MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

GREEN AND INNOVATIVE SUPPLIER SELECTION MODEL VIA MCDM TECHNIQUES AND A CASE STUDY IN AUTOMOTIVE INDUSTRY

ELİF ÇALOĞLU BÜYÜKSELÇUK

Ph. D. THESIS
Department of Engineering Management

Thesis Supervisor
Prof. Dr. Özalp VAYVAY

İSTANBUL, 2017

MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

GREEN AND INNOVATIVE SUPPLIER SELECTION MODEL VIA MCDM TECHNIQUES AND A CASE STUDY IN AUTOMOTIVE INDUSTRY

ELİF ÇALOĞLU BÜYÜKSELÇUK
(141202420060430)

Ph. D. THESIS
Department of Engineering Management

Thesis Supervisor
Prof. Dr. Özalp VAYVAY

İSTANBUL, 2017

MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

Elif ÇALOĞLU BÜYÜKSELÇUK, a Doctor of Philosophy student of Marmara University Institute for Graduate Studies in Pure and Applied Sciences, defended her thesis entitled "Green and innovative supplier selection model via MCDM techniques and a case study in automotive industry" on February 10, 2017 and has been found to be satisfactory by the jury members.

Jury Members

Prof. Dr. Özalp VAYVAY (Advisor)
Marmara University..(SIGN)..................

Assoc. Prof. Dr. Gülfem TUZKAYA (Jury Member)
Marmara University..(SIGN)..................

Assoc. Prof. Dr. Hakan TOZAN (Jury Member)
Medipol University...(SIGN)..................

Prof. Dr. Emine ÇOBANOĞLU (Jury Member)
Marmara University..(SIGN)..................

Prof. Dr. Şükran NİLVANA ATADENİZ (Jury Member)
Yeditepe University..(SIGN)..................

APPROVAL

Marmara University Institute for Graduate Studies in Pure and Applied Sciences Executive Committee approves that Elif ÇALOĞLU BÜYÜKSELÇUK be granted the degree of Doctor of Philosophy in Department of Engineering Management on February 20.03, 2017. (Resolution no: ..2017/07-02)

Director of the Institute

Prof. Dr. Uğur YAHŞİ

PREFACE/ACKNOWLEDGMENT

Companies should take some measures in order to continue its activities successfully in today's environment. The first key for companies is to select the best supplier in the supply chain. In this study, it is aimed to select the best green and innovative supplier because of the increased sensitivity on environment and the growing need for innovative actions in the market in recent years. This dissertation introduced a model to select green and innovative supplier by using multi criteria decision making techniques for small and medium-sized enterprises in automotive industry.

Firstly, I would like to thank my advisor Prof. Dr. Özalp Vayvay for the support, favour and decency of my Ph. D. study and related research.

I would like to express my deep appreciation to my thesis jury member: Assoc. Prof. Dr. Hakan Tozan for his continues support, patience, motivation and immense knowledge. Besides, I would like to thank to İlknur Karacan for her support and help.

In addition, I am grateful to my dear teacher Prof. Dr. Semra Birgün for her unique knowledge and experience that are guiding my academic life.

I would like to thank my other thesis jury member: Assoc. Prof. Dr. Gülfem Tuzkaya for their help and insightful comments. I also owe to Assoc. Prof. Dr. Serol Bulkan for his lectures and insights that expanded my horizon.

I would like to thank to my committee members Prof. Dr. Emine Çobanoğlu and Prof. Dr. Şükran Nilvana Atadeniz for their comments and contributions.

I wish to express my deep sense of gratitude to Besim Büyükselçuk and Murat Büyükselçuk for their support and help.

Finally I owe a debt of gratitude to my husband Burak, my son Doruk and my family. Their love, support, and patience were the biggest motivation of this thesis.

February, 2017 **Elif ÇALOĞLU BÜYÜKSELÇUK**

TABLE OF CONTENTS

ÖZET

YEŞİL VE YENİLİKÇİ TEDARİK SEÇİM MODELİ İLE ÇKKV TEKNİKLERİ VE OTOMOTİV SANAYİNDE BİR VAKA İNCELEMESİ

Yoğun rekabetin yaşandığı günümüz koşullarında, firmalar faaliyetlerini sürdürebilmek ve ayakta kalabilmek için bir takım önlemler almak zorundadırlar. Özellikle son yıllarda çevreye karşı olan hassasiyet artmış ve yenilikçi faaliyetler hız kazanmıştır. Bu da literatürde karşımıza iki yeni kavramı çıkarmaktadır: Yeşil ve Yenilikçi. Bu nedenle firmalar tedarik zincirlerini gözden geçirerek yeni bir tedarik zinciri yönetimi anlayışını benimsemektedirler. Başarılı bir tedarik zinciri yönetiminin birinci ve en önemli adımı da doğru tedarikçiler ile çalışmaktır. Ancak tedarikçi seçimi çok kriterli karar verme problemlerinden olup, çözümü karmaşık bir süreçtir. Bu çalışmada da, geleneksel tedarikçi seçim kriterlerinin yanı sıra yeşil ve yenilikçi tedarikçi seçimi kriterleri de göz önüne alınarak, otomotiv sektöründe faaliyet gösteren küçük ve orta ölçekli işletme (KOBİ) olan A firması için doğru tedarikçinin tespit edilmesi amacıyla bir model oluşturulmuştur. Tedarikçi seçim kriterlerinin ağırlıklarının belirlenmesinde AHP ve FAHP yaklaşımları kullanılmıştır. Kriterlerin ağırlıkları belirlendikten sonra doğru tedarikçinin belirlenebilmesi için literatürde sıkça karşımıza çıkan farklı çok kriterli karar verme (ÇKKV) teknikleri (örneğin; AHP, FAP, ANP, FANP, TOPSIS, FTOPSIS, VIKOR, FVIKOR ve GP) kullanılmıştır. Bu çalışmada DESTEC 1.0 ve DEMATSEL programları kullanılarak sonuçlar elde edilmiştir. Elde edilen sonuçlar karşılaştırılmış ve A firması için en uygun yeşil ve yenilikçi tedarikçi belirlenmiştir.

Anahtar Kelimeler: Tedarik Zinciri, Çok Kriterli Karar Verme, Bulanık Küme Teorisi, AHP, Hedef Programlama, ANP, VIKOR, TOPSIS.

ABSTRACT

GREEN AND INNOVATIVE SUPPLIER SELECTION MODEL VIA MCDM TECHNIQUES AND A CASE STUDY IN AUTOMOTIVE INDUSTRY

In today's environment that intense competition continues, companies must take some precautions in order to survive and be able to act their activities. Especially in recent years, sensitivity to the environment has been increased and innovative activities have accelerated. This reveals two new concepts in the literature: Green and Innovative. Therefore, companies are forced to adopt a new supply chain management by reviewing the existing supply chains. The first and most important step for a successful supply chain management is to collaborate with the right suppliers surely. However, supplier selection takes place into multiple-criteria decision making problem so solution of problem is a complex process. This study encourages that in addition to traditional criteria by taking into account green and innovative criteria, a model is constructed in order to identify the best supplier for company A that is a small and medium-sized enterprise (SME) operating in the automotive industry. AHP and FAHP approaches have been used to calculate the weight of the supplier selection criteria. After the determination of weight of criteria, different MCDM techniques that often encountered in the literature have been used (such as AHP, FAHP, ANP, FANP, TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP) to identify the best supplier. The results were obtained by using DESTEC 1.0 and DEMATSEL solver. Obtained results have been compared and the best green and innovative (greenovative) supplier have been defined for company A.

Keywords: Supply Chain, Multi Criteria Decision Making, Fuzzy Set Theory, AHP, Goal Programming, ANP, VIKOR, TOPSIS.

CLAIM FOR ORIGINALITY

In recent years, because of the increasing environmental damage and intense competition, researchers and practitioners start to study about environmental and innovative activities. Companies should review their existing supply chains and they introduce these two concepts that are green and innovative in their chains. The first and most important step of successful supply chain management is determine the best supplier, however it is a multiple criteria decision making problem and the solution of the problem is a complex process. So, there are many studies about the supplier selection that selection is done due to the evaluation of traditional criteria or environmental criteria or innovative criteria and problem is solved by using different multi criteria decision making (MCDM) techniques for example Analytic Hierarchy Process (AHP) or ELimination Et Choix Traduisant la REalite (ELECTRE) or Analytic Network Process (ANP) or Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) or Goal Programming (GP) or Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) or Fuzzy Set Theory or Data Envelopment Analysis (DEA) etc.

In this dissertation, it is aimed to construct a model in order to select a best "GREENOVATIVE" supplier refers to green and innovative supplier and many MCDM approaches are used to solve the problem. With this thesis, "greenovative" which is the new concept is gained and the results obtained from many MCDM techniques such as AHP, FAHP, ANP, FANP, TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP are compared in the study.

SYMBOLS

A^+ : Positive ideal solution

A^- : Negative ideal solution

CI : Consistency index

C^{i*} : The relative closeness of an alternative

CR : Consistency ratio

l : Lower value of the fuzzy number

m : Medium value of the fuzzy number

S^{i*} : Separation distance of each alternative from the positive ideal solution

S^{i-} : Separation distance of each alternative from the negative ideal solution

S_j : Maximum group utility

u : Upper value of the fuzzy number

V : The weighted normalized decision matrix

X_{ij} : The performance measure of the i_{th} alternative in terms of the j_{th} criterion

λ_{max} : The maximum eigenvalue of the judgement matrix

ABBREVIATIONS

AHP	**:** Analytic Hierarchy Process
ANP	**:** Analytic Network Process
CBR	**:** Case-Based Reasoning
DEA	**:** Data Envelopment Analysis
DEMATEL	**:** Decision Making Trial and Evaluation Laboratory
DEMATSEL	**:** DEcision MAking Tool designed to SELect
DESTEC	**:** Decision Support Tool for Enhanced Choose
DMUs	**:** Decision Making Units
DSSs	**:** Decision Support Systems
DT	**:** Decision Tree
EC	**:** Environmental Criteria
ELECTRE	**:** ELimination Et Choix Traduisant la REalité
FAD	**:** Fuzzy Axiomatic Design
FAHP	**:** Fuzzy Analytic Hierarchy Process
FANP	**:** Fuzzy Analytic Network Process
FTOPSIS	**:** Fuzzy Technique for Order of Preference by Similarity to Ideal Solution
FVIKOR	**:** Fuzzy ViseKriterijumska Optimizacija I Kompromisno Resenje
GA	**:** Genetic Algorithm
GMCDM	**:** Group Multi Criteria Decision Making

GP : Goal Programming

GRA : Grey Relational Analysis

GSCM : Green Supply Chain Management

IC : Innovative Criteria

ID : Influence Diagram

LP : Linear Programming

MADM : Multi Attribute Decision Making

MAUT : Multi Attribute Utility Theory

MCDM : Multi Criteria Decision Making

MCGP : Multi Choice Goal Programming

MCMP : Multi Criteria Mathematical Problem

MCSP : Multi Criteria Selection Problem

MODM : Multi Objective Decision Making

QFD : Quality Function Deployment

PROMETHEE : Preference Ranking Organization METHod for Enrichment Evaluations

SAW : Simple Additive Weighting

SMART : Simple Multi-Attribute Rating Technique

SMEs : Small and Medium Sized Enterprises

SODM : Single Objective Decision Making

TC : Traditional Criteria

TOPSIS **:** Technique for Order of Preference by Similarity to Ideal Solution

VIKOR **:** ViseKriterijumska Optimizacija I Kompromisno Resenje

LIST OF FIGURES

LIST OF TABLES

1- INTRODUCTION

1.1. Overview

In recent years, companies should care green and innovative activities due to environmental issues and increased competition respectively in order to survive. Cooperation with proper green and innovative supplier affects a company's green and innovative performance positively. This dissertation introduced a model to select green and innovative (greenovative) supplier by applying multi criteria decision making (MCDM) techniques for small and medium-sized enterprises (SMEs) in automotive industry. Firstly a questionnaire was prepared and applied after literature review. Green and innovative (greenovative) supplier selection criteria were determined by using weighted average method due to the questionnaire results. Secondly these criteria are ranked by using analytic hierarchy process (AHP) and fuzzy analytic hierarchy process (FAHP). After determining relative significance of each criteria, this study proposes multi-criteria decision making (MCDM) techniques like that TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), fuzzy TOPSIS, analytic hierarchy process (AHP), fuzzy analytic hierarchy process (FAHP), VIKOR (ViseKriterijumska Optimizacija I Kompromisno Resenje), fuzzy VIKOR, analytic network process (ANP), fuzzy analytic network process (FANP), Goal Programming (GP) methods etc. to select the best greenovative supplier for a SME based automobile spare parts manufacturing company A. Finally results were discussed.

