6	1	1	4	7

Appendix 5: Initial data about the criteria

Criteria Name	Slope Rate	Difference Between Above-Below Value	Max/Min	Criteria No	Decision Maker	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11
Age	0.5	20	MAX	C 1	DM 1	-	FI	WI	AI	AI	AI	FI	WI	WI	FI	
Marital Status	0.8	10	MAX	C 2			-		WI	WI	WI				EI	
Distance To Branch	4	30	MIN	C 3			FI	-	FI	SI	SI	FI	WI	WI	FI	
Driver License	1	0	MAX	C 4					-		WI					
English Level	0.4	20	MAX	C 5					EI	-						
Second Foreign Language Level	0.8	20	MAX	C 6						EI	-					
Educational Status	0.7	10	MAX	C 7			EI		WI	WI	FI	-			EI	
Experience / Other Sector (Year)	0.75	20	MAX	C 8			WI		FI	FI	FI	EI	-		WI	
Experience / In Sector (Year)	0.75	20	MAX	C 9			WI		FI	FI	FI	WI	WI	-	FI	
Reference Status	0.5	30	MAX	C 10					WI	EI	EI				-	
Presentation Ability	0.4	40	MAX	C 11		EI	FI	WI	SI	AI	AI	FI	WI	WI	FI	-

DM 1 Weight Coefficient	1

Appendix 6: Initial data about the candidates

	Candidate Numbers																			
Criteria No	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C 1	10	6	8	10	10	9	9	10	8	6	9	10	6	9	10	10	9	6	10	8
C 2	5	3	5	5	5	5	5	5	3	3	5	5	5	5	5	3	5	5	5	5
C 3	13	53	5	115	5	2	6	5	5	11	5	5	11	5	5	31	59	11	2	6
C 4	4	5	4	5	4	4	4	5	4	5	5	4	4	4	5	4	5	5	5	5
C 5	5	3	3	2	2	5	1	2	3	3	3	3	3	2	3	2	3	3	3	1
C 6	2	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
C 7	6	6	4	6	6	4	6	6	4	6	6	6	1	4	6	6	6	6	6	1
C 8	1	6	1	1	3	4	1	3	1	5	3	1	1	1	1	1	3	4	3	6
C 9	1	1	1	1	1	1	3	3	3	1	1	1	1	1	1	1	1	3	3	1
C 10	6	4	4	4	1	4	6	6	4	4	1	4	1	4	4	1	4	4	1	4
C 11	4	7	1	7	4	7	1	4	4	7	4	4	7	1	4	7	4	7	7	7

Appendix 7: Initial data about the criteria in fuzzy number format

Criteria No	Decision Maker	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11
C 1		(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(9.000, 9.000, 9.000)	(9.000, 9.000, 9.000)	(9.000, 9.000, 9.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)
C 2		(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(0.250, 0.333, 0.500)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)
C 3		(0.250, 0.333, 0.500)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(6.000, 7.000, 8.000)	(6.000, 7.000, 8.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(4.000, 5.000, 6.000)	(0.250, 0.333, 0.500)
C 4		(0.111, 0.111, 0.111)	(0.250, 0.333, 0.500)	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(2.000, 3.000, 4.000)	(0.250, 0.333, 0.500)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(0.250, 0.333, 0.500)	(0.125, 0.143, 0.167)
C 5		(0.111, 0.111, 0.111)	(0.250, 0.333, 0.500)	(0.125, 0.143, 0.167)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.111, 0.111, 0.111)
C 6	DM 1	(0.111, 0.111, 0.111)	(0.250, 0.333, 0.500)	(0.125, 0.143, 0.167)	(0.250, 0.333, 0.500)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.111, 0.111, 0.111)
C 7		(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)
C 8		(0.250, 0.333, 0.500)	(2.000, 3.000, 4.000)	(0.250, 0.333, 0.500)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(2.000, 3.000, 4.000)	(0.250, 0.333, 0.500)
C 9		(0.250, 0.333, 0.500)	(2.000, 3.000, 4.000)	(0.250, 0.333, 0.500)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(0.250, 0.333, 0.500)
C 10		(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)	(2.000, 3.000, 4.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)
C 11		(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(6.000, 7.000, 8.000)	(9.000, 9.000, 9.000)	(9.000, 9.000, 9.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)

Appendix 8: Geometric mean of the criteria's fuzzy comparison values

Criteria No	$\widetilde{r}_i$		
C 1	3.210	3.811	4.332
C 2	0.576	0.712	0.882
C 3	2.022	2.557	3.176
C 4	0.304	0.362	0.448
C 5	0.312	0.343	0.390
C 6	0.265	0.297	0.344
C 7	0.696	0.825	0.974
C 8	1.000	1.270	1.630
C 9	1.370	1.795	2.318
C 10	0.490	0.557	0.643
C 11	3.094	3.725	4.286
Total	13.339	16.254	19.423
Reverse (Power of -1)	0.075	0.062	0.051
Increasing Order	0.051	0.062	0.075

Appendix 9: Fuzzy weights of the criteria

Criteria No	$\tilde{w}_i$		
C 1	0.165	0.234	0.325
C 2	0.030	0.044	0.066
C 3	0.104	0.157	0.238
C 4	0.016	0.022	0.034
C 5	0.016	0.021	0.029
C 6	0.014	0.018	0.026
C 7	0.036	0.051	0.073
C 8	0.051	0.078	0.122
C 9	0.071	0.110	0.174
C 10	0.025	0.034	0.048
C 11	0.159	0.229	0.321

Appendix 10: Weights of the criteria

Criteria No	M	N
C 1	0.241	0.231
C 2	0.047	0.045
C 3	0.166	0.159
C 4	0.024	0.023
C 5	0.022	0.021
C 6	0.019	0.018
C 7	0.053	0.051
C 8	0.084	0.080
C 9	0.118	0.113
C 10	0.036	0.034
C 11	0.236	0.226
Lamda Max	11.890	
CI	0.089	
CR	0.059	

Appendix 11: Fuzzy decision matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C1	(9.333, 10.000, 11.333)	(5.600, 6.000, 6.800)	(7.467, 8.000, 9.067)	(9.333, 10.000, 11.333)	(9.333, 10.000, 11.333)	(8.400, 9.000, 10.200)	(8.400, 9.000, 10.200)	(9.333, 10.000, 11.333)	(7.467, 8.000, 9.067)	(5.600, 6.000, 6.800)	(8.400, 9.000, 10.200)	(9.333, 10.000, 11.333)	(5.600, 6.000, 6.800)	(8.400, 9.000, 10.200)	(9.333, 10.000, 11.333)	(9.333, 10.000, 11.333)	(8.400, 9.000, 10.200)	(5.600, 6.000, 6.800)	(9.333, 10.000, 11.333)	(7.467, 8.000, 9.067)
C2	(4.778, 5.000, 5.278)	(2.867, 3.000, 3.167)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(2.867, 3.000, 3.167)	(2.867, 3.000, 3.167)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(2.867, 3.000, 3.167)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)	(4.778, 5.000, 5.278)
C3	(9.880, 13.000, 13.780)	(40.280, 53.000, 56.180)	(3.800, 5.000, 5.300)	(87.400, 115.000, 121.900)	(3.800, 5.000, 5.300)	(1.520, 2.000, 2.120)	(4.560, 6.000, 6.360)	(3.800, 5.000, 5.300)	(3.800, 5.000, 5.300)	(8.360, 11.000, 11.660)	(3.800, 5.000, 5.300)	(3.800, 5.000, 5.300)	(8.360, 11.000, 11.660)	(3.800, 5.000, 5.300)	(3.800, 5.000, 5.300)	(23.560, 31.000, 32.860)	(44.840, 59.000, 62.540)	(8.360, 11.000, 11.660)	(1.520, 2.000, 2.120)	(4.560, 6.000, 6.360)
C4	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(4.000, 4.000, 4.000)	(4.000, 4.000, 4.000)	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(5.000, 5.000, 5.000)	(4.000, 4.000, 4.000)	(4.000, 4.000, 4.000)	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(4.000, 4.000, 4.000)	(5.000, 5.000, 5.000)	(5.000, 5.000, 5.000)	(5.000, 5.000, 5.000)	(5.000, 5.000, 5.000)
C5	(4.714, 5.000, 5.714)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(1.886, 2.000, 2.286)	(1.886, 2.000, 2.286)	(4.714, 5.000, 5.714)	(0.943, 1.000, 1.143)	(1.886, 2.000, 2.286)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(1.886, 2.000, 2.286)	(2.829, 3.000, 3.429)	(1.886, 2.000, 2.286)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(2.829, 3.000, 3.429)	(0.943, 1.000, 1.143)
C6	(1.822, 2.000, 2.222)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(1.822, 2.000, 2.222)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)	(0.911, 1.000, 1.111)
C7	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(3.835, 4.000, 4.235)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(3.835, 4.000, 4.235)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(3.835, 4.000, 4.235)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(0.959, 1.000, 1.059)	(3.835, 4.000, 4.235)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(5.753, 6.000, 6.353)	(0.959, 1.000, 1.059)
C8	(0.914, 1.000, 1.114)	(5.486, 6.000, 6.686)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(2.743, 3.000, 3.343)	(3.657, 4.000, 4.457)	(0.914, 1.000, 1.114)	(2.743, 3.000, 3.343)	(0.914, 1.000, 1.114)	(4.571, 5.000, 5.571)	(2.743, 3.000, 3.343)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(2.743, 3.000, 3.343)	(3.657, 4.000, 4.457)	(2.743, 3.000, 3.343)	(5.486, 6.000, 6.686)
C9	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(2.743, 3.000, 3.343)	(2.743, 3.000, 3.343)	(2.743, 3.000, 3.343)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(0.914, 1.000, 1.114)	(2.743, 3.000, 3.343)	(2.743, 3.000, 3.343)	(0.914, 1.000, 1.114)
C10	(5.400, 6.000, 7.200)	(3.600, 4.000, 4.800)	(3.600, 4.000, 4.800)	(3.600, 4.000, 4.800)	(0.900, 1.000, 1.200)	(3.600, 4.000, 4.800)	(5.400, 6.000, 7.200)	(5.400, 6.000, 7.200)	(3.600, 4.000, 4.800)	(3.600, 4.000, 4.800)	(0.900, 1.000, 1.200)	(3.600, 4.000, 4.800)	(0.900, 1.000, 1.200)	(3.600, 4.000, 4.800)	(3.600, 4.000, 4.800)	(0.900, 1.000, 1.200)	(3.600, 4.000, 4.800)	(3.600, 4.000, 4.800)	(0.900, 1.000, 1.200)	(3.600, 4.000, 4.800)
C11	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(0.886, 1.000, 1.286)	(6.200, 7.000, 9.000)	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(0.886, 1.000, 1.286)	(3.543, 4.000, 5.143)	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(3.543, 4.000, 5.143)	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(0.886, 1.000, 1.286)	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(3.543, 4.000, 5.143)	(6.200, 7.000, 9.000)	(6.200, 7.000, 9.000)	(6.200, 7.000, 9.000)

Appendix 12: Fuzzy normalized decision matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C1	(0.824, 0.882, 1.000)	(0.494, 0.529, 0.600)	(0.659, 0.706, 0.800)	(0.824, 0.882, 1.000)	(0.824, 0.882, 1.000)	(0.741, 0.794, 0.900)	(0.741, 0.794, 0.900)	(0.824, 0.882, 1.000)	(0.659, 0.706, 0.800)	(0.494, 0.529, 0.600)	(0.741, 0.794, 0.900)	(0.824, 0.882, 1.000)	(0.494, 0.529, 0.600)	(0.741, 0.794, 0.900)	(0.824, 0.882, 1.000)	(0.824, 0.882, 1.000)	(0.741, 0.794, 0.900)	(0.494, 0.529, 0.600)	(0.824, 0.882, 1.000)	(0.659, 0.706, 0.800)
C2	(0.905, 0.947, 1.000)	(0.543, 0.568, 0.600)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.543, 0.568, 0.600)	(0.543, 0.568, 0.600)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.543, 0.568, 0.600)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)	(0.905, 0.947, 1.000)
C3	(0.110, 0.117, 0.154)	(0.027, 0.029, 0.038)	(0.287, 0.304, 0.400)	(0.012, 0.013, 0.017)	(0.287, 0.304, 0.400)	(0.717, 0.760, 1.000)	(0.239, 0.253, 0.333)	(0.287, 0.304, 0.400)	(0.287, 0.304, 0.400)	(0.130, 0.138, 0.182)	(0.287, 0.304, 0.400)	(0.287, 0.304, 0.400)	(0.130, 0.138, 0.182)	(0.287, 0.304, 0.400)	(0.287, 0.304, 0.400)	(0.046, 0.049, 0.065)	(0.024, 0.026, 0.034)	(0.130, 0.138, 0.182)	(0.717, 0.760, 1.000)	(0.239, 0.253, 0.333)
C4	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(0.800, 0.800, 0.800)	(0.800, 0.800, 0.800)	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(0.800, 0.800, 0.800)	(0.800, 0.800, 0.800)	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(0.800, 0.800, 0.800)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)	(1.000, 1.000, 1.000)
C5	(0.825, 0.875, 1.000)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.330, 0.350, 0.400)	(0.330, 0.350, 0.400)	(0.825, 0.875, 1.000)	(0.165, 0.175, 0.200)	(0.330, 0.350, 0.400)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.330, 0.350, 0.400)	(0.495, 0.525, 0.600)	(0.330, 0.350, 0.400)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.495, 0.525, 0.600)	(0.165, 0.175, 0.200)
C6	(0.328, 0.360, 0.400)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.328, 0.360, 0.400)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)	(0.164, 0.180, 0.200)
C7	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.604, 0.630, 0.667)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.604, 0.630, 0.667)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.604, 0.630, 0.667)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.151, 0.157, 0.167)	(0.604, 0.630, 0.667)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.906, 0.944, 1.000)	(0.151, 0.157, 0.167)
C8	(0.137, 0.150, 0.167)	(0.821, 0.897, 1.000)	(0.137, 0.150, 0.167)	(0.137, 0.150, 0.167)	(0.410, 0.449, 0.500)	(0.547, 0.598, 0.667)	(0.137, 0.150, 0.167)	(0.410, 0.449, 0.500)	(0.137, 0.150, 0.167)	(0.684, 0.748, 0.833)	(0.410, 0.449, 0.500)	(0.137, 0.150, 0.167)	(0.137, 0.150, 0.167)	(0.137, 0.150, 0.167)	(0.137, 0.150, 0.167)	(0.137, 0.150, 0.167)	(0.410, 0.449, 0.500)	(0.547, 0.598, 0.667)	(0.410, 0.449, 0.500)	(0.821, 0.897, 1.000)
C9	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.821, 0.897, 1.000)	(0.821, 0.897, 1.000)	(0.821, 0.897, 1.000)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.274, 0.299, 0.333)	(0.821, 0.897, 1.000)	(0.821, 0.897, 1.000)	(0.274, 0.299, 0.333)
C10	(0.750, 0.833, 1.000)	(0.500, 0.556, 0.667)	(0.500, 0.556, 0.667)	(0.500, 0.556, 0.667)	(0.125, 0.139, 0.167)	(0.500, 0.556, 0.667)	(0.750, 0.833, 1.000)	(0.750, 0.833, 1.000)	(0.500, 0.556, 0.667)	(0.500, 0.556, 0.667)	(0.125, 0.139, 0.167)	(0.500, 0.556, 0.667)	(0.125, 0.139, 0.167)	(0.500, 0.556, 0.667)	(0.500, 0.556, 0.667)	(0.125, 0.139, 0.167)	(0.500, 0.556, 0.667)	(0.500, 0.556, 0.667)	(0.125, 0.139, 0.167)	(0.500, 0.556, 0.667)
C11	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.069, 0.078, 0.100)	(0.482, 0.544, 0.700)	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.069, 0.078, 0.100)	(0.276, 0.311, 0.400)	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.276, 0.311, 0.400)	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.069, 0.078, 0.100)	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.276, 0.311, 0.400)	(0.482, 0.544, 0.700)	(0.482, 0.544, 0.700)	(0.482, 0.544, 0.700)

Appendix 13: Weighted fuzzy normalized decision matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C1	(0.190, 0.204, 0.231)	(0.114, 0.122, 0.138)	(0.152, 0.163, 0.185)	(0.190, 0.204, 0.231)	(0.190, 0.204, 0.231)	(0.171, 0.183, 0.208)	(0.171, 0.183, 0.208)	(0.190, 0.204, 0.231)	(0.152, 0.163, 0.185)	(0.114, 0.122, 0.138)	(0.171, 0.183, 0.208)	(0.190, 0.204, 0.231)	(0.114, 0.122, 0.138)	(0.171, 0.183, 0.208)	(0.190, 0.204, 0.231)	(0.190, 0.204, 0.231)	(0.171, 0.183, 0.208)	(0.114, 0.122, 0.138)	(0.190, 0.204, 0.231)	(0.152, 0.163, 0.185)
C2	(0.040, 0.042, 0.045)	(0.024, 0.025, 0.027)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.024, 0.025, 0.027)	(0.024, 0.025, 0.027)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.024, 0.025, 0.027)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)	(0.040, 0.042, 0.045)
C3	(0.018, 0.019, 0.024)	(0.004, 0.005, 0.006)	(0.046, 0.048, 0.064)	(0.002, 0.002, 0.003)	(0.046, 0.048, 0.064)	(0.114, 0.121, 0.159)	(0.038, 0.040, 0.053)	(0.046, 0.048, 0.064)	(0.046, 0.048, 0.064)	(0.021, 0.022, 0.029)	(0.046, 0.048, 0.064)	(0.046, 0.048, 0.064)	(0.021, 0.022, 0.029)	(0.046, 0.048, 0.064)	(0.046, 0.048, 0.064)	(0.007, 0.008, 0.010)	(0.004, 0.004, 0.005)	(0.021, 0.022, 0.029)	(0.114, 0.121, 0.159)	(0.038, 0.040, 0.053)
C4	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.018, 0.018, 0.018)	(0.018, 0.018, 0.018)	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.023, 0.023, 0.023)	(0.018, 0.018, 0.018)	(0.018, 0.018, 0.018)	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.018, 0.018, 0.018)	(0.023, 0.023, 0.023)	(0.023, 0.023, 0.023)	(0.023, 0.023, 0.023)	(0.023, 0.023, 0.023)
C5	(0.017, 0.018, 0.021)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.007, 0.007, 0.008)	(0.007, 0.007, 0.008)	(0.017, 0.018, 0.021)	(0.003, 0.004, 0.004)	(0.007, 0.007, 0.008)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.007, 0.007, 0.008)	(0.010, 0.011, 0.013)	(0.007, 0.007, 0.008)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.010, 0.011, 0.013)	(0.003, 0.004, 0.004)
C6	(0.006, 0.007, 0.007)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.006, 0.007, 0.007)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)	(0.003, 0.003, 0.004)
C7	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.031, 0.032, 0.034)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.031, 0.032, 0.034)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.031, 0.032, 0.034)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.008, 0.008, 0.008)	(0.031, 0.032, 0.034)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.046, 0.048, 0.051)	(0.008, 0.008, 0.008)
C8	(0.011, 0.012, 0.013)	(0.066, 0.072, 0.080)	(0.011, 0.012, 0.013)	(0.011, 0.012, 0.013)	(0.033, 0.036, 0.040)	(0.044, 0.048, 0.053)	(0.011, 0.012, 0.013)	(0.033, 0.036, 0.040)	(0.011, 0.012, 0.013)	(0.055, 0.060, 0.067)	(0.033, 0.036, 0.040)	(0.011, 0.012, 0.013)	(0.011, 0.012, 0.013)	(0.011, 0.012, 0.013)	(0.011, 0.012, 0.013)	(0.011, 0.012, 0.013)	(0.033, 0.036, 0.040)	(0.044, 0.048, 0.053)	(0.033, 0.036, 0.040)	(0.066, 0.072, 0.080)
C9	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.093, 0.102, 0.113)	(0.093, 0.102, 0.113)	(0.093, 0.102, 0.113)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.031, 0.034, 0.038)	(0.093, 0.102, 0.113)	(0.093, 0.102, 0.113)	(0.031, 0.034, 0.038)
C10	(0.026, 0.028, 0.034)	(0.017, 0.019, 0.023)	(0.017, 0.019, 0.023)	(0.017, 0.019, 0.023)	(0.004, 0.005, 0.006)	(0.017, 0.019, 0.023)	(0.026, 0.028, 0.034)	(0.026, 0.028, 0.034)	(0.017, 0.019, 0.023)	(0.017, 0.019, 0.023)	(0.004, 0.005, 0.006)	(0.017, 0.019, 0.023)	(0.004, 0.005, 0.006)	(0.017, 0.019, 0.023)	(0.017, 0.019, 0.023)	(0.004, 0.005, 0.006)	(0.017, 0.019, 0.023)	(0.017, 0.019, 0.023)	(0.004, 0.005, 0.006)	(0.017, 0.019, 0.023)
C11	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.016, 0.018, 0.023)	(0.109, 0.123, 0.158)	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.016, 0.018, 0.023)	(0.062, 0.070, 0.090)	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.062, 0.070, 0.090)	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.016, 0.018, 0.023)	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.062, 0.070, 0.090)	(0.109, 0.123, 0.158)	(0.109, 0.123, 0.158)	(0.109, 0.123, 0.158)

Appendix 14: Distance to positive ideal solution

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C1	0.792	0.875	0.834	0.792	0.792	0.813	0.813	0.792	0.834	0.875	0.813	0.792	0.875	0.813	0.792	0.792	0.813	0.875	0.792	0.834
C2	0.958	0.975	0.958	0.958	0.958	0.958	0.958	0.958	0.975	0.975	0.958	0.958	0.958	0.958	0.958	0.975	0.958	0.958	0.958	0.958
C3	0.980	0.995	0.948	0.998	0.948	0.869	0.956	0.948	0.948	0.976	0.948	0.948	0.976	0.948	0.948	0.992	0.996	0.976	0.869	0.956
C4	0.982	0.977	0.982	0.977	0.982	0.982	0.982	0.977	0.982	0.977	0.977	0.982	0.982	0.982	0.977	0.982	0.977	0.977	0.977	0.977
C5	0.981	0.989	0.989	0.992	0.992	0.981	0.996	0.992	0.989	0.989	0.989	0.989	0.989	0.992	0.989	0.992	0.989	0.989	0.989	0.996
C6	0.993	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.993	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
C7	0.952	0.952	0.968	0.952	0.952	0.968	0.952	0.952	0.968	0.952	0.952	0.952	0.992	0.968	0.952	0.952	0.952	0.952	0.952	0.992
C8	0.988	0.928	0.988	0.988	0.964	0.952	0.988	0.964	0.988	0.940	0.964	0.988	0.988	0.988	0.988	0.988	0.964	0.952	0.964	0.928
C9	0.966	0.966	0.966	0.966	0.966	0.966	0.898	0.898	0.898	0.966	0.966	0.966	0.966	0.966	0.966	0.966	0.966	0.898	0.898	0.966
C10	0.971	0.980	0.980	0.980	0.995	0.980	0.971	0.971	0.980	0.980	0.995	0.980	0.995	0.980	0.980	0.995	0.980	0.980	0.995	0.980
C11	0.926	0.870	0.981	0.870	0.926	0.870	0.981	0.926	0.926	0.870	0.926	0.926	0.870	0.981	0.926	0.870	0.926	0.870	0.870	0.870

Appendix 15: Distance to negative ideal solution

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
C1	0.209	0.125	0.167	0.209	0.209	0.188	0.188	0.209	0.167	0.125	0.188	0.209	0.125	0.188	0.209	0.209	0.188	0.125	0.209	0.167
C2	0.042	0.025	0.042	0.042	0.042	0.042	0.042	0.042	0.025	0.025	0.042	0.042	0.042	0.042	0.042	0.025	0.042	0.042	0.042	0.042
C3	0.020	0.005	0.053	0.002	0.053	0.133	0.044	0.053	0.053	0.024	0.053	0.053	0.024	0.053	0.053	0.009	0.005	0.024	0.133	0.044
C4	0.018	0.023	0.018	0.023	0.018	0.018	0.018	0.023	0.018	0.023	0.023	0.018	0.018	0.018	0.023	0.018	0.023	0.023	0.023	0.023
C5	0.019	0.011	0.011	0.008	0.008	0.019	0.004	0.008	0.011	0.011	0.011	0.011	0.011	0.008	0.011	0.008	0.011	0.011	0.011	0.004
C6	0.007	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.007	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
C7	0.048	0.048	0.032	0.048	0.048	0.032	0.048	0.048	0.032	0.048	0.048	0.048	0.008	0.032	0.048	0.048	0.048	0.048	0.048	0.008
C8	0.012	0.073	0.012	0.012	0.036	0.048	0.012	0.036	0.012	0.061	0.036	0.012	0.012	0.012	0.012	0.012	0.036	0.048	0.036	0.073
C9	0.034	0.034	0.034	0.034	0.034	0.034	0.103	0.103	0.103	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.103	0.103	0.034
C10	0.030	0.020	0.020	0.020	0.005	0.020	0.030	0.030	0.020	0.020	0.005	0.020	0.005	0.020	0.020	0.005	0.020	0.020	0.005	0.020
C11	0.075	0.132	0.019	0.132	0.075	0.132	0.019	0.075	0.075	0.132	0.075	0.075	0.132	0.019	0.075	0.132	0.075	0.132	0.132	0.132

Appendix 16: Proximity factor

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
d*	10.487	10.503	10.589	10.469	10.470	10.335	10.490	10.373	10.482	10.496	10.479	10.476	10.587	10.572	10.471	10.500	10.516	10.423	10.259	10.453
d-	0.515	0.500	0.413	0.534	0.533	0.670	0.512	0.631	0.521	0.507	0.524	0.527	0.416	0.430	0.532	0.504	0.487	0.581	0.746	0.550
d*+d-	11.003	11.003	11.002	11.003	11.003	11.005	11.002	11.003	11.003	11.003	11.003	11.003	11.003	11.002	11.003	11.003	11.002	11.003	11.005	11.004
CC	0.047	0.045	0.038	0.049	0.048	0.061	0.047	0.057	0.047	0.046	0.048	0.048	0.038	0.039	0.048	0.046	0.044	0.053	0.068	0.050
Assessments	NR*	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