1.2. Thesis Objective

Any goods or services to survive in today's conditions are possible only through an effective Supply Chain Management. Therefore, there is a smooth flow at the stages of the product from raw material to final consumer. The first and most important step of the chain is the supplier selection. Short-term work period based on the low cost of ownership has left a long-term study period based on the location of the principles of mutual trust, taking into account environmentally friendly and innovative activities.

A typical supplier selection problem is the determination of the best and most appropriate suppliers according to the selection criteria and what will be ordered in quantities of these suppliers. But to make that choice is a complicated issue. Initially, supplier selection criteria that are proper for our goal should be determined and then the weights of each criterion should be calculated correctly. Finally, alternatives should be evaluated based on the selection criteria and then the most appropriate supplier should be determined.

In recent years, companies are now obliged to act more carefully when selecting their suppliers because of the increased sensitivity on environment and the growing need for innovative actions in the market. Firms also begin to examine a number of criteria that include environmental and innovative activities in addition to the traditional criteria when choosing their suppliers. In this study, it is aimed to find a solution to address this issue.

The weights of the supplier selection criteria that determined from the questionnaire results applied in small and medium size enterprises (SMEs) operating in the automotive industry are calculated using Analytic Hierarchy Process (AHP) and fuzzy Analytic Hierarchy Process (FAHP). Therefore, the first task is to generate a hierarchical structure model for the greenovative supplier selection based on the selected criteria. The second task is to create a decision making team which consists of senior management, purchasing department and also academicians in the company A. Company A in Istanbul is a small and medium-sized companies operating in the automotive sector and it is mainly engaged in the production of European market. According to the preferences of decision makers, the relative importance of all criteria is calculating by applying of AHP and fuzzy AHP techniques. After that to identify the best greenovative supplier for company A, different multi criteria decision making tools for instance AHP, FAHP, ANP, FANP, VIKOR, FVIKOR, TOPSIS, FTOPSIS and GP are used.

1.3. Thesis Organization

If we take a look at the contents of the thesis, Chapter One gives brief information about it such as overview, objective and organization. After the detailed literature review, in Chapter Two, decision making, multi criteria decision making (MCDM) processes, supply chain management with green and innovative activities and supplier selection criteria are explained. Also multi criteria decision making tools that are used widely in the literature are introduced. Studies about supplier selection and evaluation in the literature and MCDM methods that are used in the thesis are given briefly. In Chapter Three, the flow chart of the study is constructed and explained shortly. Supplier selection criteria are determined and categorized into three main groups. The pair wise comparison matrices are formed by the decision maker team. The solution tools DESTEC 1.0 (Decision Support Tool for Enhanced Choose) and DEMATSEL (DEcision MAking Tool designed to SELect) are introduced shortly. Also in this chapter, used MCDM techniques and their steps are explained briefly. Solution results are given in Chapter Four. Chapter Five includes the conclusions of the research, limitations of the research, main findings and further remarks.

2- LITERATURE REVIEW

2.1. Decision Making Process

Decision making is the process of identifying and choosing alternatives according to the criteria that are defined by the decision makers. In their 2002 study, Baker et. al. defined the efficient decision making that involves “a series of steps that require the input of information at different stages of the process, as well as a process for feedback”.

As it can be seen, there are eight steps in effective decision making in Figure 2.1 (Baker et. al., 2002).

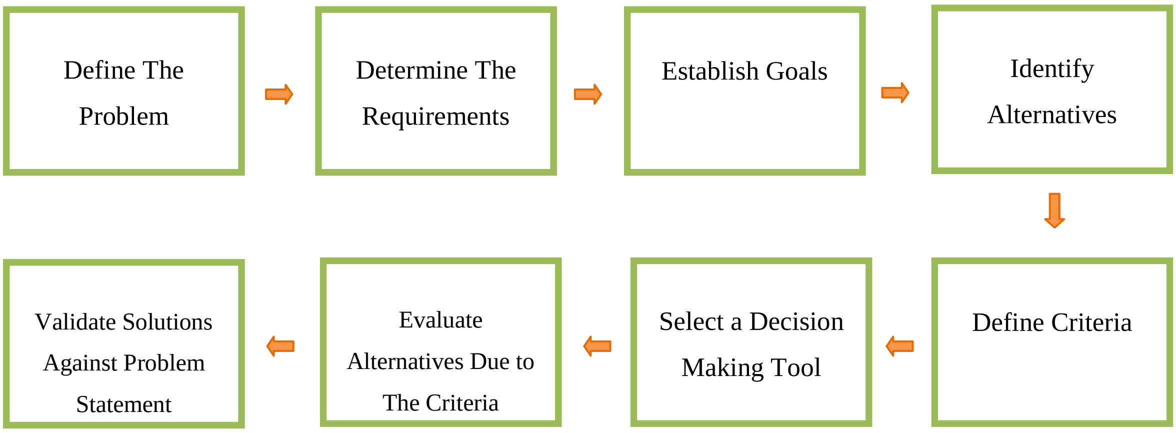


Figure 2.1. Flow of decision making process (Baker et. al., 2002).

The flow of decision making process is explained in the following steps briefly:

Step 1. Define the problem: The first and important step of the decision making process is to define the problem correctly and completely. It is the initial success key of any decision making problem to achieve the goal(s) related to the decision. If the problem is not analyzed with appropriate statements, the following steps of the problem will fail to find the effective solutions for the real requirements.

Step 2. Determine the requirements: To satisfy the aim, requirements should be identified obviously to block the uncertainty. Requirements are similar to basic needs in a Kano model. Alternatives must satisfy the requirements to become a candidate.

Step 3. Establish goals: Goals are statements that refer to as lowering costs, taking minimum risk or having minimum lead time. Negative statement should be avoided for the goal establishment.

Step 4. Identify alternatives: Alternatives are identified to satisfy requirements and optimize goals defined by decision makers. Alternatives must meet defined requirements in a decision problem. If they not, three conditions occur like that:

-Alternative is eliminated.

-Definition of requirement is updated.

-Requirement is changed as a goal (Karacan, 2015).

Step 5. Define criteria: Criterion is the key between the alternatives and goal(s) to solve the problem easily. Criteria obviously reflect the goal(s) and should be differentiate among alternatives. Criteria should be kept in minimum number.

Step 6. Select a decision making tool: A tool is selected to evaluate how well alternatives satisfy requirements and optimize the goal(s). Some hybrid and combined approaches are used to solve the decision problems in the literature.

Step 7. Evaluate alternatives due to the criteria: After the definition and selection steps, the analytical results of decision making problem are represented. These results help to obtain how well alternatives satisfy the goals. Criteria may be weighted to rank the alternatives by using selected tool.

Step 8. Validate solutions against problem statement: To prove the reliability of the selected alternative for the decision problem, a validation process should be conducted.

Decision Analysis is developed to overcome the decision problems. Decision Analysis is also known in different names such as decision support, decision evaluation used in different disciplines or using different methods. However, the aim of all is helping the decision makers in the decision making process (Omann, 2004).

Quantitative methods are widely used for decision analysis to evaluate alternative courses of actions. Decision analysis is classified in three main groups: Single Objective

Decision Making (SODM), Decision Support Systems (DSSs) and Multi-Criteria Decision Making (MCDM) methods where it is represented in Figure 2.2 (Yanar, 2011).

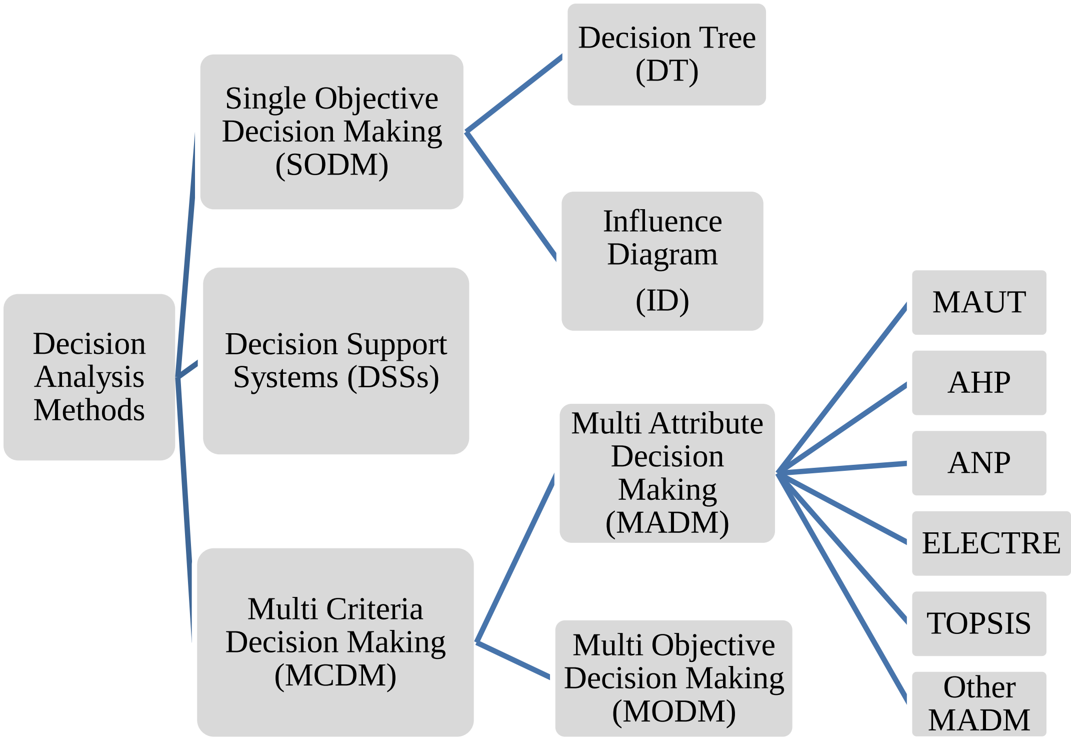


Figure 2.2. Decision analysis method (Yanar, 2011).

Single Objective Decision Making (SODM) aims to evaluate a set of available alternatives with uncertain outcomes for a single objective function. The popular approach of SODM is Decision Tree (DT) whereas the other approach is Influence Diagram (ID) that helps to analyze the complex decision problems easily (Zhou et. al., 2006). Multi-criteria Decision Making (MCDM) helps to decision makers to select or order the alternatives according to the differtent criteria (Colsonand Bruyn, 1989; Zeleny, 1982). There would be detailed explanation in the following section about MCDM methods. Decision Support System (DSS) means the flexible and interactive software system that is adopted into the decision making model easily to help the decision makers (Turban, 1995). It will be explained in the section 2.5.

Actually each person uses the decision making process consciously or unconsciously. A decision making process has mostly more than one criteria in real life problem. In the following phase, MCDM problems are introduced.

2.2. Multi Criteria Decision Making (MCDM)

MCDM problems are the decision making problems that are formed with multiple criteria. MCDM is a sub-discipline of operations research that provides a compromise solution to order the best alternatives among a number of alternatives according to evaluated related criteria to help the decision makers.

MCDM methods interest with the qualitative and quantitative criteria at the same time. Decision makers do not always have the same opinion and these methods provide a solution for the disagreement (Taha and Daim, 2013). The systematic classification of MCDM is shown in Figure 2.3 (Whaiduzzaman et. al., 2014).

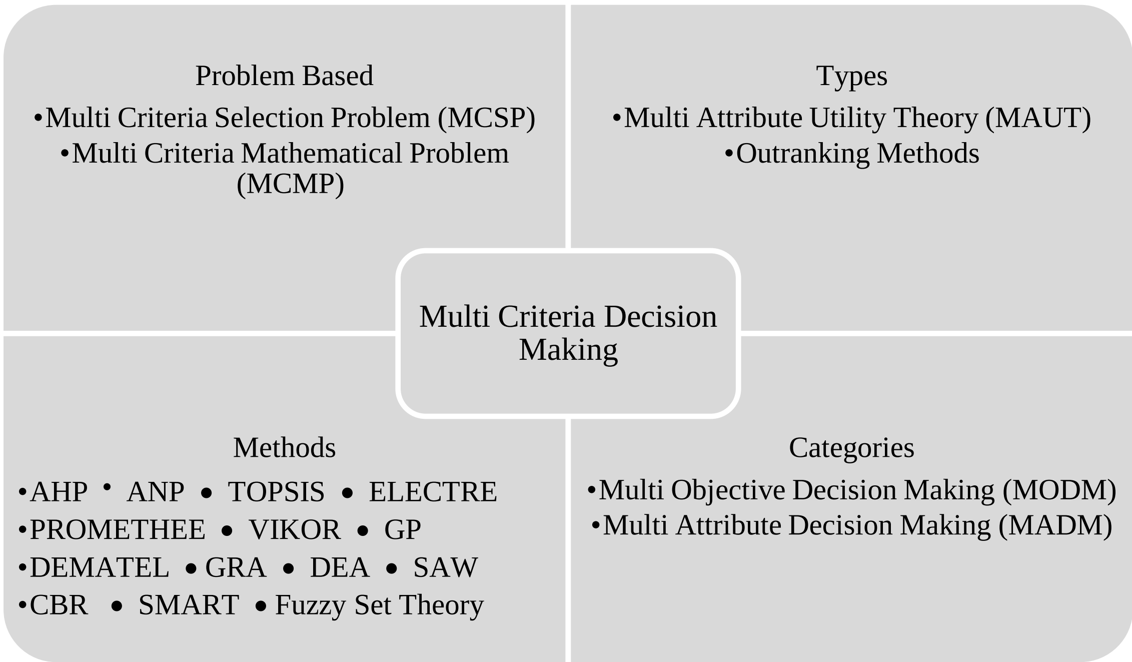


Figure 2.3. The systematic classification of MCDM (Whaiduzzaman et. al., 2014).

MCDM is a combination methodology of comparing, ranking and choosing of multiple alternatives that have multiple attributes. It depends on a matrix like that decision matrix, evaluation matrix or payoff matrix (Whaiduzzaman et. al., 2014).

The MCDM can be examined under two groups when the problem-based consideration is taken into account. These are: Multi Criteria Selection Problem (MCSP) and Multi Criteria Mathematical Problem (MCMP). There is a finite set of alternatives and MCSP aims to select the best alternative from among them. They are known a priori. On the other hand, in MCMP, there is a very large or infinite set of alternatives and it aims to select the best alternative from among them. They are not known a priori (Whaiduzzaman et. al., 2014).

MCDM can be classified into two categories: Multi Attribute Utility Theory (MAUT) and outranking methods. MAUT aims to find the utility function of a particular attribute. Each attribute has a marginal utility that is a real number representing the preferability of the considered attribute. The returned utility refers to the total sum of these marginal utilities. Outranking methods decide whether an alternative is higher than the other by using the comparison pair (Whaiduzzaman et. al., 2014).

MCDM methods are generally categorized into two categories. They are Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM) (Climaco, 1997).

In MODM, due to the multiple and competitive objectives, the decision problem is analyzed against a set of feasible and available constraints. On the other hand, in MADM, candidate alternatives are evaluated according to the criteria that are defined by the decision makers. MADM is the most popular MCDM methods to solve the decision problems. Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE), Analytic Hierarchy Process (AHP), ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality-ELECTRE), Multi-Attribute Utility Theory (MAUT) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are the best known methods of MADM. MADM is aimed to select the alternative that has the highest score that is evaluated by the set of evaluation criteria (Whaiduzzaman et. al., 2014).

2.3. MCDM Methods

The MCDM methods AHP, Analytic Network Process (ANP), ELECTRE, TOPSIS, MAUT, Data Envelopment Analysis (DEA), Goal Programming (GP) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) will be explained shortly in the following step.

When Mohammadshahi (2013) examined the studies that used MCDM methods in the literature, he found that: Fuzzy set theory was the most preferred method representing

40 % of the total; AHP and ANP together were used approximately in 20 %. On the other hand, DEA, GP and ELECTRE were used only rarely.

2.3.1. Analytic Hierarchy Process (AHP)

AHP is formed as a hierarchy that includes a goal at the top level, criteria and sub-criteria at the middle level and alternatives at the bottom level of the hierarchy. Pairwise comparison matrix is constructed according to the data from the decision makers or experts. A supplier that has the highest rank in a group of alternatives is identified as the right supplier (Yanar, 2011).

2.3.2. Analytic Network Process (ANP)

ANP method is a general form of AHP that is also developed by Saaty. When the AHP and ANP compared, AHP has simple usage, it works due to the unidirectional relationship characteristic unfortunately it cannot be suitable for solving many complex problems. On the other hand, complicated relationships between alternatives and criteria are thought to be as a network in the ANP (Velasquez and Hester, 2013).

2.3.3. Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE)

This method is easy to use and handle complexity of the problem. PROMETHEE defines the best alternative that has the highest rank due to the outranking strategy and it is based on a pair wise comparison of alternatives in order to rank them due to a number of criteria. There are several researches about PROMETHEE I and PROMETHEE II in literature. PROMETHEE I give a partial ranking compared to the PROMETHEE II (Karacan, 2015).

2.3.4. ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality-ELECTRE)

This method provides complete ordering of the alternatives and it is capable of handling discrete criteria of both qualitative and quantitative. This method deals with the dominance relations among alternatives with the outranking relationships and exploitation notions of concordance. ELECTRE family consists of ELECTRE I, II, III, IV, ELECTRE IS and ELECTRE TRI (ELECTRE Tree). ELECTRE I focus on the selection problems especially. ELECTRE II, III and IV are used for ranking problems ELECTRE TRI is the best for ranking problems (Karacan, 2015).

2.3.5. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS provides the distinguished alternative. This alternative must be at the farthermost point from the negative ideal solution and the nearest point to the positive ideal solution. Linear metric (Euclid Distance) is used to determine the closeness values between alternatives. Normalization is used to degrade all data in same scale in TOPSIS method. TOPSIS has many devices with fuzzy data sets (Karacan, 2015).

2.3.6. Multi-Attribute Utility Theory (MAUT)

It is the most common and best known method of MCDM techniques. This method is based on the decision maker preferences. Their preferences that are defined due to a group of attributes are formed into the utility function. The utility function of each attribute or criterion cannot be linear (Dyer, et. al., 1992).

2.3.7. VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

It is aimed to order the appropriate suppliers according to their fulfilment level. Criteria weighting is made due to their importance level. VIKOR method is easy to use for decision makers. In this method, normalization is used to degrade all criteria into same scale which leads equal importance for criteria. However, it is also sensitive to outliers (Karacan, 2015).

2.3.8. Goal Programming (GP)

GP is based on linear programming that includes multiple objective functions. In this method, the deviation of target values and values of alternatives are determined. Algorithm may be applied in preemptive or non-preemptive approach. In preemptive goal programming, criteria are satisfied with an order constructed by their importance. If there are major differences in importance levels of criteria, this method should be applied. In non-preemptive goal programming, it is assumed that this method depends on the minor differences between weights and criteria are considered to be satisfied due to their weights (Karacan, 2015).

2.3.9. Data Envelopment Analysis (DEA)

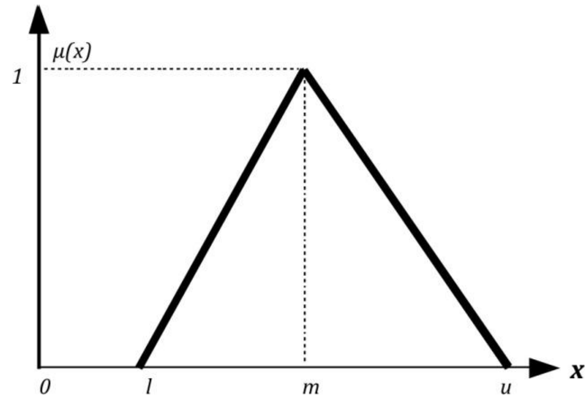
In 1978; Charnes, Cooper and Rhodes (CCR) model that is also known the non-linear model has been used Data Envelopment Analysis in the literature at first time. DEA aims to calculate the productive efficiency of Decision Making Units (DMUs). DMU refers to the alternatives in other MCDM methods. The DMUs consist of a set of input source and a set of corresponding output source. In DEA method, the ranking of DMUs due to their efficiency ratio acquired from the weighted division on outputs to inputs is made. Best DMU value should be "1.0" for this ratio (Karacan, 2015).

2.3.10. Fuzzy Set Theory

In 1965, Zadeh developed fuzzy set theory (Zadeh, 1975). Aristotle logic is used in the traditional set approach. So, in Aristotle logic, all elements are classified that meeting the specified properties or not. In other words, members of the traditional cluster are determined according to bisection rule. Events are divided by bilateral basis such as true-false, yes-no or 0-1. Whereas, bilateral basis is insufficient in the complex decision making process for the decision makers' opinions and preferences. Decision makers' perceptions and opinions contain ambiguity and uncertainty. This uncertainty is included into the resolution process by referring to the different membership degree of 0-1 of in the fuzzy set logic. Exact boundaries does not define the fuzzy sets, there are stages in the transition of elements from to be a member to not to be a member.

0-1 in the fuzzy set theory defines the minimum and maximum degrees of membership of the object of a particular cluster. Intermediate values represent the degree of partial membership. As can be seen here, a precise definition does not have to be done such as any object is a member of a cluster or not. Object can be a member of the cluster up to a degree.

An assessment is carried out by using linguistic variables and fuzzy numbers in the fuzzy sets theory. After these statements are converted into fuzzy numbers, analyzes are made. Triangular, trapezoid, or bell shaped fuzzy numbers are defined. In Figure 2.4, membership function defining the triangular fuzzy number is shown.



$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < l \text{ or } x > u, \\ \dfrac{x-l}{m-l}, & l \le x \le m, \\ \dfrac{u-x}{u-m}, & m \le x \le u, \end{cases}$$

Figure 2.4. Membership function defining the triangular fuzzy number M=(l,m,u) (Gani and Assarudeen, 2012).

Where l and u represent lower and upper values of the Ã fuzzy number respectively and m represents medium value. Basic arithmetic operations for the positive triangular fuzzy numbers such as $\tilde{A}_1$ and $\tilde{A}_2$ are performed as follows:

$\tilde{A}_1 = (l_1, m_1, u_1)$ and $\tilde{A}_2 = (l_2, m_2, u_2)$

$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$

$\tilde{A}_1 \otimes \tilde{A}_2 \approx (l_1 l_2, m_1 m_2, u_1 u_2)$

$\lambda \otimes \tilde{A}_1 = (\lambda l_1, \lambda m_1, \lambda u_1) \qquad \lambda > 0, \lambda \in R$

$\tilde{A}1\text{-}1 \approx (1/u_1, 1/m_1, 1/l_1)$

2.4. Summary of MCDM Methods

The objectives, advantageous, disadvantages and application areas of MCDM methods that are generally used in the literature will be explained in Table 2.1 (Karacan, 2015; Velasquez and Hester, 2013).

Table 2.1. Summary of MCDM methods (Karacan, 2015; Velasquez and Hester, 2013).

Method	Objective	Advantages	Disadvantages	Application Areas
AHP	Pair wise comparison of attributes structured in a hierarchical relationship.	This method is easy to use and it is user friendly method. It can be adjusted in many sized problems and it does not require intensive data.	There can be many problems between criteria and alternatives due to the interdependence. It causes inconsistency among judgment.	Planning and supply chain management, resource management, strategic decisions.
ANP	It is based on the relationships between decision levels and attributes.	Easy to implement, expressive power of modeling.	Several pairwise comparison questions. Complex survey process for non-expert participants.	Strategic planning of organizational resources, production planning, economic forecasting.
MAUT	It is a structured methodology designed to handle the tradeoffs among multiple objectives.	It can combine all preferences and it is suitable for ambiguity conditions.	It requires a lof of inputs and exact preferences.	Water and energy management, economics, agricultural areas.
Simple Multi-Attribute Rating Technique (SMART)	It aims to calculate the value of the alternative. For this calculation, the total performance value of each attribute is multiplied by the weight of the given criterion. It's a linear additive model.	It is asy to use and friendly for decision makers. It uses any weight assignment method.	Process steps cannot be appropriate by taking into account the structure.	Supply cahin and logistics activities, environmental management, assembly lines, military applications.

Table 2.1. continued.