* Not Recommended

Appendix 17: Concordance matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
01	-	0.672	0.842	0.752	0.762	0.536	0.729	0.626	0.729	0.513	0.739	0.842	0.616	0.842	0.819	0.775	0.898	0.400	0.400	0.513
02	0.493	-	0.567	0.726	0.567	0.546	0.419	0.419	0.498	0.842	0.548	0.567	0.797	0.567	0.567	0.611	0.726	0.684	0.453	0.567
03	0.420	0.621	-	0.470	0.413	0.284	0.572	0.243	0.662	0.621	0.372	0.493	0.775	0.770	0.470	0.493	0.390	0.508	0.118	0.672
04	0.768	0.741	0.821	-	0.762	0.741	0.695	0.615	0.708	0.741	0.722	0.821	0.821	0.842	0.821	0.842	0.741	0.628	0.628	0.762
05	0.927	0.617	0.946	0.718	-	0.481	0.854	0.831	0.833	0.617	0.938	0.946	0.754	0.967	0.923	0.775	0.923	0.504	0.459	0.638
06	0.667	0.847	1.001	0.696	0.719	-	0.803	0.549	0.888	0.847	0.909	0.719	1.001	1.001	0.696	0.719	0.927	0.814	0.583	0.898
07	0.505	0.651	0.821	0.500	0.284	0.515	-	0.261	0.595	0.651	0.474	0.364	0.754	0.821	0.341	0.523	0.651	0.651	0.261	0.672
08	0.961	0.674	0.980	0.775	1.001	0.515	1.001	-	0.980	0.674	0.961	0.980	0.754	1.001	0.980	0.775	0.980	0.674	0.595	0.695
09	0.601	0.621	0.956	0.426	0.595	0.240	0.641	0.538	-	0.621	0.553	0.675	0.730	0.726	0.652	0.493	0.572	0.576	0.187	0.627
10	0.652	0.921	0.567	0.726	0.567	0.546	0.419	0.419	0.498	-	0.548	0.567	0.956	0.567	0.567	0.770	0.726	0.843	0.453	0.487
11	0.715	0.661	0.967	0.510	0.770	0.481	0.854	0.623	0.854	0.661	-	0.736	0.775	0.967	0.736	0.544	0.967	0.548	0.272	0.661
12	0.927	0.672	1.001	0.752	0.921	0.515	0.854	0.751	0.888	0.672	0.880	-	0.775	1.001	0.978	0.775	0.898	0.559	0.400	0.672
13	0.646	0.813	0.526	0.662	0.480	0.425	0.413	0.310	0.413	0.813	0.439	0.526	-	0.526	0.503	0.719	0.582	0.700	0.344	0.474
14	0.420	0.600	0.980	0.470	0.413	0.515	0.803	0.243	0.641	0.600	0.582	0.472	0.754	-	0.449	0.493	0.600	0.487	0.097	0.672
15	0.927	0.695	1.001	0.775	0.921	0.515	0.854	0.774	0.888	0.695	0.902	1.001	0.775	1.001	-	0.775	0.921	0.582	0.423	0.695
16	0.724	0.843	0.742	0.899	0.717	0.662	0.650	0.547	0.674	0.684	0.655	0.742	0.776	0.763	0.719	-	0.798	0.526	0.560	0.660
17	0.538	0.536	0.842	0.544	0.611	0.515	0.695	0.464	0.729	0.536	0.823	0.611	0.616	0.842	0.611	0.385	-	0.423	0.272	0.536
18	0.697	0.921	0.611	0.770	0.611	0.590	0.577	0.577	0.611	0.921	0.593	0.611	1.001	0.611	0.611	0.770	0.770	-	0.611	0.531
19	0.927	0.887	0.967	0.967	1.001	0.866	0.967	0.967	0.967	0.887	0.982	0.967	1.001	0.967	0.967	1.001	0.967	0.887	-	0.887
20	0.646	0.929	0.770	0.698	0.539	0.539	0.572	0.392	0.657	0.929	0.521	0.539	0.980	0.539	0.539	0.698	0.698	0.816	0.426	-

Appendix 18: Discordance matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
01	-	0.725	0.580	1.000	1.000	1.000	1.000	1.000	1.000	0.670	1.000	1.000	0.670	0.580	1.000	1.000	1.000	0.821	1.000	1.000
02	1.000	-	0.427	1.000	1.000	1.000	0.613	1.000	1.000	1.000	1.000	1.000	0.313	0.560	1.000	1.000	1.000	1.000	1.000	1.000
03	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
04	0.321	0.725	0.451	-	0.901	1.000	0.613	1.000	1.000	0.580	0.901	0.901	0.259	0.451	0.901	0.365	0.433	0.821	1.000	1.000
05	0.757	0.670	0.263	1.000	-	1.000	1.000	1.000	1.000	0.670	0.221	0.608	0.670	0.263	0.608	1.000	0.305	0.821	1.000	1.000
06	0.187	0.191	0.000	0.161	0.264	-	0.613	0.867	0.867	0.150	0.205	0.264	0.000	0.000	0.264	0.169	0.127	0.636	1.000	0.276
07	0.816	1.000	0.128	1.000	0.816	1.000	-	1.000	1.000	1.000	0.816	0.816	1.000	0.128	0.816	1.000	0.816	1.000	1.000	1.000
08	0.166	0.670	0.055	0.816	0.000	1.000	0.000	-	0.091	0.670	0.055	0.055	0.670	0.000	0.055	0.816	0.055	0.670	1.000	0.816
09	0.609	0.884	0.248	0.816	0.609	1.000	0.373	1.000	-	0.816	0.354	0.609	0.816	0.305	0.609	0.816	0.354	1.000	1.000	0.884
10	1.000	0.638	0.373	1.000	1.000	1.000	0.613	1.000	1.000	-	1.000	1.000	0.351	0.560	1.000	1.000	1.000	1.000	1.000	1.000
11	0.757	0.893	0.263	1.000	1.000	1.000	1.000	1.000	1.000	0.893	-	0.861	0.893	0.263	0.861	1.000	0.305	1.000	1.000	1.000
12	0.303	0.725	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.670	1.000	-	0.670	0.000	1.000	1.000	0.503	0.821	1.000	1.000
13	1.000	1.000	0.373	1.000	1.000	1.000	0.613	1.000	1.000	1.000	1.000	1.000	-	0.560	1.000	1.000	1.000	1.000	1.000	1.000
14	1.000	1.000	0.182	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000
15	0.303	0.725	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.670	1.000	0.000	0.670	0.000	-	1.000	0.503	0.821	1.000	1.000
16	0.439	0.725	0.395	1.000	0.790	1.000	0.613	1.000	1.000	0.580	0.790	0.790	0.204	0.395	0.790	-	0.433	0.821	1.000	1.000
17	0.861	0.893	0.862	1.000	1.000	1.000	1.000	1.000	1.000	0.893	1.000	1.000	0.893	0.862	1.000	1.000	-	1.000	1.000	1.000
18	1.000	0.354	0.373	1.000	1.000	1.000	0.560	1.000	0.747	0.177	0.914	1.000	0.000	0.560	1.000	1.000	0.914	-	1.000	0.609
19	0.220	0.287	0.132	0.114	0.000	0.215	0.220	0.311	0.186	0.225	0.043	0.186	0.000	0.132	0.186	0.000	0.116	0.137	-	0.414
20	0.689	0.970	0.217	0.689	0.747	1.000	0.613	1.000	1.000	0.970	0.724	0.689	0.125	0.217	0.689	0.689	0.724	1.000	1.000	-

Appendix 19: Minimum concordance level matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
01	-	0	1	1	1	0	1	0	1	0	1	1	0	1	1	1	1	0	0	0
02	0	-	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
03	0	0	-	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
04	1	1	1	-	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1
05	1	0	1	1	-	0	1	1	1	0	1	1	1	1	1	1	1	0	0	0
06	0	1	1	0	1	-	1	0	1	1	1	1	1	1	0	1	1	1	0	1
07	0	0	1	0	0	0	-	0	0	0	0	0	1	1	0	0	0	0	0	0
08	1	0	1	1	1	0	1	-	1	0	1	1	1	1	1	1	1	0	0	0
09	0	0	1	0	0	0	0	0	-	0	0	0	1	1	0	0	0	0	0	0
10	0	1	0	1	0	0	0	0	0	-	0	0	1	0	0	1	1	1	0	0
11	1	0	1	0	1	0	1	0	1	0	-	1	1	1	1	0	1	0	0	0
12	1	0	1	1	1	0	1	1	1	0	1	-	1	1	1	1	1	0	0	0
13	0	1	0	0	0	0	0	0	0	1	0	0	-	0	0	1	0	1	0	0
14	0	0	1	0	0	0	1	0	0	0	0	0	1	-	0	0	0	0	0	0
15	1	0	1	1	1	0	1	1	1	0	1	1	1	1	-	1	1	0	0	0
16	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	-	1	0	0	0
17	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-	0	0	0
18	0	1	0	1	0	0	0	0	0	1	0	0	1	0	0	1	1	-	0	0
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1
20	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	-

Appendix 20: Minimum discordance level matrix

	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
01	-	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
02	0	-	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
03	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1	0	1	-	0	0	1	0	0	1	0	0	1	1	0	1	1	0	0	0
05	0	1	1	0	-	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0
06	1	1	1	1	1	-	1	0	0	1	1	1	1	1	1	1	1	1	0	1
07	0	0	1	0	0	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0
08	1	1	1	0	1	0	1	-	1	1	1	1	1	1	1	0	1	1	0	0
09	1	0	1	0	1	0	1	0	-	0	1	1	0	1	1	0	1	0	0	0
10	0	1	1	0	0	0	1	0	0	-	0	0	1	1	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	0	-	0	0	1	0	0	1	0	0	0
12	1	0	1	0	0	0	0	0	0	1	0	-	1	1	0	0	1	0	0	0
13	0	0	1	0	0	0	1	0	0	0	0	0	-	1	0	0	0	0	0	0
14	0	0	1	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0
15	1	0	1	0	0	0	0	0	0	1	0	1	1	1	-	0	1	0	0	0
16	1	0	1	0	0	0	1	0	0	1	0	0	1	1	0	-	1	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
18	0	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	-	0	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1
20	1	0	1	1	0	0	1	0	0	0	0	1	1	1	1	1	0	0	0	-

Appendix 21: The global matrix

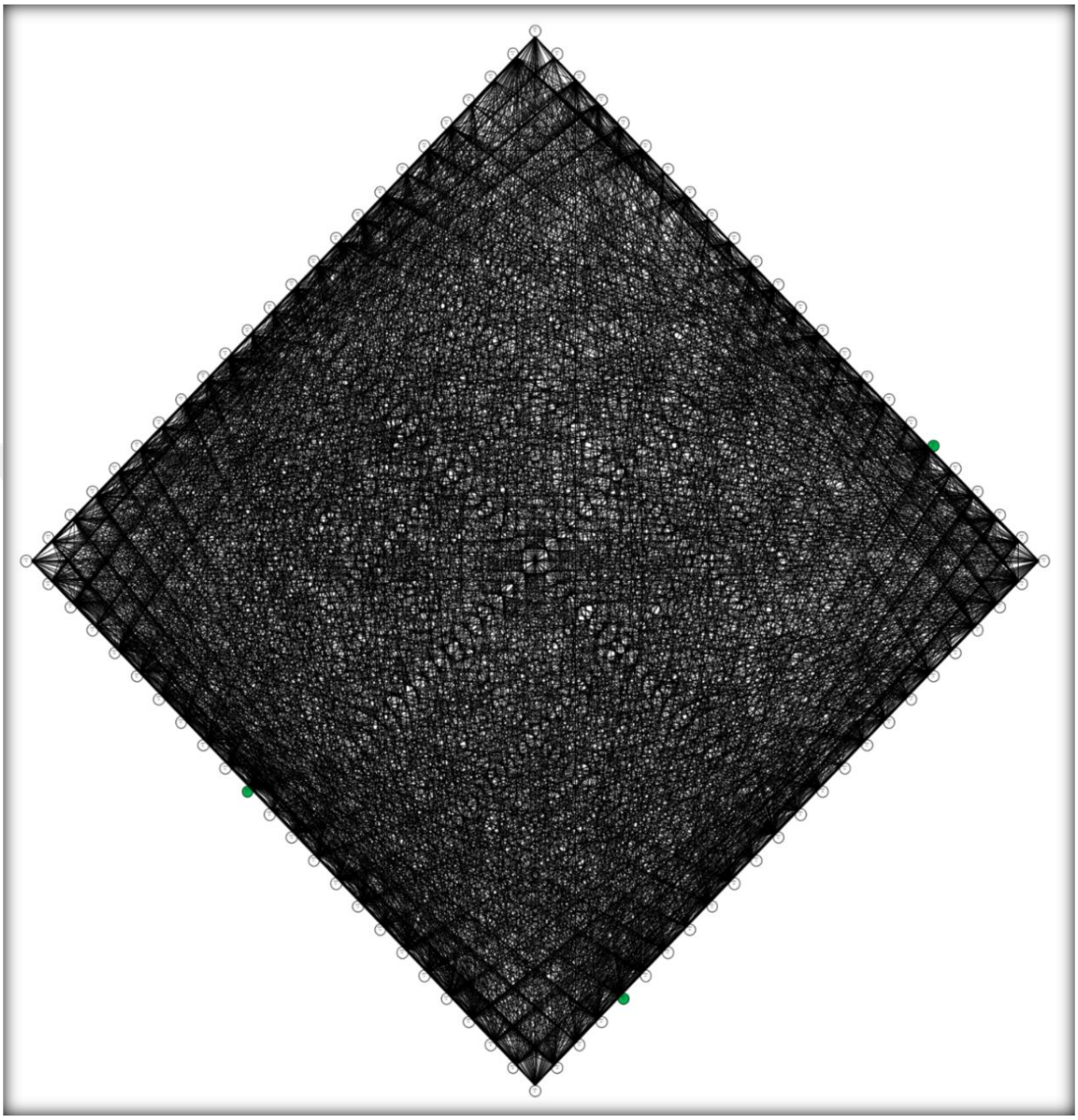
	Candidate Numbers																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
01	-	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
02	0	-	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
03	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1	0	1	-	0	0	0	0	0	1	0	0	1	1	0	1	1	0	0	0
05	0	0	1	0	-	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0
06	0	1	1	0	1	-	1	0	0	1	1	1	1	1	0	1	1	1	0	1
07	0	0	1	0	0	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0
08	1	0	1	0	1	0	1	-	1	0	1	1	1	1	1	0	1	0	0	0
09	0	0	1	0	0	0	0	0	-	0	0	0	0	1	0	0	0	0	0	0
10	0	1	0	0	0	0	0	0	0	-	0	0	1	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	0	-	0	0	1	0	0	1	0	0	0
12	1	0	1	0	0	0	0	0	0	0	0	-	1	1	0	0	1	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0
14	0	0	1	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0
15	1	0	1	0	0	0	0	0	0	0	0	1	1	1	-	0	1	0	0	0
16	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	-	1	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
18	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	-	0	0
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1
20	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	-