Method	Objective	Advantages	Disadvantages	Application Areas
Simple Additive Weighting (SAW)	Its basis is weighted average and evaluation value is calculated for each alternative. It is a common aggregation method of MAUT for decision maker's assessment of alternatives in a decision group.	Simple calculation, recuperation between criteria and instinctive decision making.	Sometimes results can be illogical and it cannot represent real conditions.	Financial applications, business world areas and water management.
DEA	It is based on the assessment of an observation due to the similar observations.	It measures efficiency and allows multiple inputs and outputs.	It works decisive data and it assumed all data are completely defined.	Financial and economical areas, agricultural applications, business areas.
GP	It is based on the linear programming to analyze the problems that contain contradictory and multiple objects.	It is suitable for large scale problems and it gives infinite alternatives.	It can calculate weight coefficients and it should work with other MCDM techniques to weight coefficients.	Water and energy management, scheduling and distribution problems, production planning.
PROMETHEE	It is similar to ELECTRE but pairwise comparison step is different in here.	Simple usage and there is no proportion among alternatives.	It is not a proper method for calculating weights.	Water management, environmental problems, supply chain management.

Table 2.1. continued.

Method	Objective	Advantages	Disadvantages	Application Areas
VIKOR	According to the closeness of the ideal solution, the ranking is made.	Determine a compromise solution to reflect the attitude of most decision makers by using utility weight; consider majority and also a minimum of an individual regret.	Difficult to keep consistency of judgment.	Category of design, mechanical engineering and manufacturing consist of material selection, robout selection, new product development, machine tool selection etc.
ELECTRE	Pairwise comparison matrix between alternatives is formed to determine and eliminate alternatives dominated by other alternatives.	It handles the ambiguity and doubt.	Strengths and weakness of the alternatives cannot be defined completely because of the outranking. The process and outcome can be hard to identify.	Water, environmental and energy management, supply chain management, economics areas.
TOPSIS	It is based on the determination of the best alternative that is close to the positive ideal solution and farthermost from the negative ideal solution.	It is a simple method and it is user friendly. The number of program steps does not change with a series of attributes.	Correlations of attributes are not taken into account because of the usage of Euclidean Distance. Calculation of weight of judgment is so hard.	Water and environmental management, supply chain management, logistics problems, business world applications.

Table 2.1. continued.

Method	Objective	Advantages	Disadvantages	Application Areas
Fuzzy Set Theory	It is based on the evaluation of signification in the form of linguistic variables that are represented by fuzzy numbers.	It can use a lack of information and uncertain input.	It requires many simulations before usage and it is hard to develop.	Environmental areas, engineering and medical areas, finance and economics.

2.5. Decision Support Systems

Many researchers examined some techniques for solving MCDM problems and computer technology helped to find an optimal solution for decision makers. So a new branch that is called "Decision Support System (DSS)" was developed (Yanar, 2011).

Decision support systems deal with the following conceptions in most research:

- The structure of the task is identified in a DSS.
- A distinctive design strategy that is defined due to the evolution and middle-out techniques is created in a DSS.
- The cognitive processes of decision makers are supported in a DSS. Decision research is important because it helps to management for problem-solving and improving effectiveness of normative theories.
- An implementation strategy is necessary in a DSS for using of computer effectively to managers. It is based on the use of skilled intermediates, responsive service and humanized software interfaces (Keen, 1980).

As a result, the terms Decision Support Systems refer to computer-based tools such as simulation models, techniques and methods developed to support the decision and participatory processes. Inputs (factors, numbers and characteristics to analyze), user knowledge and expertise, outputs and decisions are components of a DSS so it collects, organizes and processes data and information (Welp, 2001). DSSs are used in several areas for example medical diagnosis, business and management, agricultural production and forest management.

A DSS has some advantages such as time saving, enhancing effectiveness, competitive advantage, cost reduction, promoting learning, improving personal efficiency, increasing decision maker satisfaction and improving interpersonal communication. On the other hand, it also has some disadvantages such as monetary cost, overemphasizing decision making, assumption of relevance, transfer of power, unanticipated effects, obscuring responsibility, false belief in objectivity, status reduction and information overload. Some DSSs and their features are listed in the following table (Karacan, 2015).

Table 2.2. Some properties of DSSs (Karacan, 2015).

No.	Software Name	Supported MCDM Method(s)	Fuzzy Methods Supported	Sensitivity Analysis	Group Decision Making
1	1000 Minds	PAPRIKA	-	√	√
2	Aliah Think	AHP	-	√	√
3	Choice Reaults	AHP	-	√	√
4	Criterium Decision Plus	AHP, SMART	-	√	-
5	Decision ERA	FAHP, FANP, TOPSIS, DEMATEL	√	-	√
6	Decision Lab 2000	PROMETHEE	-	√	-
7	Decision Lens	AHP	-	√	√
8	Decision Manager	Utility Theory	-	√	-
9	Decision Oven	AHP	-	-	-
10	Decision Pad	AHP, MAUT	-	√	-
11	DEMATSEL	AHP, FAHP, TOPSIS, FTOPSIS, GP, VIKOR	√	-	√
12	DESTEC 1.0	AHP, FAHP, ANP, FANP	√	-	-
13	D-Sight	PROMETHEE, MAUT	-	√	√
14	ELECCALC	ELECTRE II	-	-	-
15	ELECTRE III-IV	ELECTRE III, ELECTRE IV	-	-	-
16	ELECTRE IS	ELECTRE I	-	-	-
17	ELECTRE TRI	ELECTRE TRI	-	-	-
18	ERGO	MAUT	-	√	-

Table 2.2. continued.

No.	Software Name	Supported MCDM Method(s)	Fuzzy Methods Supported	Sensitivity Analysis	Group Decision Making
19	Expert Choice	AHP	-	√	√
20	HiPriority	SMART	-	-	-
21	Hiview3	MACBETH	-	√	√
22	IRIS	ELECTRE TRI	-	-	-
23	Logical Decisions	AHP	-	√	-
24	MACBETH	MACBETH	-	√	-
25	MakeltRational	AHP	-	√	√
26	Mind Decider	AHP	-	√	√
27	NAIADE	NAIADE	√	-	-
28	Open Decision Maker	AHP	-	√	-
29	Prime Option	MFEP	-	√	-
30	Right Choice DSS	AHP	-	√	√
31	Select Pro	AHP	-	√	√
32	SETED 1.0	ELECTRE I, TOPSIS, PROMETHEE II, Fuzzy ELECTRE I, FTOPSIS	√	-	-
33	Tribium Decisions	Utility Theory	-	√	√
34	TRIPTYCH	AHP, TOPSIS	√	√	-
35	Super Decisions	ANP	-	√	
36	Visual PROMETHEE	PROMETHEE	-	-	√
37	Web-HIPRE	AHP	-	√	√

It is obvious that when the Table 2.2 is examined, AHP the best known of MCDM methods is used in almost the half of all DSSs (45.95 %). Also the percentage of only one method that is used in them is 75.68 %. There is a little amount of DSSs that fuzzy theory is applied (16.22 %).

In this thesis, DESTEC 1.0 by Yanar (2011) and DEMATSEL by Karacan (2015) software are used to identify the greenovative supplier. They will be explained in the next section shortly.

2.6. Supply Chain Management

Supply chain management is the integrated management of material, information and money flow that involves the movement of right product to the customer at the right place, time and price (Tuzkaya et. al., 2009). Today's businesses have been in a new era with the developing technologies and the internet. Anymore, firms do not struggle with their competitors in areas such as quality, cost, flexibility and customer service; new concepts have also entered into supply chain management. Especially green and innovative concepts for successful and effective supply chain management are frequently found in the literature in recent years (Hsu et. al., 2013; Schiele, 2006).

2.6.1. Green Supply Chain Management

Until awareness of responsibility towards the environment emerged, companies never thought how much to can pollute the world with harmful gases they gave to the air, the wastewater they discharged directly to the sewerage, and the solid wastes they had put into the domestic garbage can. The production of hybrid and electric vehicles in the automotive industry, the use of reusable materials in the packaging industry, and the production of recyclable papers in the paper industry are some of the examples that can be given to green activities from different sectors. There can be various forces that encourage or force an enterprise to implement green activities. The most important part of this power is the government authority and the laws that are laid down accordingly. Another power is the negative financial and legal consequences that companies have experienced as a result of mismanagement in the environmental activities. While many companies consider environmental activities as cost, these activities that should be considered in long term periods will return to operation like profitability, operational efficiency and cost minimization (Büyüközkan and Erkut, 2008). For this reason, all companies have to identify their environmental strategies and move to green supply chain practices (Linton et. al., 2007).

Green supply chain management (GSCM) involves green purchasing, green production/green materials management, green distribution/green marketing and reverse logistics activities that represented in Figure 2.5 (Sarkis et. al., 2005). The most important step of GSCM is green purchasing (Zhu et. al., 2008). Decisions of green purchasing can be recyclable or reusable. In addition to purchases of raw materials and components to be used in production, environmentally sensitive technologies should be preferred for technology purchases. These technologies are technologies that consume less energy and produce less harm to the environment (Lo and Leung, 2000). Supplier selection is the most important issue of this step because, if we think about the holistic approach of supply chain management, suppliers should be responsive to the environment. Otherwise it cannot be thought about a good green supply chain management. Such that companies in developed countries also assess suppliers' suppliers (Zhu et. al., 2008).

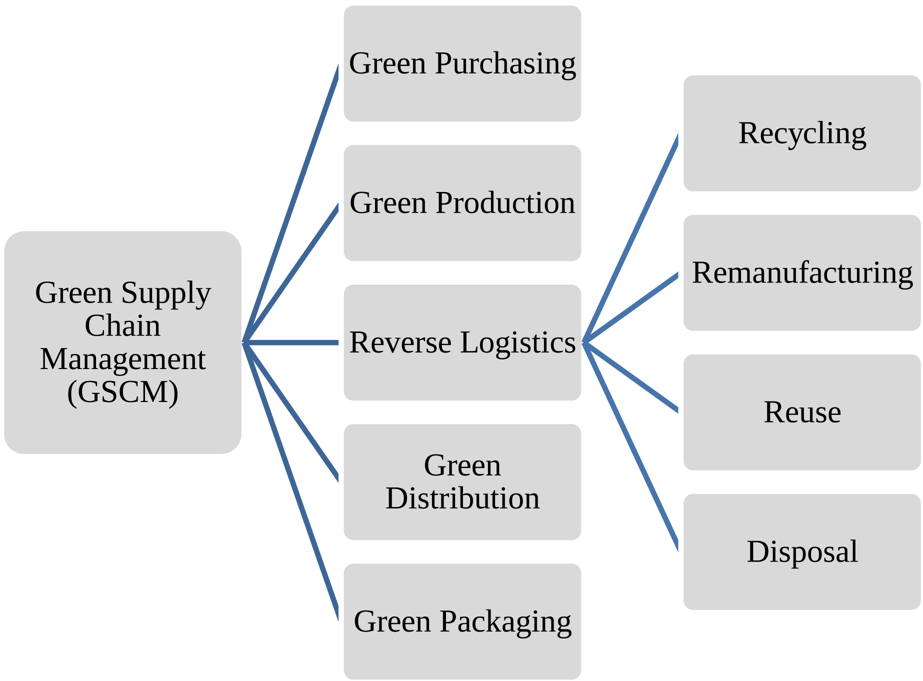


Figure 2.5. The green activities in GSCM (Sarkis et. al., 2005).

Environmentally sensitive design and production processes of the product are an important influence on the management of the green supply chain. Green production involves two fundamental aspects namely evaluating the environmental impacts of products at every stage of product life cycle and making better decisions during design and production processes to maintain at the desired level of the environmental characteristics of product and production processes (Güngör and Gupta, 1999).

Distribution and transport networks are an important activity affecting the green supply chain. Determination of the distribution points, determination of the transportation type to be used, control systems, just in time production and distribution policies affect the logistics networks. The fuel used by the transport vehicle, the transportation frequency, the distance to the customers, the packaging character (weight, shape, material) affect the green distribution performance (Sarkis, 2003).

It should be paid to attention to sizes and shapes of packages with the use of environmentally friendly materials in order to perform environmentally sensitive packaging activities. Good packaging affects the distribution activities positively (Sarkis, 2003).