Appendix 22: The Results

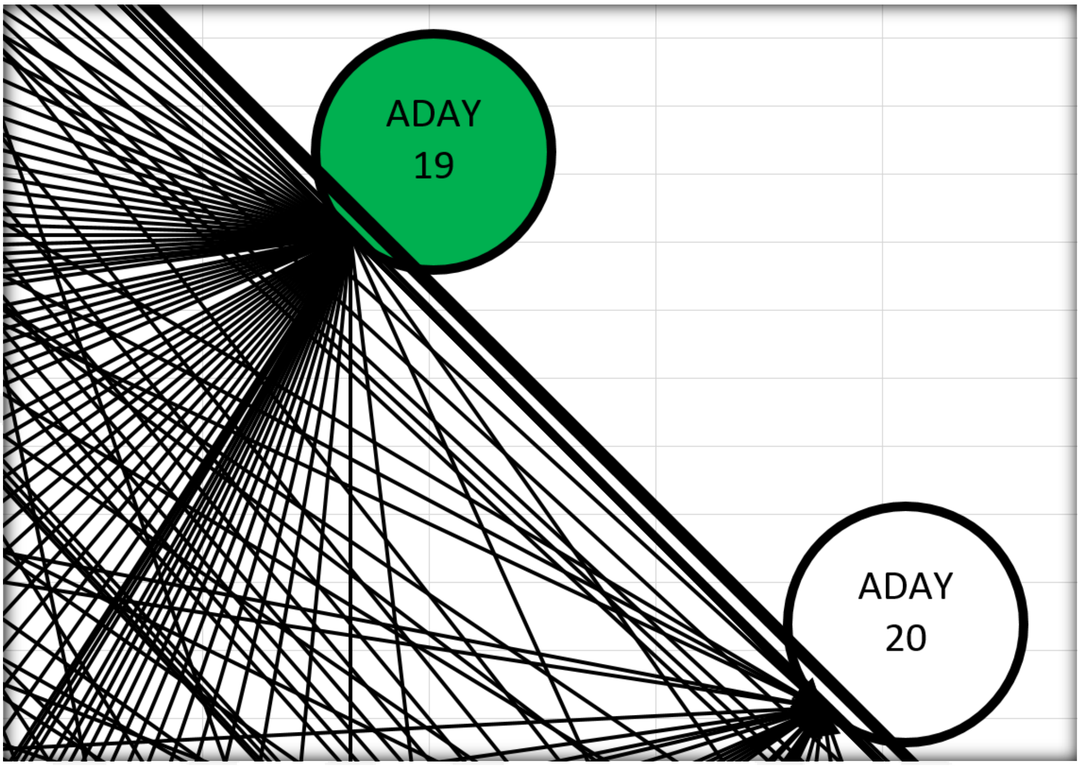
Cand.	ELECTRE Kernel	TOPSIS	TOPSIS Assessment	Cand.	ELECTRE Kernel	TOPSIS	TOPSIS Assessment	Cand.	ELECTRE Kernel	TOPSIS	TOPSIS Assessment	Cand.	ELECTRE Kernel	TOPSIS	TOPSIS Assessment
01		0.047	NR*	24		0.042	NR	47		0.060	NR	70		0.048	NR
02		0.045	NR	25		0.055	NR	48		0.044	NR	71		0.048	NR
03		0.038	NR	26		0.044	NR	49		0.049	NR	72		0.042	NR
04		0.049	NR	27		0.065	NR	50		0.039	NR	73		0.050	NR
05		0.048	NR	28		0.049	NR	51		0.056	NR	74		0.056	NR
06		0.061	NR	29		0.044	NR	52		0.056	NR	75		0.042	NR
07		0.047	NR	30		0.049	NR	53		0.051	NR	76		0.049	NR
08		0.057	NR	31		0.045	NR	54		0.048	NR	77		0.053	NR
09		0.047	NR	32		0.044	NR	55		0.048	NR	78		0.043	NR
10		0.046	NR	33		0.046	NR	56		0.061	NR	79		0.033	NR
11		0.048	NR	34		0.048	NR	57		0.047	NR	80		0.041	NR
12		0.048	NR	35		0.042	NR	58		0.041	NR	81		0.049	NR
13		0.038	NR	36		0.057	NR	59		0.047	NR	82		0.049	NR
14		0.039	NR	37		0.045	NR	60	Kernel	0.067	NR	83		0.046	NR
15		0.048	NR	38		0.040	NR	61		0.053	NR	84		0.052	NR
16		0.046	NR	39		0.043	NR	62		0.039	NR	85		0.045	NR
17		0.044	NR	40		0.051	NR	63		0.045	NR	86		0.064	NR
18		0.053	NR	41		0.048	NR	64		0.046	NR	87		0.044	NR
19	Kernel	0.068	NR	42		0.050	NR	65		0.042	NR	88		0.040	NR
20		0.050	NR	43	Kernel	0.067	NR	66		0.059	NR	89		0.050	NR
21		0.049	NR	44		0.038	NR	67		0.044	NR	90		0.045	NR
22		0.037	NR	45		0.056	NR	68		0.067	NR	91		0.047	NR
23		0.046	NR	46		0.038	NR	69		0.052	NR	92		0.050	NR

* Not Recommended

Appendix 23: ELECTRE I kernel structure



The figure below is zoomed in version of Fuzzy ELECTE I Kernel structure of candidate 19.



Appendix 24: Different rates of slope and different values of difference between above-below values

CRITERIA NAME	SLOPE RATE	DIFFERENCE BETWEEN ABOVE-BELOW VALUE	MAX/ MIN
AGE	1	0	MAX
MARITAL STATUS	1	0	MAX
DISTANCE TO BRANCH	1	0	MIN
DRIVER LICENCE	1	0	MAX
ENGLISH LEVEL	1	0	MAX
SECOND FOREIGN LANGUAGE SEVİYESİ	1	0	MAX
EDUCATIONAL STATUS	1	0	MAX
EXPERIENCE / OTHER SECTOR (YEAR)	1	0	MAX
EXPERIENCE / IN SECTOR (YEAR)	1	0	MAX
REFERENCE STATUS	1	0	MAX
PRESENTATION ABILITY	1	0	MAX

CRITERIA NAME	SLOPE RATE	DIFFERENCE BETWEEN ABOVE-BELOW VALUE	MAX/ MIN
AGE	0.5	20	MAX
MARITAL STATUS	0.8	10	MAX
DISTANCE TO BRANCH	4	30	MIN
DRIVER LICENCE	1	0	MAX
ENGLISH LEVEL	0.4	20	MAX
SECOND FOREIGN LANGUAGE SEVİYESİ	0.8	20	MAX
EDUCATIONAL STATUS	0.7	10	MAX
EXPERIENCE / OTHER SECTOR (YEAR)	0.75	20	MAX
EXPERIENCE / IN SECTOR (YEAR)	0.75	20	MAX
REFERENCE STATUS	0.5	30	MAX
PRESENTATION ABILITY	0.4	40	MAX

The result of statements above is located below.

Candidate	ELECTRE I Kernel	TOPSIS	TOPSIS Assessment
01		0.052	NR*
02		0.051	NR
03		0.042	NR
04		0.054	NR
05		0.054	NR
06		0.069	NR
07		0.051	NR
08		0.064	NR
09		0.053	NR
10		0.052	NR
11		0.053	NR
12		0.054	NR
13		0.043	NR
14		0.043	NR
15		0.054	NR
16		0.051	NR
17		0.049	NR
18		0.059	NR
19	KERNEL	0.077	NR
20		0.056	NR
21		0.055	NR
22		0.040	NR
23		0.051	NR
24		0.047	NR
25		0.062	NR
26		0.049	NR
27		0.074	NR
28		0.055	NR

Candidate	ELECTRE I Kernel	TOPSIS	TOPSIS Assessment
01		0.047	NR
02		0.045	NR
03		0.038	NR
04		0.049	NR
05		0.048	NR
06		0.061	NR
07		0.047	NR
08		0.057	NR
09		0.047	NR
10		0.046	NR
11		0.048	NR
12		0.048	NR
13		0.038	NR
14		0.039	NR
15		0.048	NR
16		0.046	NR
17		0.044	NR
18		0.053	NR
19	KERNEL	0.068	NR
20		0.050	NR
21		0.049	NR
22		0.037	NR
23		0.046	NR
24		0.042	NR
25		0.055	NR
26		0.044	NR
27		0.065	NR
28		0.049	NR

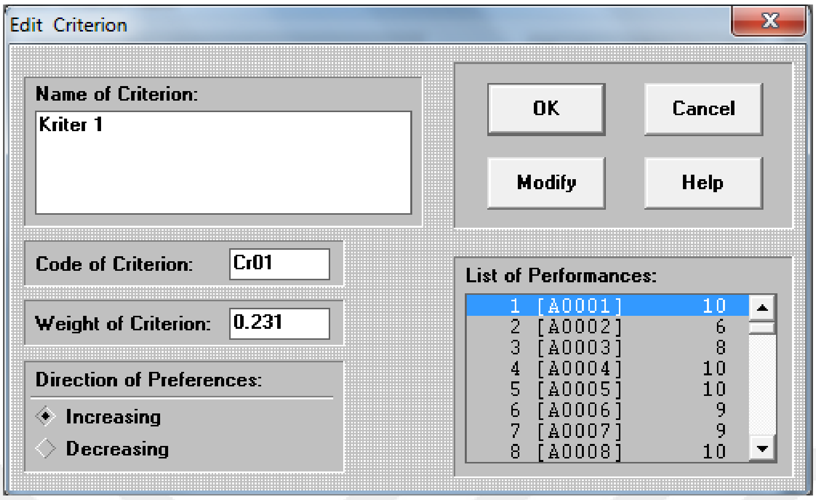
29		0.049	NR		29		0.044	NR
30		0.055	NR		30		0.049	NR
31		0.050	NR		31		0.045	NR
32		0.049	NR		32		0.044	NR
33		0.052	NR		33		0.046	NR
34		0.053	NR		34		0.048	NR
35		0.047	NR		35		0.042	NR
36		0.064	NR		36		0.057	NR
37		0.051	NR		37		0.045	NR
38		0.044	NR		38		0.040	NR
39		0.048	NR		39		0.043	NR
40		0.057	NR		40		0.051	NR
41		0.053	NR		41		0.048	NR
42		0.057	NR		42		0.050	NR
43	KERNEL	0.076	NR		43	KERNEL	0.067	NR
44		0.042	NR		44		0.038	NR
45		0.063	NR		45		0.056	NR
46		0.042	NR		46		0.038	NR
47		0.068	NR		47		0.060	NR
48		0.048	NR		48		0.044	NR
49		0.055	NR		49		0.049	NR
50		0.044	NR		50		0.039	NR
51		0.063	NR		51		0.056	NR
52		0.062	NR		52		0.056	NR
53		0.058	NR		53		0.051	NR
54		0.054	NR		54		0.048	NR
55		0.053	NR		55		0.048	NR
56		0.069	NR		56		0.061	NR
57		0.053	NR		57		0.047	NR
58		0.045	NR		58		0.041	NR
59		0.053	NR		59		0.047	NR
60	KERNEL	0.076	NR		60	KERNEL	0.067	NR
61		0.059	NR		61		0.053	NR

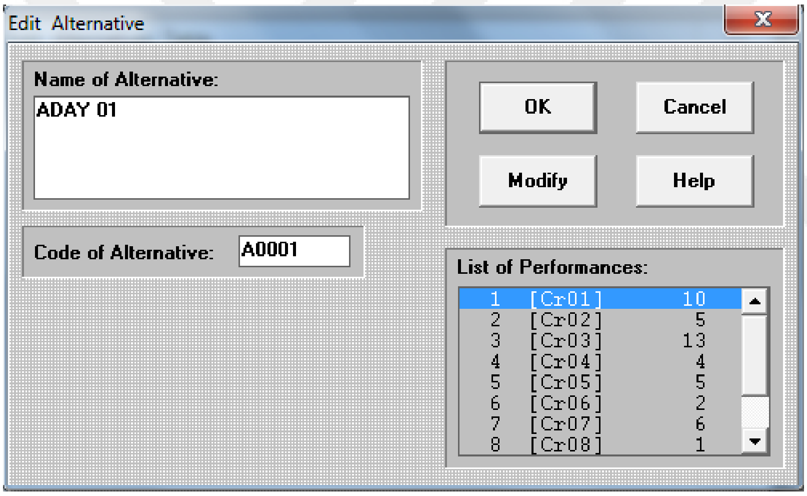
62		0.044	NR
63		0.050	NR
64		0.051	NR
65		0.047	NR
66		0.066	NR
67		0.049	NR
68		0.077	NR
69		0.057	NR
70		0.054	NR
71		0.053	NR
72		0.047	NR
73		0.056	NR
74		0.063	NR
75		0.046	NR
76		0.055	NR
77		0.059	NR
78		0.048	NR
79		0.037	NR
80		0.047	NR
81		0.055	NR
82		0.055	NR
83		0.051	NR
84		0.059	NR
85		0.050	NR
86		0.073	NR
87		0.050	NR
88		0.045	NR
89		0.055	NR
90		0.049	NR
91		0.052	NR
92		0.056	NR

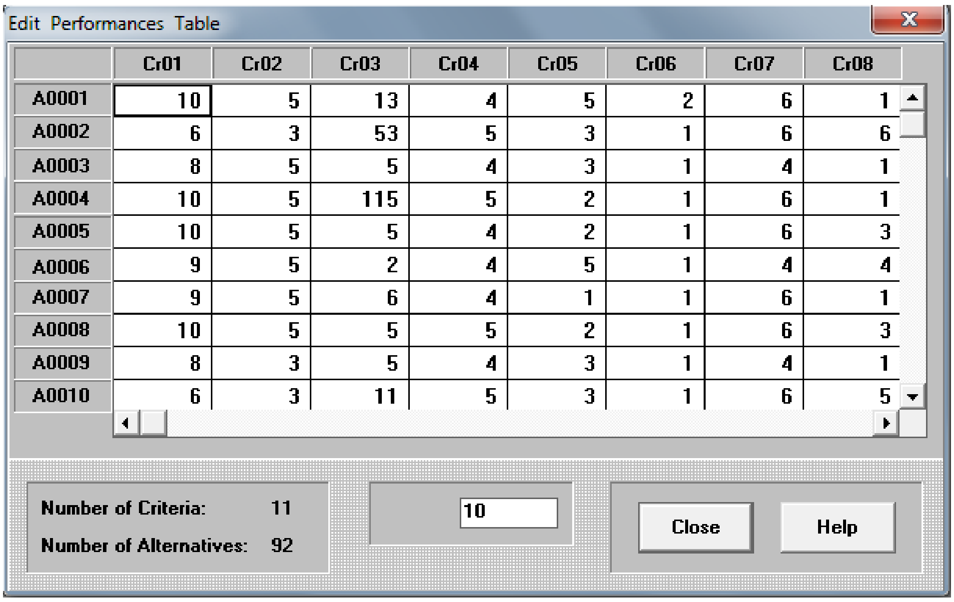
62		0.039	NR
63		0.045	NR
64		0.046	NR
65		0.042	NR
66		0.059	NR
67		0.044	NR
68		0.067	NR
69		0.052	NR
70		0.048	NR
71		0.048	NR
72		0.042	NR
73		0.050	NR
74		0.056	NR
75		0.042	NR
76		0.049	NR
77		0.053	NR
78		0.043	NR
79		0.033	NR
80		0.041	NR
81		0.049	NR
82		0.049	NR
83		0.046	NR
84		0.052	NR
85		0.045	NR
86		0.064	NR
87		0.044	NR
88		0.040	NR
89		0.050	NR
90		0.045	NR
91		0.047	NR
92		0.050	NR

*Not Recommended

Appendix 25: Application with LAMSADE

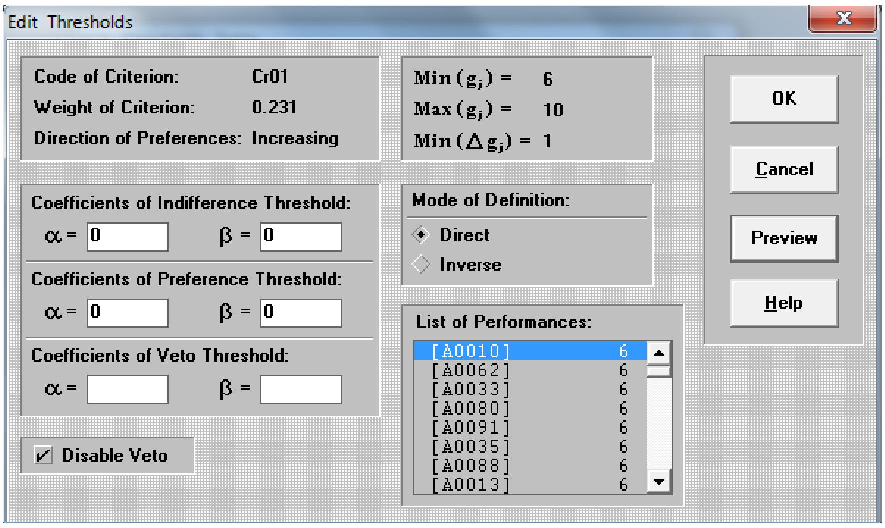


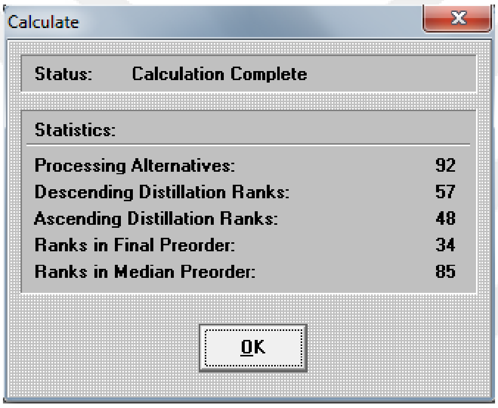


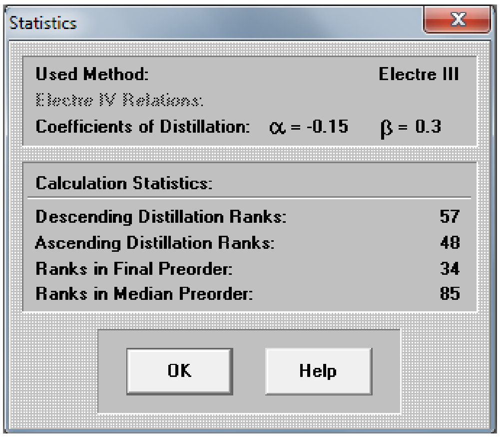

Edit Performances Table

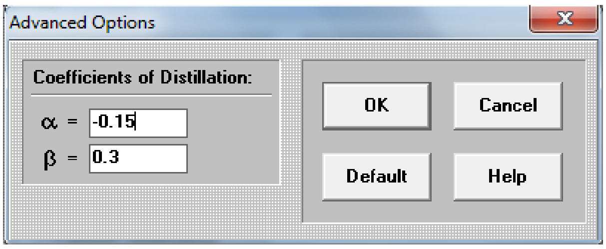
	Cr01	Cr02	Cr03	Cr04	Cr05	Cr06	Cr07	Cr08
A0001	10	5	13	4	5	2	6	1
A0002	6	3	53	5	3	1	6	6
A0003	8	5	5	4	3	1	4	1
A0004	10	5	115	5	2	1	6	1
A0005	10	5	5	4	2	1	6	3
A0006	9	5	2	4	5	1	4	4
A0007	9	5	6	4	1	1	6	1
A0008	10	5	5	5	2	1	6	3
A0009	8	3	5	4	3	1	4	1
A0010	6	3	11	5	3	1	6	5

Number of Criteria: 11
Number of Alternatives: 92
10
Close
Help


Edit Thresholds
Code of Criterion: Cr01
Weight of Criterion: 0.231
Direction of Preferences: Increasing
Min (g_i) = 6
Max (g_i) = 10
Min (Δg_i) = 1
OK
Cancel
Preview
Help
Coefficients of Indifference Threshold:
α = 0 β = 0
Coefficients of Preference Threshold:
α = 0 β = 0
Coefficients of Veto Threshold:
α = β =
Disable Veto
Mode of Definition:
Direct
Inverse
List of Performances:
[A0010] 6
[A0062] 6
[A0033] 6
[A0080] 6
[A0091] 6
[A0035] 6
[A0088] 6
[A0013] 6


Calculate
Status: Calculation Complete
Statistics:
Processing Alternatives: 92
Descending Distillation Ranks: 57
Ascending Distillation Ranks: 48
Ranks in Final Preorder: 34
Ranks in Median Preorder: 85
OK


Statistics
Used Method: Electre III
Electre IV Relations:
Coefficients of Distillation: α = -0.15 β = 0.3
Calculation Statistics:
Descending Distillation Ranks: 57
Ascending Distillation Ranks: 48
Ranks in Final Preorder: 34
Ranks in Median Preorder: 85
OK
Help


Advanced Options
Coefficients of Distillation:
α = -0.15
β = 0.3
OK
Cancel
Default
Help

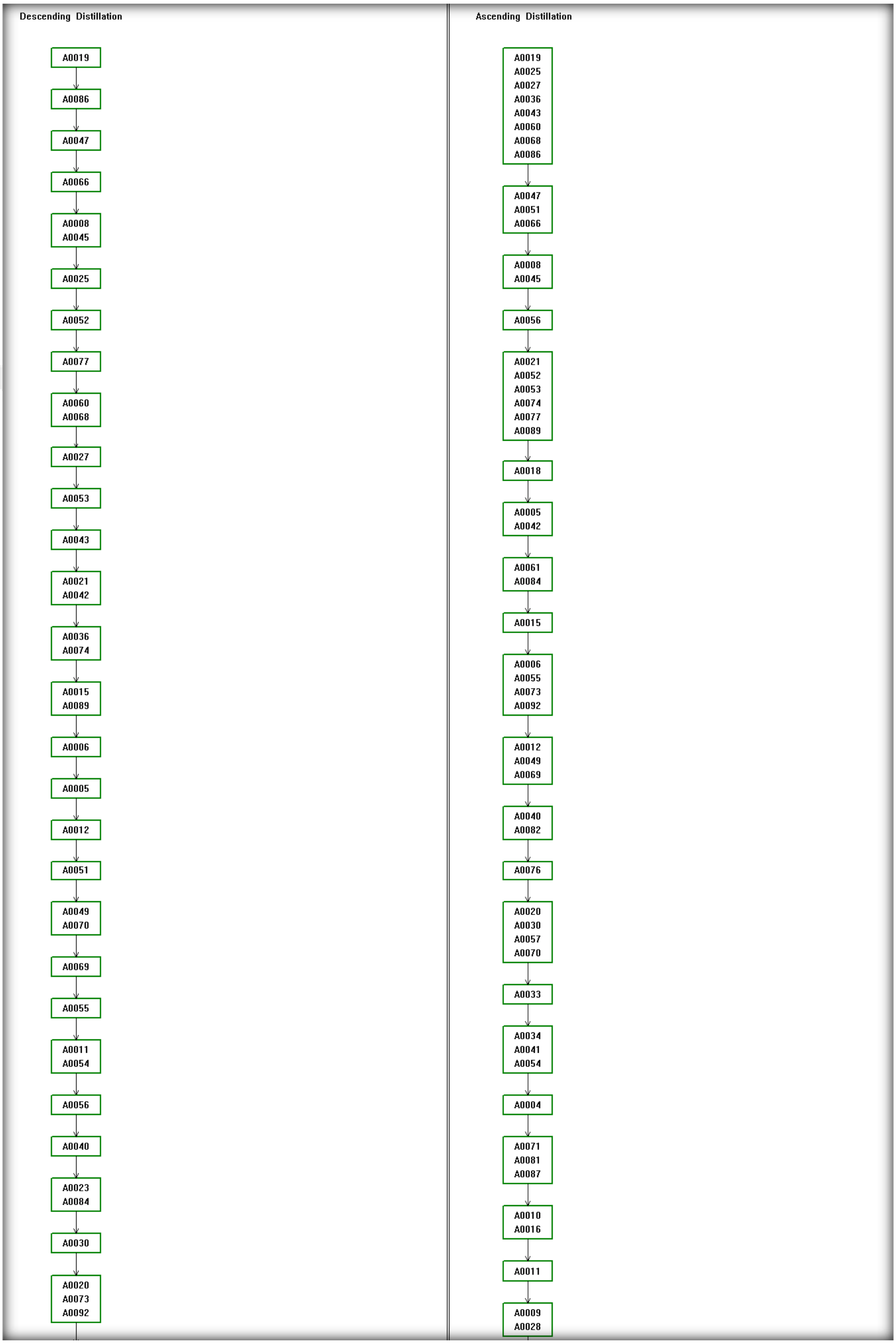
Credibility Matrix

	A0001	A0002	A0003	A0004	A0005	A0006	A0007	A0008	A0009	A0010	A0011	A0012	A0013	A0014	A0015	A0016	A0017	A0018	A0019	A0020	A0021	A0022	A0023	A0024
A0001	1	0.67	0.84	0.75	0.76	0.54	0.73	0.63	0.73	0.51	0.74	0.84	0.62	0.84	0.82	0.77	0.9	0.4	0.4	0.51	0.74	0.84	0.84	0.84
A0002	0.49	1	0.57	0.72	0.57	0.54	0.42	0.42	0.5	0.84	0.55	0.57	0.8	0.57	0.57	0.61	0.72	0.68	0.45	0.57	0.57	0.57	0.54	0.57
A0003	0.42	0.62	1	0.47	0.41	0.28	0.57	0.24	0.66	0.62	0.37	0.49	0.77	0.77	0.47	0.49	0.39	0.51	0.12	0.67	0.39	0.77	0.47	0.77
A0004	0.77	0.74	0.82	1	0.76	0.74	0.69	0.61	0.71	0.74	0.72	0.82	0.82	0.84	0.82	0.84	0.74	0.63	0.63	0.76	0.74	0.82	0.82	0.84
A0005	0.93	0.62	0.95	0.72	1	0.48	0.85	0.83	0.83	0.62	0.94	0.95	0.75	0.97	0.92	0.77	0.92	0.5	0.46	0.64	0.96	0.95	0.95	0.97
A0006	0.67	0.85	1	0.7	0.72	1	0.8	0.55	0.89	0.85	0.91	0.72	1	1	0.7	0.72	0.93	0.81	0.58	0.9	0.7	1	0.72	1
A0007	0.5	0.65	0.82	0.5	0.28	0.51	1	0.26	0.59	0.65	0.47	0.36	0.75	0.82	0.34	0.52	0.65	0.65	0.26	0.67	0.26	0.98	0.52	0.62
A0008	0.96	0.67	0.98	0.77	1	0.51	1	1	0.98	0.67	0.96	0.98	0.75	1	0.98	0.77	0.98	0.67	0.59	0.69	0.98	0.98	0.98	1
A0009	0.6	0.62	0.96	0.42	0.59	0.24	0.64	0.54	1	0.62	0.55	0.67	0.73	0.72	0.65	0.49	0.57	0.58	0.19	0.63	0.57	0.72	0.65	0.96
A0010	0.65	0.92	0.57	0.72	0.57	0.54	0.42	0.42	0.5	1	0.55	0.57	0.96	0.57	0.57	0.77	0.72	0.84	0.45	0.49	0.57	0.72	0.7	0.57
A0011	0.71	0.66	0.97	0.51	0.77	0.48	0.85	0.62	0.85	0.66	1	0.74	0.77	0.97	0.74	0.54	0.97	0.55	0.27	0.66	0.77	0.97	0.71	0.97
A0012	0.93	0.67	1	0.75	0.92	0.51	0.85	0.75	0.89	0.67	0.88	1	0.77	1	0.98	0.77	0.9	0.56	0.4	0.67	0.9	1	0.98	1
A0013	0.65	0.81	0.53	0.66	0.48	0.42	0.41	0.31	0.41	0.81	0.44	0.53	1	0.53	0.5	0.72	0.58	0.7	0.34	0.47	0.46	0.68	0.66	0.53
A0014	0.42	0.6	0.98	0.47	0.41	0.51	0.8	0.24	0.64	0.6	0.58	0.47	0.75	1	0.45	0.49	0.6	0.49	0.097	0.67	0.37	0.98	0.47	0.77
A0015	0.93	0.69	1	0.77	0.92	0.51	0.85	0.77	0.89	0.69	0.9	1	0.77	1	1	0.77	0.92	0.58	0.42	0.69	0.92	1	0.98	1
A0016	0.72	0.84	0.74	0.9	0.72	0.66	0.65	0.55	0.67	0.68	0.65	0.74	0.78	0.76	0.72	1	0.8	0.53	0.56	0.66	0.67	0.74	0.74	0.76
A0017	0.54	0.54	0.84	0.54	0.61	0.51	0.69	0.46	0.73	0.54	0.82	0.61	0.62	0.84	0.61	0.38	1	0.42	0.27	0.54	0.61	0.84	0.59	0.84
A0018	0.7	0.92	0.61	0.77	0.61	0.59	0.58	0.58	0.61	0.92	0.59	0.61	1	0.61	0.61	0.77	0.77	1	0.61	0.53	0.61	0.77	0.75	0.61
A0019	0.93	0.89	0.97	0.97	1	0.87	0.97	0.97	0.97	0.89	0.98	0.97	1	0.97	0.97	1	0.97	0.89	1	0.89	1	0.97	0.95	0.97
A0020	0.65	0.93	0.77	0.7	0.54	0.54	0.57	0.39	0.66	0.93	0.52	0.54	0.98	0.54	0.54	0.7	0.7	0.82	0.43	1	0.54	0.7	0.7	0.79
A0021	0.93	0.66	0.97	0.74	1	0.48	0.85	0.85	0.85	0.66	0.98	0.97	0.77	0.97	0.97	0.77	0.97	0.55	0.5	0.66	1	0.97	0.95	0.97
A0022	0.42	0.62	0.84	0.47	0.25	0.51	0.64	0.084	0.5	0.46	0.44	0.33	0.62	0.84	0.31	0.49	0.62	0.35	0.12	0.51	0.23	1	0.31	0.62
A0023	0.95	0.67	0.84	0.75	0.76	0.54	0.69	0.59	0.73	0.67	0.72	0.84	0.77	0.84	0.82	0.77	0.9	0.56	0.4	0.51	0.74	1	1	0.84
A0024	0.65	0.6	0.98	0.45	0.62	0.28	0.57	0.45	0.87	0.6	0.58	0.7	0.75	0.75	0.67	0.47	0.59	0.49	0.097	0.67	0.59	0.75	0.7	1
A0025	0.95	0.89	0.81	0.97	0.76	0.73	0.69	0.61	0.69	0.89	0.74	0.81	1	0.81	0.81	1	0.89	0.77	0.65	0.73	0.76	0.97	0.97	0.81
A0026																								