Reverse logistics involves reusing, remanufacturing, recycling and disposal. Reuse refers the distribution and sale of materials, products and components that collect from the production area used in production. At this time, the actual value of the product is reduced, but no further processing is required. Remanufacturing process is the process of replacing the parts of the used products or components collected from the production area with new ones by checking the status of the old, broken or inoperable parts. In this case, the identity and functionality of the original product is protected. The remanufactured product is examined and tested to achieve or even exceed the specifications of a brand new product. In some cases, products that exceed the quality of the original product can also be found. Recycling that is the element of the extended supply chain is the process of converting used products, components and/or materials into recycled products, components and/or materials after being collected, disassembly, and separated, if necessary. In this case the original material loses its identity and functionality. In disposal activities, it is checked whether or not the product contains harmful substances. These activities aim to dispose the hazardous wastes that generated by the product itself or during the production process by using suitable technology without damaging the environment (Sarkis, 2003).

2.6.2. Supply Chain Management and Innovation

There are many different definitions of innovation in the literature. Innovation which derives from the Latin word “novare” is the process of commercial converting of new ideas. It is not the right approach to perceive innovation as simply the emergence of new ideas, knowledge, inventions and technologies. Because innovation has to gain commercial meaning in order to be able to create social and economic benefits. For this reason, the return of the investments to be made and the improvement of their performance will be possible by applying an effective commercialization process (Gao et. al., 2017). It refers renovating and denotes the introduction of product, process or service that did not exist before (Schiele, 2006). The first economist Joseph Schumpter has defined five types of innovation in the 1930s:

- The emergence of new product or a qualitative variation in an available product
- Process innovation for an industry
- The emergence of a new market
- The presence of new resources of supply for raw materials or other inputs
- Changes in industrial organization (Rogers, 1998).

In the last years when global competition has accelerated, companies have to restructure themselves, keep up with the marketplace, and create different new products with low-cost and high quality in order to survive. The importance of supply chain management has been increased as a result of the shortening of the product life cycles. For this reason, businesses should align their supply chains with innovation activities (Erciş and Can, 2013). At this point, supply chain management and supplier relations, which are indispensable elements, have gained importance for companies. In this sense, supplier relationships have influenced the formation of innovation ideas (Yoon et. al., 2016).

Choosing the right suppliers and establishing the powerful relations with the suppliers are the success key issues of innovation. First of all, it is necessary to determine the used methods in selecting suppliers and to identify the evaluation methods of the suppliers in the future. The relationships with the suppliers are important as a source of innovation ideas. Particularly, quality and supplier relations contribute significant benefit to innovation process (Petroni and Panciroli, 2002).

The partnership in the supply chain is a set of specially structured relationships based on the mutual trust, co-operation, open communication, reward and risk sharing of the members. The partnership can take place at various levels. It is not possible for companies to partner with every supplier in the chain as it requires intensive effort and long time to develop partnership relationship. It is necessary to evaluate which members will develop a partnership relationship and what the size of the relationship will be. The systematic evaluation of the partnership development process ensures that the required potential is determined, that the expected benefits are achieved and that the partnership has a long life span (Erciş and Can, 2013).

Process-related information should be easily shared by all members of the supply chain to ensure that supply chain management is successful. This information should also assist firms in their production and marketing practices. There are various risks that can be encountered when preparing plans based on estimates. These risks include risks such as not giving required importance for innovation activities, the lack of collaboration among the members of the supply chain, and the non-adoption of innovation by other members (Petroni and Panciroli, 2002).

Today, innovation is inevitable however it can bring with it many risks for companies. The most important of these risks is that the parties to the innovation the reaction it will show. This reaction is that it is difficult to change the structure of the company with past experiences. If the resistance in front of innovation can be overcome, co-operation with goals and predictions can be easier. The main problem to be solved is not a technological hurdle. For this reason, the use of information technology is only a means of ensuring supply chain integration. The main problem is that supply chain members have no common purpose.

2.7. Supplier Selection Criteria

Because of the strategic significance of the supplier selection process, many researchers focused on the supplier selection and evaluation. We mentioned earlier, the supplier selection is a complex problem and it should be determined correctly for successful Supply Chain Management activities.

Supplier selection criteria which frequently come out in the literature are examined in three main groups in connection with this study. They are called Traditional, Environmental and Innovative Criteria.

2.7.1. Traditional Criteria

In 1966, Dickson made a study for the selection and evaluation of suppliers and with this study, he focused on 23 different criteria that is called traditional criteria such as quality, price, delivery, performance history, warranties and claim policies (Benyoucef et. al., 2003). According to Weber and his colleagues, price, delivery, quality, production facilities and capacity are the most preferred criteria through Dickson's 23 criteria (Weber et. al., 1991). The traditional supplier selection criteria that are frequently used in the literature are summarized briefly below. Quality system, reject rate, return policies and warranties and compensation of faulty products are considered as criteria for quality in the traditional group.

Quality Systems: It is an important issue that supplier should have some quality indicators (for instance ISO 9000, QS 9000 etc.) on the products (Yang and Wu, 2007).

Reject Rate: At what percentage the products are rejected by the quality control (Weber et. al., 1991).

Return Policies and Warranties: Returns and agreements about the faulty products between the supplier and the customer are the important criteria (Kuo et. al., 2010).

Compensation for Faulty Quality: Supplier should have the ability to compensate for defective products without any additional charge (Yang and Wu, 2007).

Purchasing price, price performance value and transportation cost are considered as criteria for cost in the traditional group.

Purchasing Price: Withoout sacrificing quality and guarantee, supplier should provide the lowest cost for the product (Weber et. al., 1991).

Price Performance Value: Supplier should provide high performance product that occurs minimum cost (Weber et. al, 1991).

Transportation Cost: The total cost of transportation of the product should be at minimum level (Benyoucef et. al., 2003).

Supplier involvement, supplier technique capability, orders fulfill rate, technology level, flexibility of the supplier, supplier inventory management and lead time are considered as criteria for capability of supplier and delivery in the traditional group.

Supplier Involvement: Supplier should respond quickly to customer orders and have a capability to compensate delivery schedules and promises (Tseng, 2011).

Supplier Technique Capability: Supplier should have sufficient techniques for scheduling and delivery activities (Grisi et. al., 2010).

Order Fulfil Rate: Supplier should adapt quickly to predetermined order of quantities (Kuo et. al., 2010).

Technology Level: Supplier should have an ability to develop its technology for the current and future demand of the customer (Lee et. al., 2009).

Flexibility of the Supplier: Supplier should be open and flexible to customer orders and requests (Hsu and Hu, 2009).

Supplier Inventory Management: Supplier should control the production line and inventory management system simultaneously (Hsu and Hu, 2009).

Lead Time: Lead time that is defined as the time from when an order is placed by the customer to when the customer is delivered to that order should be minimum time (Kuo et. al., 2010).

2.7.2. Environmental Criteria

With increasing environmental awareness, companies have started to take into environmental criteria in addition to the Dickson's 23 selection criteria for the supplier selection to ensure their green image and environmental responsibilities. Green supplier selection should be considered to the process that deals with the environmental issues, such as waste reduction, green design and recycling activities (Hamdan and Cheaitou, 2017). Igarashi et. al. (2013) examined 60 articles which have been focused on the green supplier selection process that were published in years between 1991 and 2011. They evaluated environmental criteria in two different scopes like product-related criteria and organization-related criteria. According to the study, product-related criteria contain restriction of the use of hazardous substances, green packaging, recycling and environmental labelling. Organization-related criteria include observance of environmental regulations, environmental management systems and certifications, environmental policies and evaluations of the second tier suppliers' environmental performances. Grisi et. al. (2010) preferred to use some main environmental criteria like that green image, environmental competences, environmental management system and current environmental impact. In 2009, Lee and his colleagues examined quality and technology capability of their suppliers. They also studied total product life cycle cost, green image, pollution control, environment management, green product and green competencies to select the their appropriate supplier.

Feyzioglu and Buyukozkan (2010) emphasized not only product cost, product quality, service performance but also environmental performance criteria in their study. Also environmental criteria have been important for the measurement assessment (Large and Thomsen, 2011).

Wang et. al. (2009) solved the supplier selection problem by using fuzzy hierarchical TOPSIS approach. Cost, processing flexibility, on-time delivery and response to change were defined as supplier selection criteria. Lee and his colleagues (2009) proposed a green supplier selection model for high tech industry. Quality (quality related certificates, capability of quality management, etc.), finance (past finance performance, stability of finance, price, etc.), organization (attitudes of managers, future strategy direction, etc.), technology management (technology level, ability of design, ability of research and development, etc.), service (credible delivery, flexibility, etc.), total product life cycle cost, green image, pollution control and environmental management are the key supplier selection criteria in this research.

Kuo et. al. (2010) studied green supplier selection problem and they chose the selection criteria like quality (reject rate, quality assurance, process improvement, etc.), cost (price performance value, transportation cost, etc.), delivery (order fulfill rate, lead time, etc.), service (inventory control, responsiveness, design ability etc.), environment (ozone depleting chemicals, restriction of hazardous substance, etc.) and corporate social responsibility (respect for the policy, the rights of stakeholder, information disclosure, etc).

As a result of the literature research, environmental criteria are classified into four main categories that are environment protection and management, pollution control, green product and green image (Humphreys et. al., 2003a; Kuo et. al., 2010; Lee et. al., 2009). Environment protection system certification, environment efficiency, energy using products, restriction of hazardous substances and environmental protection policies/plans take part into the category of environment protection and management.

Environment Protection System Certification: Suppliers should have some environmental certificate documents (ISO 14000, etc.) (Lu et. al., 2007).

Environment Efficiency: Production process should be ecologically productive (Humphreys et. al., 2003a).

Energy Using Products: According to product design, energy usage should be minimum level (Büyüközkan and Çifçi, 2012).

Restriction of Hazardous Substances: It should be important that the level of hazardous substances in the production process (Kuo and Lin, 2012).

Environmental Protection Policies/Plans: Supplier should behave with compliance on the local regulations and policies (Büyüközkan and Çifçi, 2012).

Pollution control category involves the criteria of air emissions, waste water, pollution control initiatives and pollution reduction capability (Tuzkaya et. al., 2009).

Air Emissions: Supplier should control the quantity of hazardous emissions such as SO_2, CO, NH_3, HC_1 etc. and they should be treated (Tuzkaya, et. al., 2009).

Waste Water: Supplier should control the quantity of waste water and manage the treatment of it (Tuzkaya, et. al., 2009).

Pollution Control Initiatives: Supplier should have initiatives to minimize its pollution in the areas of energy usage, disposal of waste water, hazardous and harmful materials, solid wastes and air emissions (Tuzkaya, et. al., 2009).

Pollution Reduction Capability: Supplier should have the capability to use a number of systems to reduce pollution (Tuzkaya, et. al., 2009).

Recycling, green raw materials, green packaging, cost of component disposal, green certifications, green production, reusing, remanufacturing and disposal are the sub-criteria of the green product category.

Recycle: Supplier should be able to use its used products or parts of that product when producing new products (Lee et. al., 2009).

Green Raw Materials: Supplier should choose raw materials and materials that are environmentally friendly during production process (Yazdani et. al., 2017).

Green Packaging: Supplier should prefer to use recyclable materials during packaging process (Büyüközkan and Çifçi, 2012).

Cost of Component Disposal: Supplier should reduce the cost of product disposal by giving importance to recycling activities after the product becomes unusable (Lee et. al., 2009).

Green Certifications: Supplier should provide a number of green certifications for the products when it produces (Humphreys et. al., 2003a).

Green Production: Supplier should use environmentally friendly production technologies (Kuo et. al., 2010).

Reuse: Supplier should design and produce products with reusable properties (Kuo et. al., 2010).

Remanufacture: Supplier should separate the useful parts from the used products for future usage (Lee et. al., 2009).

Disposal: When the product completes its life cycle, it must be disposed of or burned without damaging the environment (Lee et. al., 2009).

Now, green image category is analyzed in detail.

Used Materials' Harmful Effects on the Natural Resources: The damage on natural resources is an important issue. So supplier should prefer to use the materials that should have lower damage on the natural resources in the manufacturing process (Yeh and Chuang, 2011).

Ability to Alter Process and Product for Reducing the Impact on Natural Resources: Supplier should have a capability to change the process and the design of product to prevent and decrease harmful effect on the natural resources (Lee et. al., 2009).

Ratio of Green Customers to Total Customers: It should be important for the supplier that the proportion of the green customers to the total customer should be high (Lee et. al., 2009).

Stakeholder's Relationship: Suppliers and their business partners should be involved in environmentally activities and initiatives (Büyüközkan and Çifçi, 2012).

Green Materials Coding and Recording: Supplier should code its materials and they should be recorded as hazardous and non-hazardous substances in storage to prevent material mixing (Hsu and Hu, 2009).

2.7.3. Innovative Criteria

Concurrently, companies have begun to give importance to innovative activities to sustain their lives successfully in the increasingly competitive environment. For instance, Luzzini and his colleagues (2015) conducted a study to identify the supplier collaboration on the impact of the company's innovative performance. Schiele (2006) also studied to determine the innovative supplier and aimed to set up a theoretical link between purchasing and innovation. Upadhyay and Baglieri (2012) underlined the importance of the innovation and they focused on the key success factors for the selection of the innovative suppliers.

Innovative criteria are classified into three main groups: Technical criteria, Research and Development (R&D)/ New Product Development (NPD) and Organizational / Cultural criteria. These criteria will be defined in below respectively.

Technology capabilities, level of IT systems and technical resources, technical capabilities and information level of personnel are the sub criteria of technical criteria group (Dasgupta and Gupta, 2009; Rouyendegh and Saputro, 2014; Hoetker, 2005).

Technology Capabilities: Supplier should have an ability to understand and adopt new technologies into its process immediately (Petersen et. al., 2005).

Level of IT Systems and Technical Resources: Supplier should have information systems and technical equipment related to demand forecasts, customer services and inventory management (Dasgupta and Gupta, 2009).

Technical Capabilities and Information Level of Personnel: Technical knowledge and skills of employees of suppliers should be at the desired level (Sarkis and Talluri, 2006).

R&D capabilities, capabilities of NPD, team work between departments along NPD process, R&D budget and return of investment (ROI) on R&D projects are the criteria of R&D / NPD category (Pulles et. al., 2014; Baumann and Kritikos, 2016; Seman et. al., 2012; Lee et. al., 2009).

Research and Development (R&D) Capabilities: Supplier should have a capability on R&D activities (Pulles et. al., 2014).

Capabilities of New Product Development (NPD): Supplier should have an ability to respond the current and future requests for the NPD activities (Seman et. al., 2012).

Team Work between Departments along NPD Process: Team working between departments along NPD process should be an important issue for the supplier (Petersen et. al., 2005).

R&D Budget: Supplier should allocate a sufficient budget on R&D activities (Becker and Dietz, 2004).

Return of Investment (ROI) on R&D Projects: ROI on R&D activities of supplier should be maximum level (Baumann and Kritikos, 2016).

Organizational / Cultural category covers level of innovation of information of personnel, cooperation with partners, commitment of senior management to innovation, success and number of innovative projects at past criteria (Sarkis and Talluri, 2006; Luzzini et. al., 2015; Sarkis and Talluri, 2006; Kuo et. al., 2010).

Level of Innovation Information of Personnel: It is important that supplier’s each employee should be an ability to accomplish innovative activities (Rouyendegh and Saputro, 2014).

Cooperation with Partners: Supplier should be a good cooperation with business partners (Pulles et. al., 2014).

Commitment of Senior Management to Innovation: Attitudes and behaviors of senior management of supplier are the key factor on the innovative activities (Sarkis and Talluri, 2006).

Success and Number of Innovative Projects at Past: The number and the success of innovative projects at past of supplier are important (Lee et. al., 2009).

2.8. Supplier Selection and Evaluation

According to Nazeri et. al. (2011), supplier evaluation and selection process is an important issue in the supply chain and they also underlined that this process is multi criteria decision making (MCDM) because many criteria can be considered in supplier selection process. In the past, various mathematical methods based on specific and certain data with single objective have been used for the solution of the supplier selection problem. However, the situation encountered in real life is not so simple. When it comes to supplier selection problems, data usually are vague and inaccurate or incomplete and also they are not intended to optimize a single objective. Therefore, often multi-criteria decision-making (MCDM) techniques in the solution of these problems are preferred.

The literature shows that many researchers use the MCDM technique for solving the problem of supplier selection. Önüt and colleagues (2009) proposed a combined fuzzy MCDM approach for the supplier selection in long-term period. To determination of the best and proper supplier, they used fuzzy ANP and TOPSIS techniques in their study.

Agarwal et. al. (2011) examined sixty-eight research articles including eight review articles that published between years of 2000-2011. As a result of this review article, the distribution of MCDM methods used in these articles as follows: Genetic Algorithm (GA): 2 %; Case Based Reasoning (CBR): 11 %; Data Envelopment Analysis (DEA): 30 %; mathematical programming models: 17 %; Analytic Hierarchy Process (AHP): 15 %; Fuzzy Set Theory: 10 %; Analytic Network Process (ANP): 5 %; Simple Multi-Attribute Rating Technique (SMART): 3 % and PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations): 7 % (Senvar, 2014).

Govindan et. al. (2015) published a report that the goal and purpose of it is to evaluate research in international scientific journals and international conference proceedings made in from 1997 to 2011 that focus on green supplier evaluation and selection. According to this review, many researchers examine different MCDM techniques for the solution of this complex problem.

Many researchers have used fuzzy AHP (Fuzzy Analytic Hierarchy Process) and fuzzy TOPSIS (Fuzzy Technique for Order of Preference by Similarity to Ideal Solution) separately in solving supplier selection problem. Junior et. al. (2014) proposed a comparative analysis report of these two methods in supplier selection decision making process. According to the results of the studies, both methods are suitable for the supplier selection problem. However, they showed that fuzzy TOPSIS method is better suited for the supplier selection process in regard to changes of alternatives and criteria, agility and number of criteria and alternative suppliers.

In 2015, Galankashi et. al. determined the critical performance measures to select the green supplier by using fuzzy ANP (Fuzzy Analytic Network Process). They defined ten key performance indicators for the green supplier selection. These are price, quality, reputation, service and delivery, distance, use of green materials, air emission level, waste level, energy efficiency and green design capability.

Supplier selection has been considered a group multi criteria decision making (GMCDM) problem. Decision makers' opinions have been collected in the form of linguistic terms and then they have been converted to trapezoidal fuzzy numbers. Fuzzy Vikor approach has been used to supplier selection problem (Shemshadi et. al., 2011). On the other hand, Kannan et. al. (2015) proposed a multi criteria decision making approach called Fuzzy Axiomatic Design (FAD) to select the best green supplier for Singapore based plastic manufacturing company.

As a result of the literature research, it has been seen that many different MCDM approaches that are summarized in Table 2.3 were applied for the selection of best and proper supplier in the supply chain. At the next step of this study, a combined model of AHP and fuzzy AHP with the MCDM techniques such as ANP, fuzzy ANP, TOPSIS, fuzzy TOPSIS, GP, VIKOR and fuzzy VIKOR will be proposed to select the best greenovative supplier for the automobile industry.

Table 2.3. Summary of different applied MCDM methods for supplier selection and evaluatin process.

Author(s)	Methodology Used	Application Area
Fallahpour et. al., (2017)	Fuzzy Preference Programming with fuzzy TOPSIS	Iranian textile industry
Dweiri et. al., (2016)	Integrated AHP based decision support system	Automobile industry in Pakistan
Wu et. al., (2016)	The extended VIKOR method	Nuclear power industry in China
Rouyendegh and Saputro, (2014)	Integrated fuzzy TOPSIS and MCGP	Fertilizer industry
Galankashi et. al., (2016)	Mixed Balanced Scorecard and fuzzy AHP	Automobile industry
Galankashi et. al., (2015)	FANP	Electrical industry
Prakash and Barua, (2016)	Fuzzy AHP and VIKOR	Indian electronics industry
Mavi et. al., (2016)	Shannon entrophy and Fuzzy TOPSIS	Motorcycle spare parts manufacturing industry
You et. al., (2015)	Extended VIKOR method	Health care sector
Lima Junior et. al., (2014)	Fuzzy AHP and fuzzy TOPSIS	Transmissions cables for motorcycles manufacturer
Karsak and Dursun, (2014)	Integrated QFD and DEA	Health care sector
Lu et. al., (2007)	AHP	Electronics industry
Tuzkaya et. al., (2009)	Fuzzy ANP and PROMETHEE	White goods manufacturing industry in Turkey
Kannan et. al., (2015)	Fuzzy Axiomatic Design	Plastic raw material manufacturing
Jadidi et. al., (2015)	Improved multi choice goal programming	
Wen and Chi, (2010)	DEA with AHP and ANP	

Table 2.3. continued.

Author(s)	**Methodology Used**	**Application Area**
Büyüközkan and Çifçi, (2012)	Fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS	Automotive industry in Turkey
Büyüközkan and Güleryüz, (2016)	Integrated DEMATEL and ANP approach	Renewable energy resources
Kabak et. al., (2012)	Combination of fuzzy ANP fuzzy TOPSIS and fuzzy ELECTRE	Personnel selection
Kannan et. al., (2014)	Fuzzy TOPSIS	Electronics company in Brasil
Kumar et. al., (2014)	Green DEA	Automobile spare parts manufacturing in India
Mahdiloo et. al., (2015)	DEA	Steel making company in Korea
Chamodrakas et. al., (2010)	Fuzzy AHP	Metal manufacturing company
Zak, (2015)	ELECTRE III/IV and AHP	Diffrent industries
Lee et. al., (2009)	Delphi and fuzzy extended AHP	High-tech industry
Shen et. al., (2013)	Fuzzy TOPSIS	Automotive industry
Hsu et. al., (2013)	DEMATEL	Electronics manufacturing industry
Kuo and Lin, (2012)	DEA and ANP	High-tech industry
Humphreys et. al., (2003b)	Knowledge based system and CBR	Telecommunication company
Li and Zhao, (2009)	Grey correlation analysis and AHP	Electronics industry
Chen et. al., (2010)	Fuzzy set theory and grey relational analysis	Electronics industry
Famuyiwa et. al., (2008)	Fuzzy goal programming	Automotive industry

3- RESEARCH METHODOLOGY

3.1. Greenovative Supplier Selection Process

Company A is a small and medium-sized enterprise operating in the automotive industry in Istanbul. In this study, the selection of the preferable greenovative supplier is aimed and flow chart is shown in Figure 3.1.

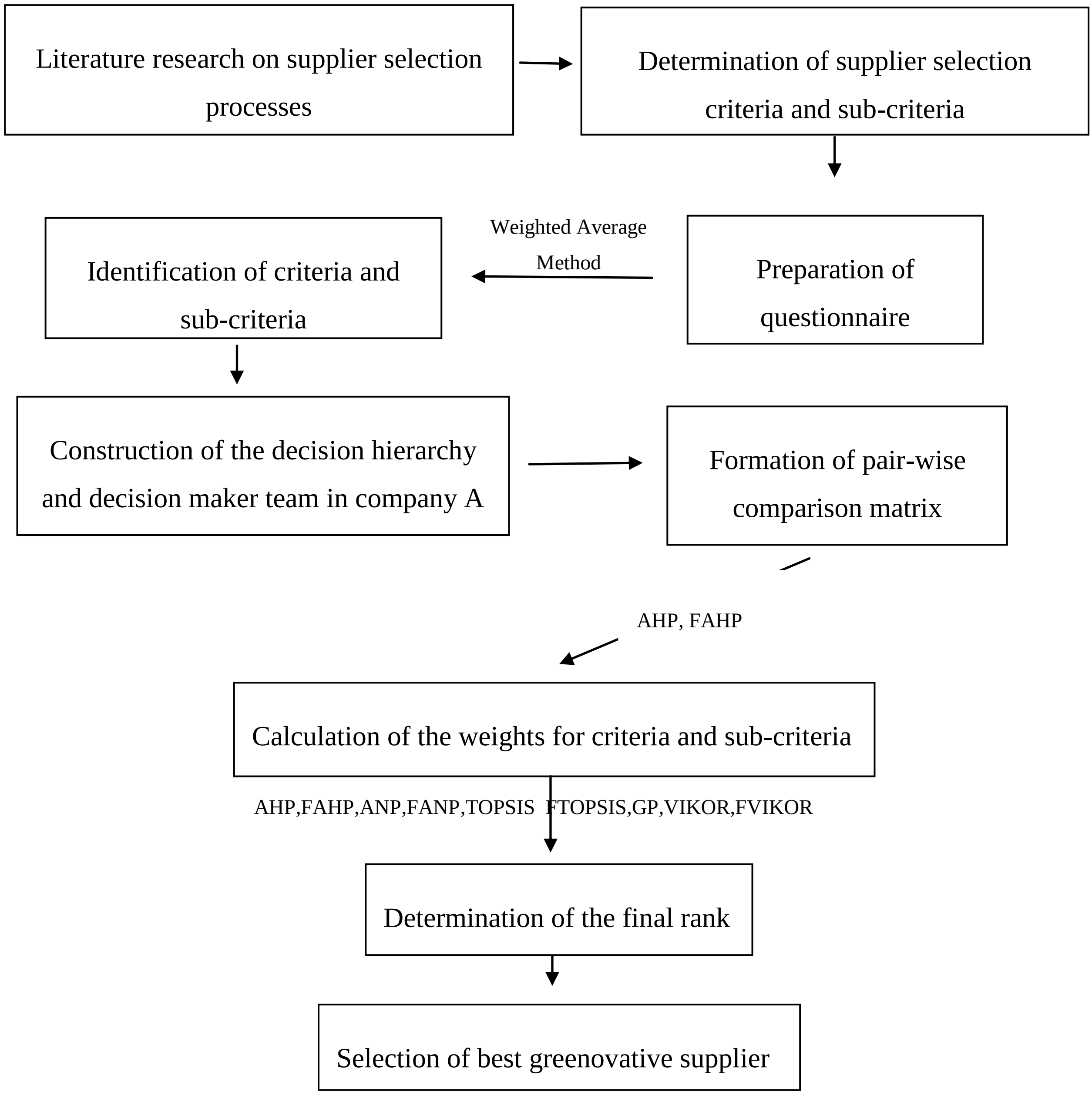


Figure 3.1. Flow chart for the greenovative supplier selection process.