Ranking Matrix

	A0001	A0002	A0003	A0004	A0005	A0006	A0007	A0008	A0009	A0010	A0011	A0012	A0013	A0014	A0015	A0016	A0017	A0018	A0019	A0020	A0021	A0022	A0023	A0024
A0001	I	P	P	R	P^-	P^-	P	P^-	R	R	P^-	P^-	P	P	P^-	R	P	R	P^-	P^-	P^-	P	P^-	P
A0002	P^-	I	R	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	R	P^-	P^-	P^-	R	P^-	P^-	P^-	P^-	R	P^-	P^-
A0003	P^-	R	I	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	R	P^-	P^-	P^-	R	P^-	P^-	P^-	P^-	R	P^-	P^-
A0004	R	P	P	I	P^-	P^-	R	P^-	R	R	R	P^-	P	R	P^-	R	P	P^-	P^-	P^-	P^-	R	R	R
A0005	P	P	P	P	I	R	P	P^-	P	P	P	P	P	P	R	P	P	R	P^-	P	P^-	P	P	P
A0006	P	P	P	P	R	I	P	P^-	P	P	P	P	P	P	P^-	P	P	R	P^-	P	P^-	P	P	P
A0007	P^-	P	P	R	P^-	P^-	I	P^-	P^-	P^-	P^-	P^-	P	P^-	P^-	P^-	P	P^-	P^-	P^-	P^-	P	P^-	P^-
A0008	P	P	P	P	P	P	P	I	P	P	P	P	P	P	P	P	P	P	P^-	P	P	P	P	P
A0009	R	P	P	R	P^-	P^-	P	P^-	I	R	P^-	P^-	P	P	P^-	R	P	P^-	P^-	P^-	P^-	P	R	P
A0010	R	P	P	R	P^-	P^-	P	P^-	R	I	R	P^-	P	P	P^-	P	P	P^-	P^-	P^-	P^-	P	R	P
A0011	P	P	P	R	P^-	P^-	P	P^-	P	R	I	P^-	P	P	P^-	R	P	R	P^-	R	P^-	P	P	P
A0012	P	P	P	P	P^-	P^-	P	P^-	P	P	P	I	P	P	P^-	P	P	R	P^-	P	P^-	P	P	P
A0013	P^-	R	R	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	I	P^-	P^-	P^-	R	P^-	P^-	P^-	P^-	R	P^-	P^-
A0014	P^-	P	P	R	P^-	P^-	P	P^-	P^-	P^-	P^-	P^-	P	I	P^-	P^-	P	P^-	P^-	P^-	P^-	P	P^-	P^-
A0015	P	P	P	P	R	P	P	P^-	P	P	P	P	P	P	I	P	P	R	P^-	P	P^-	P	P	P
A0016	R	P	P	R	P^-	P^-	P	P^-	R	P^-	R	P^-	P	P	P^-	I	P	P^-	P^-	P^-	P^-	P	R	R
A0017	P^-	R	R	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	R	P^-	P^-	P^-	I	P^-	P^-	P^-	P^-	P^-	P^-	P^-
A0018	R	P	P	P	R	R	P	P^-	P	P	R	R	P	P	R	P	P	I	P^-	R	P^-	P	R	P
A0019	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	I	P	P	P	P	P
A0020	P	P	P	P	P^-	P^-	P	P^-	P	P	R	P^-	P	P	P^-	P	P	R	P^-	I	P^-	P	R	P
A0021	P	P	P	P	P	P	P	P^-	P	P	P	P	P	P	P	P	P	P	P^-	P	I	P	P	P
A0022	P^-	R	R	R	P^-	P^-	P^-	P^-	P^-	P^-	P^-	P^-	R	P^-	P^-	P^-	P	P^-	P^-	P^-	P^-	I	P^-	P^-
A0023	P	P	P	R	P^-	P^-	P	P^-	R	R	P^-	P^-	P	P	P^-	R	P	R	P^-	R	P^-	P	I	P
A0024	P^-	P	P	R	P^-	P^-	P	P^-	P^-	P^-	P^-	P^-	P	P	P^-	R	P	P^-	P^-	P^-	P^-	P	P^-	I
A0025	P	P	P	P	P	P	P	R	P	P	P	P	P	P	P	P	P	P	P^-	P	P	P	P	P
A0026																								

Distillations



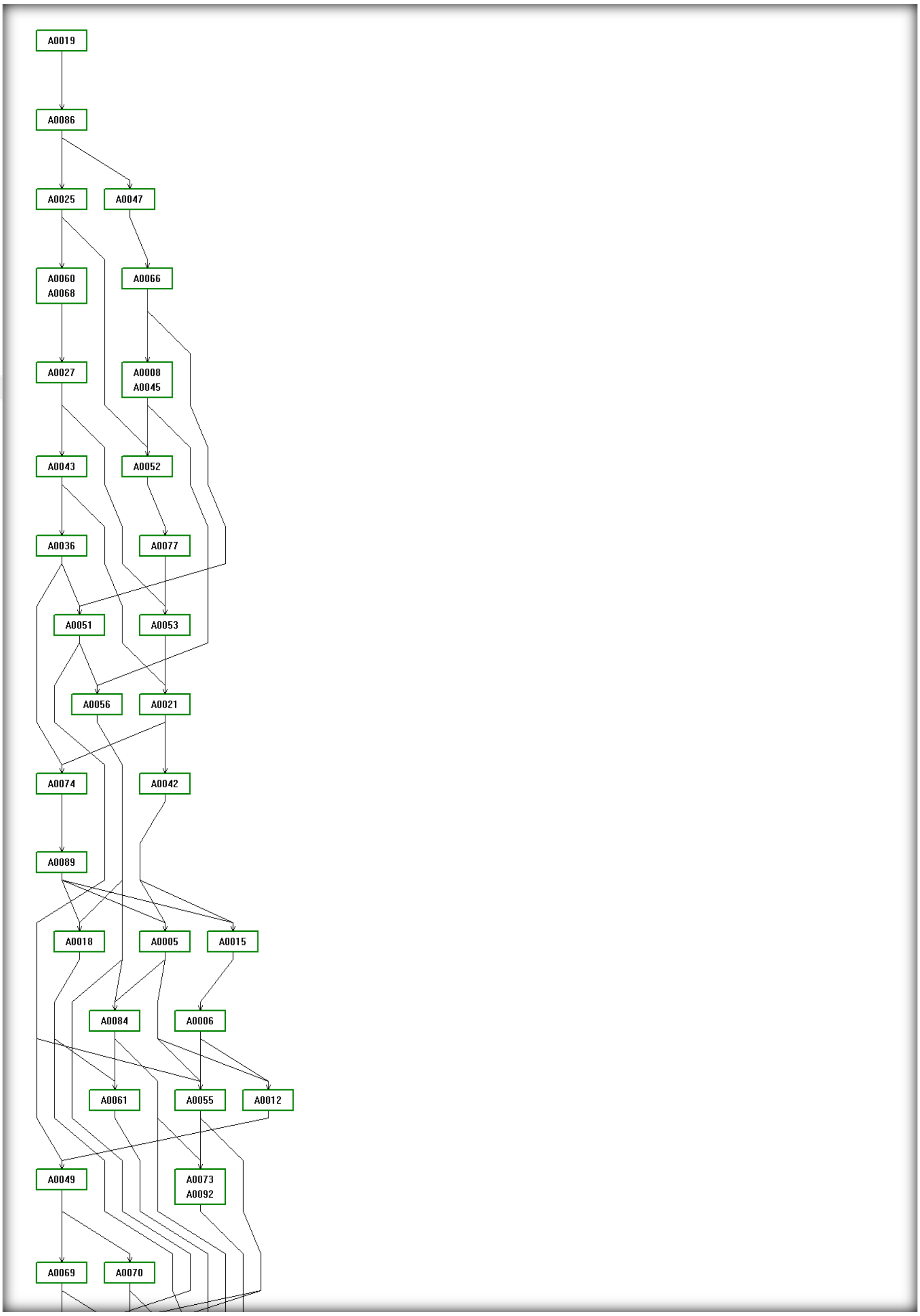
Ranks in Final Preorder

Rank	Alternative
1	A0019
2	A0086
3	A0025 A0047
4	A0060 A0066 A0068
5	A0008 A0027 A0045
6	A0043 A0052
7	A0036 A0077
8	A0051 A0053
9	A0021 A0056
10	A0042 A0074
11	A0089
12	A0005 A0015 A0018
13	A0006 A0084
14	A0012 A0055 A0061
15	A0049 A0073 A0092
16	A0069 A0070
17	A0040 A0054
18	A0011 A0030 A0076 A0082
19	A0020 A0023
20	A0034 A0041 A0057

Median Preorder

Rank	Alternative
1	A0019
2	A0086
3	A0025 A0047
4	A0066
5	A0060 A0068
6	A0008 A0045
7	A0027
8	A0052
9	A0043
10	A0077
11	A0036
12	A0053
13	A0051
14	A0021
15	A0056
16	A0074
17	A0042
18	A0089
19	A0005
20	A0015
21	A0018
22	A0006
23	A0084
24	A0055
25	A0012
26	A0061
27	A0049
28	A0073 A0092
29	A0069
30	A0070
31	A0040
32	A0054
33	A0030
34	A0076
35	A0011
36	A0082
37	A0020
38	A0023
39	A0034 A0041

Final Graph


A0019
A0086
A0025
A0047
A0060
A0068
A0066
A0027
A0008
A0045
A0043
A0052
A0036
A0077
A0051
A0053
A0056
A0021
A0074
A0042
A0089
A0018
A0005
A0015
A0084
A0006
A0061
A0055
A0012
A0049
A0073
A0092
A0069
A0070

Appendix 26: Implementation with DECISION LAB

Stability Intervals

Stability Level: 92 first actions ☑ AutoLevel

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
Criterion1	0.2310	0.2307	0.2318	23.08%	23.06%	23.14%
Criterion2	0.0450	0.0449	0.0453	4.50%	4.49%	4.52%
Criterion3	0.1590	0.1588	0.1592	15.88%	15.87%	15.90%
Criterion4	0.0230	0.0227	0.0232	2.30%	2.27%	2.32%
Criterion5	0.0210	0.0207	0.0213	2.10%	2.07%	2.13%
Criterion6	0.0180	0.0162	0.0190	1.80%	1.62%	1.89%
Criterion7	0.0510	0.0506	0.0512	5.09%	5.06%	5.11%
Criterion8	0.0800	0.0793	0.0801	7.99%	7.92%	8.00%
Criterion9	0.1130	0.1129	0.1133	11.29%	11.28%	11.32%
Criterion10	0.0340	0.0337	0.0343	3.40%	3.36%	3.43%
Criterion11	0.2260	0.2255	0.2261	22.58%	22.54%	22.59%

Properties

Criterion | Action | Category

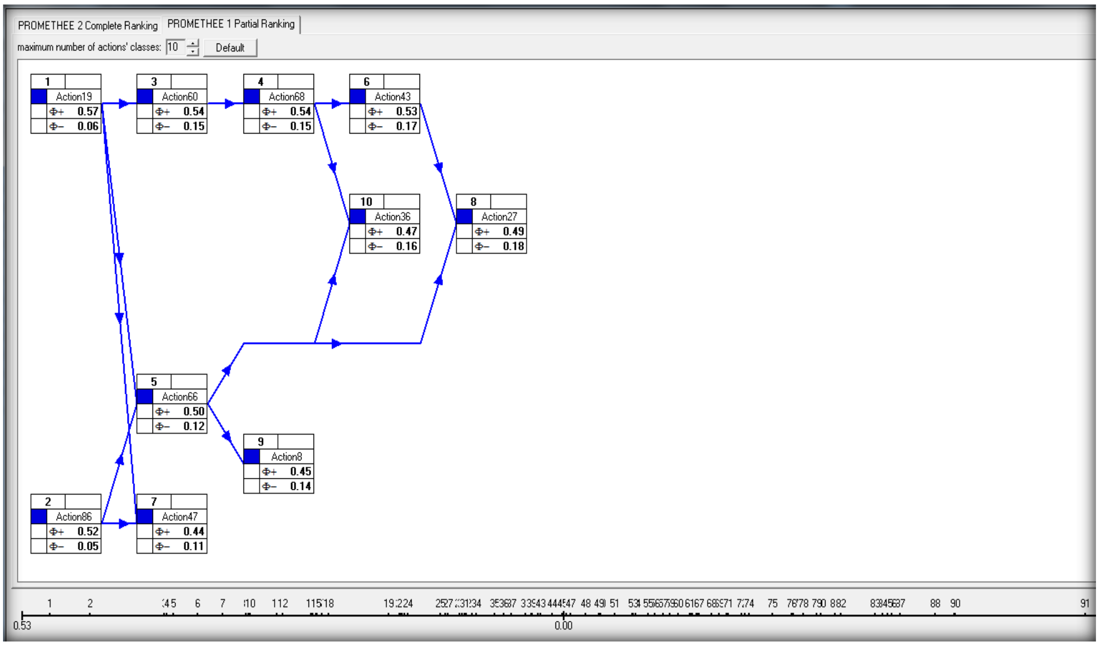
Item	Criterion1
Name	Criterion1
Short Name	Cri.
Description	
Enabled	True
Unit	
Decimals	3
Category	(None)
Threshold Unit	Absolute
Min/Max	Maximize
Absolute Weight	0.231
Preference Func	Usual
Scale	(Numerical)
Indiference Thres	-
Preference Thres	-
Gaussian Thresh	-

	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7	Criterion8	Criterion9	Criterion10	Criterion11
Unit											
Action1	10.000	5.000	13.000	4.000	5.000	2.000	6.000	1.000	1.000	6.000	4.000
Action2	6.000	3.000	53.000	5.000	3.000	1.000	6.000	6.000	1.000	4.000	7.000
Action3	8.000	5.000	5.000	4.000	3.000	1.000	4.000	1.000	1.000	4.000	1.000
Action4	10.000	5.000	115.000	5.000	2.000	1.000	6.000	1.000	1.000	4.000	7.000
Action5	10.000	5.000	5.000	4.000	2.000	1.000	6.000	3.000	1.000	1.000	4.000
Action6	9.000	5.000	2.000	4.000	5.000	1.000	4.000	4.000	1.000	4.000	7.000
Action7	9.000	5.000	6.000	4.000	1.000	1.000	6.000	1.000	3.000	6.000	1.000
Action8	10.000	5.000	5.000	5.000	2.000	1.000	6.000	3.000	3.000	6.000	4.000
Action9	8.000	3.000	5.000	4.000	3.000	1.000	4.000	1.000	3.000	4.000	4.000
Action10	6.000	3.000	11.000	5.000	3.000	1.000	6.000	5.000	1.000	4.000	7.000
Action11	9.000	5.000	5.000	5.000	3.000	2.000	6.000	3.000	1.000	1.000	4.000
Action12	10.000	5.000	5.000	4.000	3.000	1.000	6.000	1.000	1.000	4.000	4.000
Action13	6.000	5.000	11.000	4.000	3.000	1.000	1.000	1.000	1.000	1.000	7.000
Action14	9.000	5.000	5.000	4.000	2.000	1.000	4.000	1.000	1.000	4.000	1.000
Action15	10.000	5.000	5.000	5.000	3.000	1.000	6.000	1.000	1.000	4.000	4.000
Action16	10.000	3.000	31.000	4.000	2.000	1.000	6.000	1.000	1.000	1.000	7.000
Action17	9.000	5.000	59.000	5.000	3.000	1.000	6.000	3.000	1.000	4.000	4.000
Action18	6.000	5.000	11.000	5.000	3.000	1.000	6.000	4.000	3.000	4.000	7.000
Action19	10.000	5.000	2.000	5.000	3.000	1.000	6.000	3.000	3.000	1.000	7.000
Action20	8.000	5.000	6.000	5.000	1.000	1.000	1.000	6.000	1.000	4.000	7.000
Action21	10.000	5.000	5.000	5.000	3.000	1.000	6.000	3.000	1.000	1.000	4.000
Action22	9.000	5.000	12.000	4.000	3.000	1.000	4.000	1.000	1.000	4.000	1.000
Action23	10.000	5.000	11.000	4.000	5.000	1.000	6.000	1.000	1.000	4.000	4.000
Action24	8.000	5.000	5.000	4.000	1.000	1.000	4.000	1.000	1.000	4.000	4.000
Action25	10.000	5.000	11.000	5.000	5.000	1.000	6.000	1.000	1.000	1.000	10.000
Action26	10.000	5.000	12.000	4.000	1.000	1.000	6.000	1.000	1.000	4.000	4.000

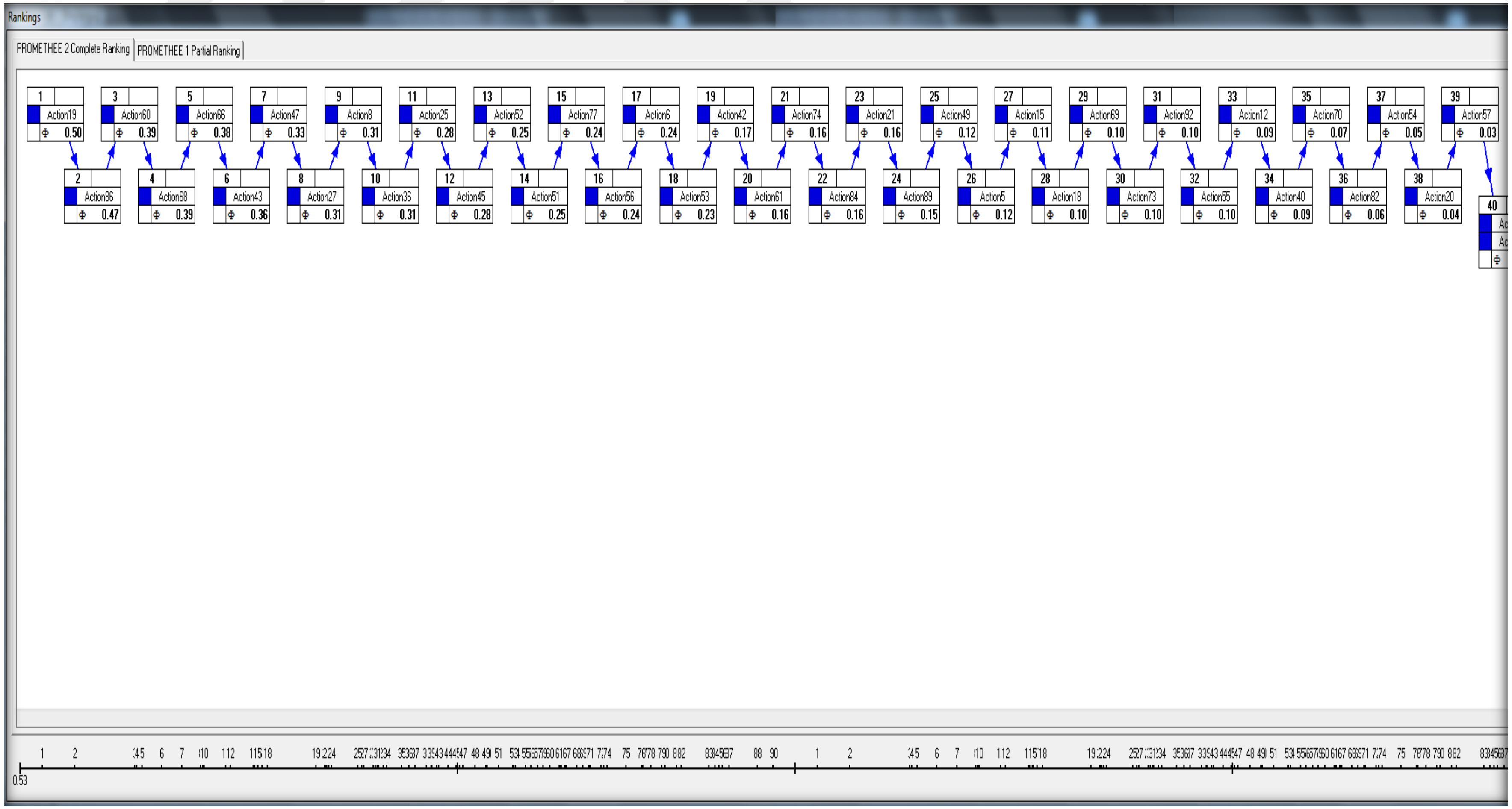
Preference Flows

Preference Flows

	Φ+	Φ−	Φ
Action1	0.2697	0.2721	-0.0024
Action2	0.2568	0.4341	-0.1773
Action3	0.1722	0.5019	-0.3297
Action4	0.2879	0.2621	0.0258
Action5	0.3171	0.2009	0.1162
Action6	0.4522	0.2148	0.2374
Action7	0.3119	0.4441	-0.1323
Action8	0.4522	0.1427	0.3095
Action9	0.2826	0.4146	-0.1320
Action10	0.3101	0.3600	-0.0499
Action11	0.3032	0.2916	0.0116
Action12	0.2874	0.1971	0.0903
Action13	0.2065	0.4411	-0.2346
Action14	0.2033	0.4691	-0.2658
Action15	0.2990	0.1854	0.1136
Action16	0.2800	0.3159	-0.0360
Action17	0.1838	0.4093	-0.2254
Action18	0.4068	0.3042	0.1026
Action19	0.5667	0.0626	0.5041
Action20	0.3623	0.3248	0.0375
Action21	0.3331	0.1764	0.1567
Action22	0.1536	0.5365	-0.3830
Action23	0.2514	0.2501	0.0013
Action24	0.1890	0.4125	-0.2235
Action25	0.4428	0.1609	0.2819
Action26	0.2278	0.2946	-0.0669
Action27	0.4925	0.1808	0.3117
Action28	0.3195	0.3900	-0.0705
Action29	0.1931	0.3053	-0.1121
Action30	0.3278	0.3023	0.0255
Action31	0.2179	0.3477	-0.1299



Promethee II Complete Rating

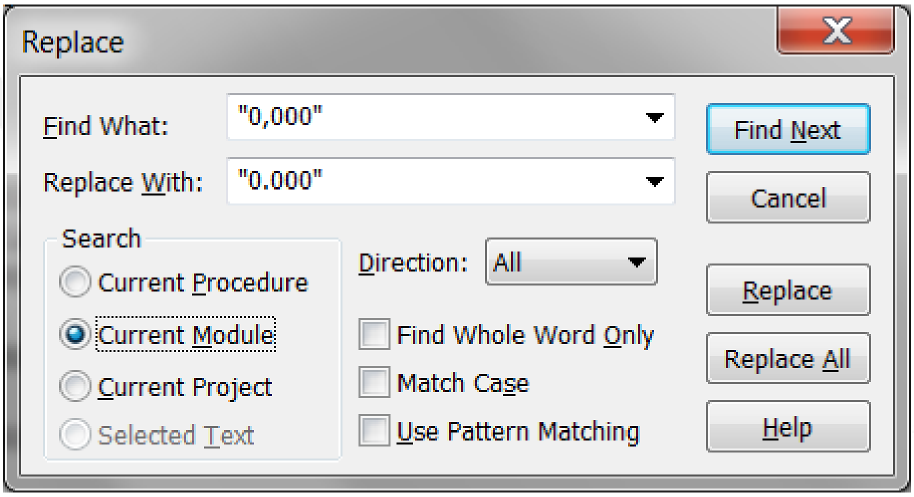


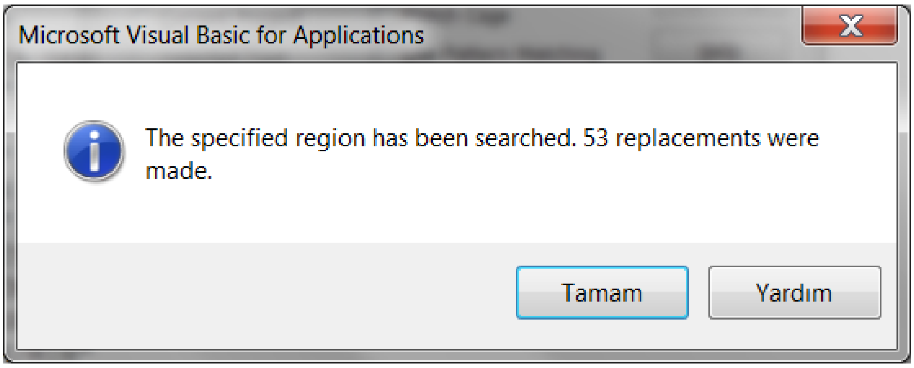
Appendix 27: Excel macro codes

In this study, Excel software is used for the calculations made in Fuzzy AHP, Fuzzy TOPSIS and Fuzzy ELECTRE I methods.

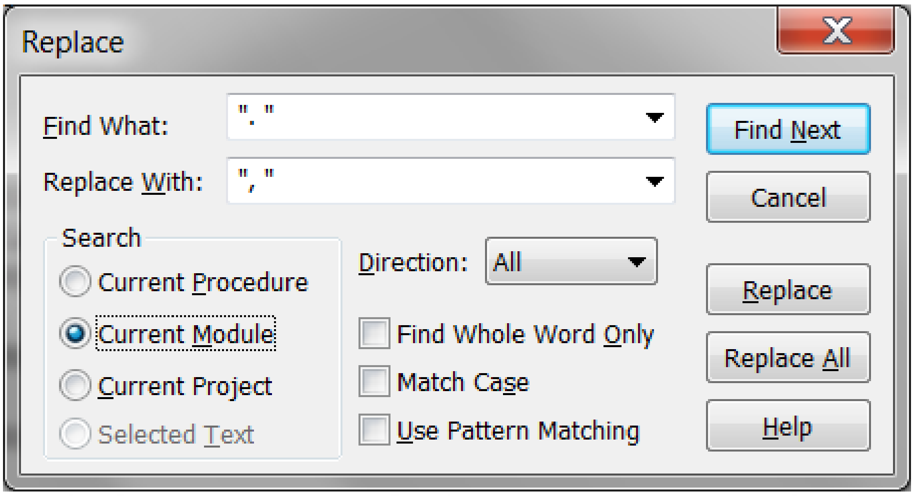
According to the difference of MS Office versions, the following five changes need to be made.