As mentioned earlier, the first and most important issue is to determine the best and preferable supplier for the sustainability of the successful supply chain management. For this reason, supplier selection criteria should be determined accurately and completely. As a result of literature survey, a set of traditional, environmental and innovative criteria are identified. And then prepared questionnaire is applied and results are evaluated to select nine sub criteria that have the highest score that is acquired from weighted average method. The hierarchical structure of problem is illustrated in Figure 3.2. To provide the objective, a decision maker team established in company A that includes company owner, general manager, purchasing department manager and an academician.

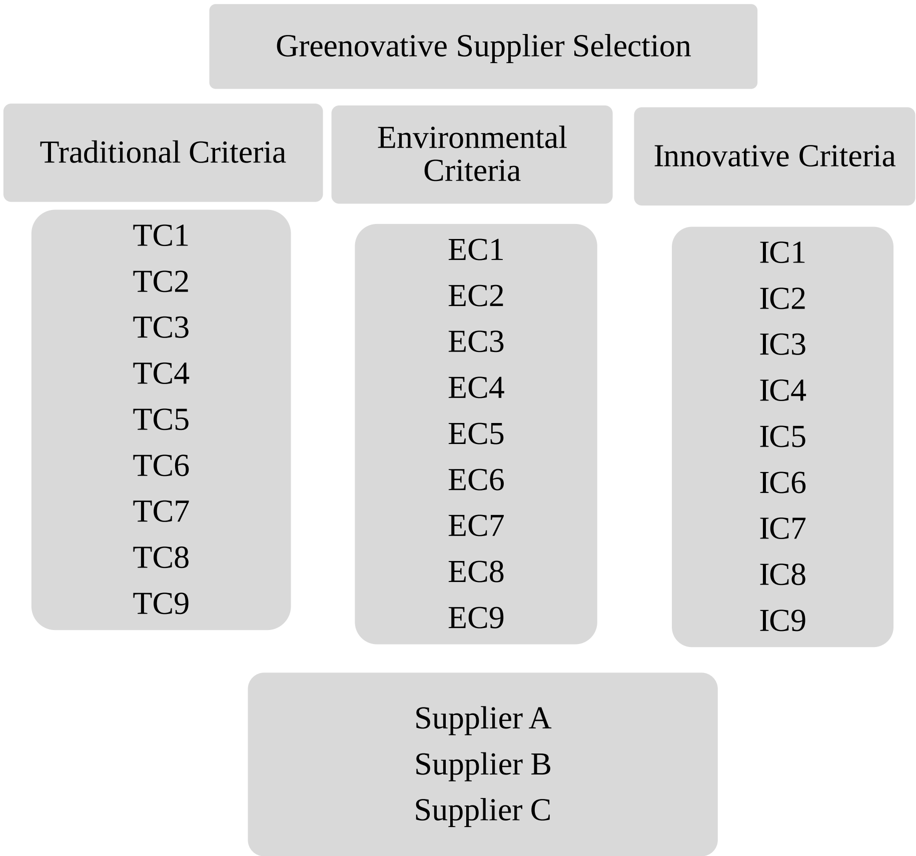


Figure 3.2. Proposed hierarchical structure to select the greenovative supplier.

The decision maker team evaluated criteria, sub-criteria and alternatives, pair wise comparison matrices are formed that are represented in the following tables. In the previous section, DSSs were explained. Some of them only use single MCDM methods and they serve a specific purpose. The others use hybrid MCDM methods. In this thesis, DESTEC 1.0 (Decision Support Tool for Enhanced Choose) and DEMATSEL (DEcision MAking Tool Designed to SELect) have been used to solve the existing problem. The weights of all criteria have been determined by using DESTEC 1.0 software (Yanar, 2011). It is developed by C Sharp Programming Language and uses Microsoft Excel for data entrance. The program consists of the four decision methods that are AHP, FAHP, ANP and FANP using the information provided by the decision maker and gives the rates of all alternatives for each method. The steps of the usage of the software are seen in the flow diagram in Figure 3.3.

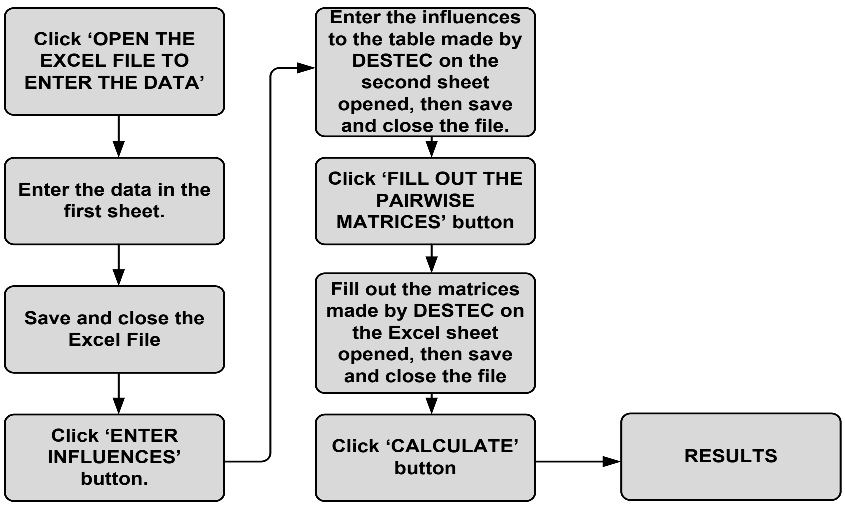


Figure 3.3. Flow diagram for usage DESTEC 1.0 (Yanar, 2011).

Because of the lack of a DSS that covers integrate multiple techniques and their fuzzy applications initialized with another MCDM technique for weight determination purpose, Karacan developed DEMATSEL in 2015. It provides reliable and robust solutions for the selection problems. It is a compact and hybrid MCDM tool that consists of AHP and FAHP for weight determination integrated with TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP to rank the alternatives. DEMATSEL is created with C# Language based on .NET framework 4.0. It is a Windows Form Application with a tab-based GUI. Open source Microsoft Solver Foundation library is integrated for solving goal programming and open source graph library ZedGraph is integrated for drawing ranking charts. It is composed of seven tabs that are Welcome Tab, Alternatives Tab, Values Tab, Weights Tab, AHP Weights Tab and Solution Tab which activate in process order. By using these solvers, the weights of criteria and sub criteria are determined with AHP and FAHP approaches. At the last step, by using different MCDM techniques (such as AHP, FAHP, ANP, FANP, TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP), suppliers are ranked according to the evaluations criteria and sub-criteria for company A.

3.2. Supplier Selection Criteria Determination via Questionnaire

In this study, it is aimed to a greenovative supplier selection model including not only the traditional criteria but also environmental and innovative criteria. A questionnaire is prepared containing the traditional, environmental and innovative criteria and applied to small and medium-sized enterprises (SMEs) operating in the automotive industry in Marmara Region. Traditional, environmental and innovative sub criteria that are located in the questionnaire have been determined according to the literature review in years of between 1999 and 2017, surveys and collaboration with the related stakeholders. Especially the criteria used frequently in the literature were included in the questinannaire. As a result of the research, 14 sub-criteria for traditional criteria, 23 sub-criteria for environmental criteria and 12 sub-criteria for innovative criteria were determined. Firstly 500 related firms that are the members of the Chamber of Commerce and Industry in İstanbul, Kocaeli, Yalova, Bursa, Sakarya, Edirne, Kırklareli, Tekirdağ, Balıkesir, Çanakkale and Bilecik are defined in this sector and the information of firms are also obtained from the Association of Automotive Parts and Components Manufacturers. Then this questionnaire is made to them by face to face or electronically. Questionnaire has been represented in Appendix A in English language and Appendix B in Turkish language (original language). Evaluation was made due to the five-point interval scale. The return rate of the questionnaire is approximately 30 %. After that the evaluation of the questionnaire results, weighted average method was used to determine the weight of each criterion to rank all criteria and results have been represented in Table 3.1.

Table 3.1. Weighted average values of all criteria.

Category	Criteria	Weighted Average
TC* -Quality	Quality Systems	4.443
	Reject Rate	4.436
	Return Policies and Warranties	4.685
	Compensation for Faulty Quality	4.779
TC-Price	Purchasing Price	3.638
	Price Performance Value	4.054
	Transportation Cost	4.315
TC-Capability of Supplier / Delivery	Supplier Involvement	4.624
	Supplier Technique Capability	4.685
	Order Fulfil Rate	4.631
	Technology Level	4.530
	Flexibility of the Supplier	4.295
	Supplier Inventory Management	4.517
	Lead Time	4.611
EC** -Environment Protection and Management	Environment Protection System Certification	3.987
	Environment Efficiency	4.100
	Energy Using Products	4.289
	Restriction of Hazardous Substances	4.664
	Environmental Protection Policies / Plans	4.362
EC-Pollution Control	Air Emissions	4.658
	Waste Water	4.644
	Pollution Control Initiatives	4.490
	Pollution Reduction Capability	4.403

Table 3.1. continued.

Category	Criteria	Weighted Average
EC-Green Product	Recycle	4.020
	Green Raw Materials	4.478
	Green Packaging	4.570
	Cost of Component Disposal	4.275
	Green Certifications	4.027
	Green Production	4.289
	Reuse	4.208
	Remanufacture	4.100
	Disposal	4.329
EC-Green Image	Used Materials Effects on Natural Resources	4.591
	Ability to Alter Process and Product	4.436
	Ratio of Green Customers to Total Customers	4.040
	Stakeholder's Relationship	4.054
	Green Materials Coding and Recording	4.530
IC*** - Technical	Technology Capabilities	4.436
	Level of IT Systems and Technical Resources	4.389
	Technical Capabilities and Information Level	4.497
IC-R&D / NPD	R&D Capabilities	4.409
	Capabilities of NPD	4.403
	Team Work	4.450
	R&D Budget	4.188
	ROI on R&D Projects	4.349
IC-Organizational Cultural	Level of Innovation Information of Personnel	4.020
	Cooperation with Partners	4.430
	Commitment of Senior Management	4.436
	Success and Number of Innovative Projects	4.148

*Traditional Criteria **Environmental Criteria ***Innovative Criteria

As a result of the evaluation; nine sub-criteria for each main criterion have been determined in order to reduce the complexity of the problem and the inconsistency in constructing the pairwise comparison matrix. Nine selection sub-criteria for each main selection criteria that have the highest weight are listed in the following tables 3.2, 3.3 and 3.4.

According to these weighted averages in shown Table 3.1, compensation for faulty quality (4.779), return policies and warranties (4.685), supplier technique capability (4.685), order fulfil rate (4.631), supplier involvement (4.624), lead time (4.611), technology level (4.530), supplier inventory management (4.517) and quality systems (4.443) are the selected sub criteria from the traditional main criteria group. Restriction of hazardous substances (4.664), air emissions (4.658), waste water (4.644), used materials' harmful effects on the natural resources (4.591), green packaging (4.570), green materials coding and recording (4.530), pollution control initiatives (4.490), green raw materials (4.478) and ability to alter process and product for reducing the impact on natural resources are the selected sub criteria from the environmental main criteria group. From the innovative main criteria group, technical capabilities and information level of personnel (4.497), team work between departments along new product development process (4.450), technology capabilities (4.436), commitment of senior management (4.436), cooperation with partners (4.430), R&D capabilities (4.409), capabilities of NPD (4.403), level of IT systems and technical resources (4.389), ROI on R&D projects (4.349) are the selected sub criteria.