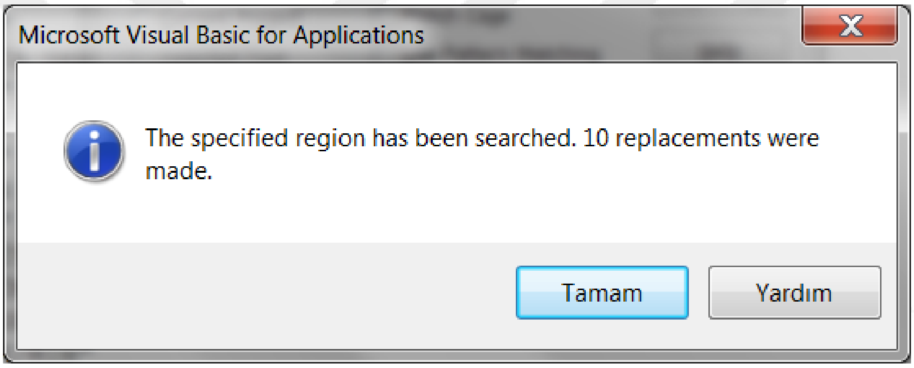
- Replace “0,000” with “0.000”



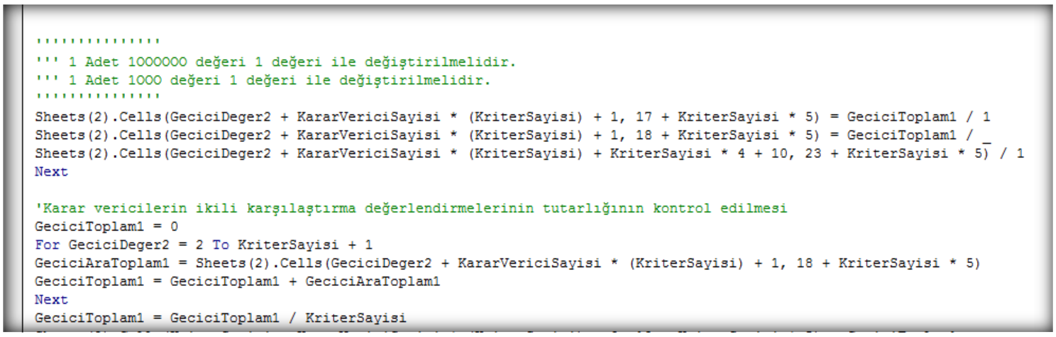


➢ Replace “.” with “,”



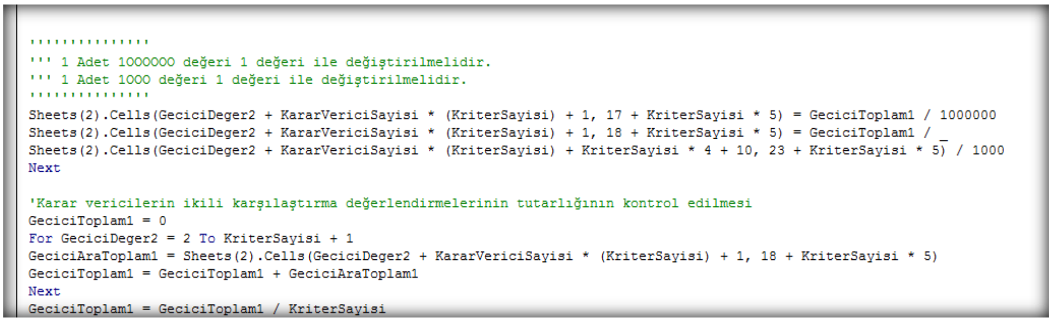


➢ Replace “1” with “1000000” and “1” with “1000”



```
'''''''''''''''
''' 1 Adet 1000000 değeri 1 değeri ile değiştirilmelidir.
''' 1 Adet 1000 değeri 1 değeri ile değiştirilmelidir.
'''''''''''''''
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 17 + KriterSayisi * 5) = GeciciToplam1 / 1
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 18 + KriterSayisi * 5) = GeciciToplam1 / _
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + KriterSayisi * 4 + 10, 23 + KriterSayisi * 5) / 1
Next

'Karar vericilerin ikili karşılaştırma değerlendirmelerinin tutarlığının kontrol edilmesi
GeciciToplam1 = 0
For GeciciDeger2 = 2 To KriterSayisi + 1
GeciciAraToplam1 = Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 18 + KriterSayisi * 5)
GeciciToplam1 = GeciciToplam1 + GeciciAraToplam1
Next
GeciciToplam1 = GeciciToplam1 / KriterSayisi
```



```
'''''''''''''''
''' 1 Adet 1000000 değeri 1 değeri ile değiştirilmelidir.
''' 1 Adet 1000 değeri 1 değeri ile değiştirilmelidir.
'''''''''''''''
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 17 + KriterSayisi * 5) = GeciciToplam1 / 1000000
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 18 + KriterSayisi * 5) = GeciciToplam1 / _
Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + KriterSayisi * 4 + 10, 23 + KriterSayisi * 5) / 1000
Next

'Karar vericilerin ikili karşılaştırma değerlendirmelerinin tutarlığının kontrol edilmesi
GeciciToplam1 = 0
For GeciciDeger2 = 2 To KriterSayisi + 1
GeciciAraToplam1 = Sheets(2).Cells(GeciciDeger2 + KararVericiSayisi * (KriterSayisi) + 1, 18 + KriterSayisi * 5)
GeciciToplam1 = GeciciToplam1 + GeciciAraToplam1
Next
GeciciToplam1 = GeciciToplam1 / KriterSayisi
```

➢ During the Fuzzy ELECTRE I solution studies, while naming Kernel structure shapes, sometimes there are some skipping according to difference of the Office versions.

```
Sheets(1).Cells(j, AlternatifSayisi + 4) = Sheets(1).Cells(j, 1)
Sheets(1).Cells(j, AlternatifSayisi + 5) = "Oval " & AdayNo2
Sheets(1).Cells(j, AlternatifSayisi + 6) = j - 1
'Bazı Office versiyonlarında Oval şekillerinin adlandırılması farklı olmaktadır.
'If AdayNo2 = 30 Then
'AdayNo2 = 1022
'End If
'If AdayNo2 = 1023 Then
'AdayNo2 = AdayNo2 + 1
'End If
AdayNo2 = AdayNo2 + 1
Next
iii = 1
For i = 2 To AlternatifSayisi + 1
For j = 2 To AlternatifSayisi + 1
```

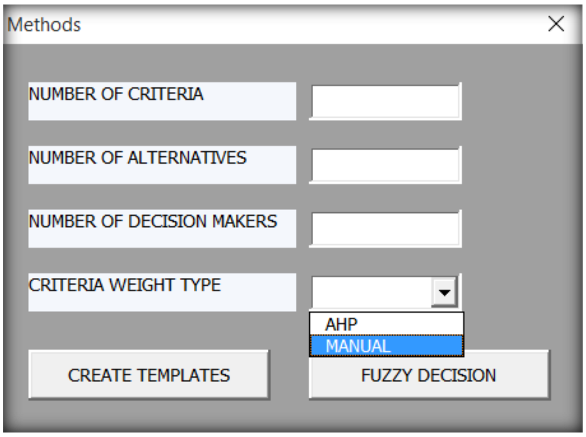
➢ If required, the following Fuzzy AHP values have to be changed in macro codes.

```
GeciciDeger1 = GeciciDeger1 + KriterSayisi - 1
End If
Next
Next

'Kriterlerin ikili karşılaştırmalarının bulanık sayılara dönüştürülmesi
For GeciciDeger1 = 2 To KararVericiSayisi + 1
For GeciciDeger2 = 2 To KriterSayisi + 1
For GeciciDeger3 = 2 To KriterSayisi + 1
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "-" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(1,000. 1,000. 1,000)"
End If
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "EÖ" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(1,000. 1,000. 1,000)"
Sheets(2).Cells(GeciciDeger3 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger2 + 11 + KriterSayisi) = "(1,000. 1,000. 1,000)"
End If
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "BÖ" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(2,000. 3,000. 4,000)"
Sheets(2).Cells(GeciciDeger3 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger2 + 11 + KriterSayisi) = "(0,250. 0,333. 0,500)"
End If
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "OÖ" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(4,000. 5,000. 6,000)"
Sheets(2).Cells(GeciciDeger3 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger2 + 11 + KriterSayisi) = "(0,167. 0,200. 0,250)"
End If
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "ÇÖ" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(6,000. 7,000. 8,000)"
Sheets(2).Cells(GeciciDeger3 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger2 + 11 + KriterSayisi) = "(0,125. 0,143. 0,167)"
End If
If Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 8) = "SÖ" Then
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 11 + KriterSayisi) = "(9,000. 9,000. 9,000)"
Sheets(2).Cells(GeciciDeger3 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger2 + 11 + KriterSayisi) = "(0,111. 0,111. 0,111)"
End If
Next
Next
Next

'Bulanık sayıların ayrıştırılması
For GeciciDeger1 = 2 To KararVericiSayisi + 1
For GeciciDeger2 = 2 To KriterSayisi + 1
For GeciciDeger3 = 2 To KriterSayisi + 1
Sheets(2).Cells(GeciciDeger2 + (GeciciDeger1 - 2) * (KriterSayisi), GeciciDeger3 + 12 + KriterSayisi * 2).Select
Selection.NumberFormat = "General"
```

Macro 1 Codes



“ThisWorkbook” Codes

```
Sub CommandButton2_Tıklat()
UserForm1.ComboBox1.List = Array("AHP", "MANUEL")
UserForm1.Show
End Sub
```

“UserForm1” Codes

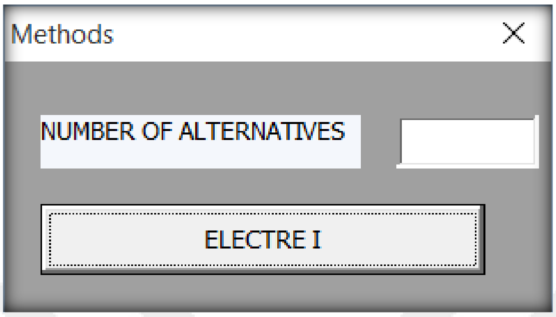
```
Private Sub CommandButton1_Click()
UserForm1.Hide
Dim KriterSayisi As Integer
Dim AlternatifSayisi As Integer
Dim KararVericiSayisi As Integer
KriterSayisi = TextBox1.Text
AlternatifSayisi = TextBox2.Text
KararVericiSayisi = TextBox3.Text

.
.
.
```

```
Sheets(1).Select
Sheets(1).Cells(1, 1).Select
Sheets(1).Cells(3, 3) = "TOPSİS"
Sheets(1).Cells(3, 2) = "ELECTRE KERNEL"
Sheets(1).Cells(3, 4) = "TOPSİS DEĞERLENDİRME"
For GeciciDeger1 = 2 To AlternatifSayisi + 1
Sheets(1).Cells(GeciciDeger1 + 2, 1) = Sheets(3).Cells(1, GeciciDeger1)
Sheets(1).Cells(GeciciDeger1 + 2, 2) = Sheets(3).Cells(KriterSayisi * 6 +
AlternatifSayisi * 5 + 31, GeciciDeger1)
If Sheets(1).Cells(GeciciDeger1 + 2, 2) <> 0 Then
Sheets(1).Cells(GeciciDeger1 + 2, 2) = ""
End If
If Sheets(1).Cells(GeciciDeger1 + 2, 2) = 0 Then
Sheets(1).Cells(GeciciDeger1 + 2, 2) = "KERNEL"
End If
Sheets(1).Cells(GeciciDeger1 + 2, 3) = Sheets(3).Cells(KriterSayisi * 6 + 17,
GeciciDeger1)
Sheets(1).Cells(GeciciDeger1 + 2, 4) = Sheets(3).Cells(KriterSayisi * 6 + 18,
GeciciDeger1)
Next
MsgBox "İşlem Tamam"
654566677
End Sub
```

Macro 2 Codes

Because of the “Procedure too large” warning, MACRO 2 Codes cannot add to MACRO 1 codes.



“ThisWorkbook” Codes

```
Sub CommandButton2_Tıklat()
UserForm1.Show
End Sub
```

“UserForm1” Kodları

```
Private Sub CommandButton2_Click()
UserForm1.Hide
Dim AlternatifSayisi As Integer
AlternatifSayisi = TextBox1.Text
Sheets(1).Select
Sheets(1).Cells(AlternatifSayisi + 3, 1) = "TOPLAM"
Sheets(1).Cells(AlternatifSayisi + 4, 1) = "ELECTRE KERNEL"
Sheets(1).Cells(AlternatifSayisi + 5, 1) = "AD UZUNLUK"
```

.

.

.

```
If Sheets(1).Cells(zzz, AlternatifSayisi + 13).Value <= AlternatifSayisi2 * 4 / 4
Then
Selection.ShapeRange.ConnectorFormat.EndConnect
ActiveSheet.Shapes(Sheets(1).Cells(zzz, AlternatifSayisi + 11).Value), 6
GoTo 555334557
End If
555334557
Selection.ShapeRange.ShapeStyle = msoLineStylePreset1
zzz = zzz + 1
Loop
Sheets(2).Cells(1, 1).Select
MsgBox "İşlem Tamam"
End Sub
```