The traditional, environmental and innovative sub-criteria, codes and their descriptions have been represented in the following tables (Table 3.2, Table 3.3 and Table 3.4). Also the researchers that used these criteria in their studies were represented in the tables.

Table 3.2. Definition of traditional sub-criteria.

Criteria Code	Criteria Name	Criteria Description	References
TC1	Compensation for faulty quality	Supplier should have the ability to compensate for defective products without any additional charge.	Yang and Wu, (2007); Hsu and Hu, (2009); Lee et. al., (2009); Kuo et. al., (2010); Tseng, (2011).
TC2	Return Policies and Warranties	Returns and agreements about the faulty products between the supplier and the customer are the important criteria.	Yang and Wu, (2007); Kuo et. al., (2010); Cao, (2011); Rouyendegh and Saputro, (2014); Büyüközkan and Göçer, (2017).
TC3	Supplier Technique Capability	Supplier should have sufficient techniques for scheduling and delivery activities.	Yang and Wu, (2007); Grisi et. al., (2010); Cao, (2011).
TC4	Order Fulfil Rate	Supplier should adapt quickly to predetermined order of quantities.	Kuo et. al., (2010); Büyüközkan and Göçer, (2017).
TC5	Supplier Involvement	Supplier should respond quickly to customer orders and have a capability to compensate delivery schedules and promises.	Chiou et. al., (2008); Kuo et. al., (2010); Tseng, (2011); Rouyendegh and Saputro, (2014).
TC6	Lead Time	Lead time that is defined as the time from when an order is placed by the customer to when the customer is delivered to that order should be minimum time.	Kuo et. al., (2010); Cao, (2011); Rouyendegh and Saputro, (2014); Büyüközkan and Göçer, (2017); Yazdeni et. al., (2017).
TC7	Technology Level	Supplier should have an ability to develop its technology for the current and future demand of the customer.	Lee et. al., (2009).
TC8	Supplier Inventory Management	Supplier should control the production line and inventory management system simultaneously.	Hsu and Hu, (2009); Grisi et. al., (2010); Kuo et. al., (2010).
TC9	Quality Systems	It is an important issue that supplier should have some quality indicators (for instance ISO 9000, QS9000 etc.) on the products.	Yang and Wu, (2007); Hsu and Hu, (2009); Büyüközkan and Göçer, (2017); Yazdani et. al., (2017).

Table 3.3. Definition of environmental sub-criteria.

Criteria Code	Criteria Name	Criteria Description	References
EC1	Restriction of Hazardous Substances	It should be important that the level of hazardous substances in the production process.	Kuo et. al., (2010); Tseng, (2011); Kuo and Lin, (2012); Yazdani et. al., (2017).
EC2	Air Emissions	Supplier should control the quantity of hazardous emissions such as SO_2, CO, NH_3, HC_1 etc. and they should be treated.	Handfield et. al., (2002); Humphreys et. al., (2003a); Lu et. al., (2007); Yeh and Chuang, (2011); Yazdani et. al., (2017).
EC3	Waste Water	Supplier should control the quantity of waste water and manage the treatment of it.	Humphreys et. al., (2003a); Lu et. al., (2007); Yeh and Chuang, (2011); Yazdani et. al., (2017).
EC4	Used materials' harmful effects on the natural resources	The damage on natural resources is an important issue. So supplier should prefer to use materials that should have lower damage on the natural resources in the manufacturing process.	Humphreys et. al., (2003a); Lee et. al., (2009); Yeh and Chuang, (2011); Yazdani et. al., (2017).
EC5	Green Packaging	Supplier should prefer to use recyclable materials in packaging process.	Handfield et. al., (2002); Chiou et. al., (2008); Lee et. al., (2009); Büyüközkan and Çifçi, (2012).
EC6	Green Materials Coding and Recording	Supplier should code its materials and they should be recorded as hazardous and non-hazardous substances in storage to prevent material mixing.	Hsu and Hu, (2009).

Table 3.3. continued.

Criteria Code	Criteria Name	Criteria Description	References
EC7	Pollution Control Initiatives	Supplier should have initiatives to minimize its pollution in the areas of energy usage, disposal of waste water, hazardous and harmful materials, solid wastes and air emissions.	Awasthi et. al., (2010).
EC8	Green Raw Materials	Supplier should prefer to use environmental friendly raw materials during manufacturing process.	Yazdani et. al., (2017).
EC9	Ability to Alter Process and Product for Reducing the Impact on Natural Resources	Supplier should have a capability to change the process and the design of product to prevent and decrease harmful effect on the natural resources.	Lee et. al., (2009).

Table 3.4. Definition of innovative sub-criteria.

Criteria Code	Criteria Name	Criteria Description	References
IC1	Technical Capabilities and Information Level of Personnel	Technical knowledge and skills of employees of suppliers should be at the desired level.	Hoetker, (2005); Sarkis and Talluri, (2006); Rouyendegh and Saputro, (2014).
IC2	Team Work Between Departments Along NPD Process	Team working between departments along NPD process should be an important issue for the supplier.	Petersen et. al., (2005); Lee et. al., (2009); Kuo et. al., (2010).
IC3	Technology Capabilities	Supplier should have an ability to understand and adopt new technologies into its process immediately.	Petersen et. al., (2005); Lee et. al., (2009); Rouyendegh and Saputro, (2014).

Table 3.4. continued.

Criteria Code	Criteria Name	Criteria Description	References
IC4	Commitment of Senior Management to Innovation	Attitudes and behaviours of senior management of supplier are the key factor on the innovative activities.	Daellenbach, (1999); Sarkis and Talluri, (2006).
IC5	Cooperation with Partners	Supplier should be a good cooperation with business partners.	Hoetker, (2005); Sarkis and Talluri, (2006); Pulles et. al., (2014); Luzzini et. al., (2015).
IC6	Research and Development (R&D) Capabilities	Supplier should have a capability on R&D activities.	Becker and Dietz, (2004); Lee et. al., (2009); Pulles et. al., (2014).
IC7	Capabilities of New Product Development (NPD)	Supplier should have an ability to respond the current and future requests for the NPD activities.	Yang and Wu, (2007); Lee et. al., (2009); Kuo et. al., (2010); Seman et. al., (2012); Luzzini et. al., (2015).
IC8	Level of IT Systems and Technical Resources	Supplier should have information systems and technical equipment related to demand forecasts, customer services and inventory management.	Dasgupta and Gupta, (2009); Jean and Sinkovics, (2010).
IC9	Return of Investment (ROI) on R&D Projects	ROI on R&D activities of supplier should be maximum level.	Baumann and Kritikos, (2016); Lopez-Rodriguez and Martinez-Lopez, (2017).

3.3. Evaluation of Supplier Selection Criteria and Sub-Criteria

Decision maker team that established in the company A evaluated the supplier selection criteria by using linguistic terms that are shown in Table 3.5.

Table 3.5. Linguistic variables describing weights of the criteria (Yılmaz, 2012).

Definition	Triangular Fuzzy Scale	Reciprocal Fuzzy Scale
Equally important	(1,1,1)	(1,1,1)
Weakly more important	(2/3,1,3/2)	(2/3,1,3/2)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(5/2,3,7/2)	(2/7,1/3,2/5)
Absolutely important	(7/2,4,9/2)	(2/9,1/4,2/7)

Bilateral comparison matrix of main supplier selection criteria that determined by the unanimity of the decision maker team are shown in the following Table 3.6.

Table 3.6. Main supplier selection criteria evaluation results.

	Traditional Criteria	Environmental Criteria	Innovative Criteria
Traditional Criteria	(1,1,1)	(2/3,1,3/2)	(1,1,1)
Environmental Criteria	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
Innovative Criteria	(1,1,1)	(2/3,1,3/2)	(1,1,1)

Bilateral comparison matrix of traditional sub-criteria that determined by the unanimity of the decision maker team are shown in the following Table 3.7. Bilateral comparison matrix of environmental sub-criteria that determined by the unanimity of the decision maker team are shown in the following Table 3.8. Bilateral comparison matrix of innovative sub-criteria that determined by the unanimity of the decision maker team are shown in the following Table 3.9.

Table 3.7. Traditional sub-criteria evaluation results.

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9
TC1	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(3/2,2,5/2)	(5/2,3,7/2)	(3/2,2,5/2)
TC2	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/5,1/2,2/3)	(1,1,1)	(1,1,1)	(1,1,1)
TC3	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)
TC4	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(3/2,2,5/2)
TC5	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(3/2,2,5/2)
TC6	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(3/2,2,5/2)
TC7	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)
TC8	(2/7,1/3,2/5)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
TC9	(2/5,1/2,2/3)	(1,1,1)	(1,1,1)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)

Table 3.8. Environmental sub-criteria evaluation results.

	EC1	TC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9
EC1	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)
EC2	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
EC3	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
EC4	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)
EC5	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)
EC6	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)
EC7	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)
EC8	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)
EC9	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)

Table 3.9. Innovative sub-criteria evaluation results.

	IC1	IC2	IC3	IC4	IC5	IC6	IC7	IC8	IC9
IC1	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)
IC2	(2/5,1/2,2/3)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)
IC3	(2/3,1,3/2)	(3/2,2,5/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)
IC4	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)
IC5	(3/2,2,5/2)	(5/2,3,7/2)	(2/3,1,3/2)	(3/2,2,5/2)	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)
IC6	(2/3,1,3/2)	(3/2,2,5/2)	(2/3,1,3/2)	(2/3,1,3/2)	(2/5,1/2,2/3)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)
IC7	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)
IC8	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)
IC9	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)

Decision team in the company A evaluated supplier A (Spr A), supplier B (Spr B) and supplier C (Spr C) for each selection criteria. Comparison pair wise matrices for suppliers are shown in the following tables.

Table 3.10. Evaluation results for suppliers due to sub-criteria of TC1.

TC1	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1/5
Spr B	3	1	1/3
Spr C	5	3	1

Table 3.11. Evaluation results for suppliers due to sub-criteria of TC2.

TC2	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1/3
Spr B	3	1	1
Spr C	3	1	1

Table 3.12. Evaluation results for suppliers due to sub-criteria of TC3.

TC3	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.13. Evaluation results for suppliers due to sub-criteria of TC4.

TC4	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1/3
Spr B	1	1	1/3
Spr C	3	3	1

Table 3.14. Evaluation results for suppliers due to sub-criteria of TC5.

TC5	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1/3
Spr B	3	1	1
Spr C	3	1	1

Table 3.15. Evaluation results for suppliers due to sub-criteria of TC6.

TC6	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1/5
Spr B	3	1	1/3
Spr C	5	3	1

Table 3.16. Evaluation results for suppliers due to sub-criteria of TC7.

TC7	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.17. Evaluation results for suppliers due to sub-criteria of TC8.

TC8	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.18. Evaluation results for suppliers due to sub-criteria of TC9.

TC9	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.19. Evaluation results for suppliers due to sub-criteria of EC1.

EC1	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1
Spr B	3	1	3
Spr C	1	1/3	1

Table 3.20. Evaluation results for suppliers due to sub-criteria of EC2.

EC2	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1/3	1
Spr B	3	1	3
Spr C	1	1/3	1

Table 3.21. Evaluation results for suppliers due to sub-criteria of EC3.

EC3	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.22. Evaluation results for suppliers due to sub-criteria of EC4.

EC4	**Spr A**	**Spr B**	**Spr C**
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.23. Evaluation results for suppliers due to sub-criteria of EC5.

EC5	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.24. Evaluation results for suppliers due to sub-criteria of EC6.

EC6	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.25. Evaluation results for suppliers due to sub-criteria of EC7.

EC7	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.26. Evaluation results for suppliers due to sub-criteria of EC8.

EC8	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.27. Evaluation results for suppliers due to sub-criteria of EC9.

EC9	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.28. Evaluation results for suppliers due to sub-criteria of IC1.

IC1	Spr A	Spr B	Spr C
Spr A	1	1	1/3
Spr B	1	1	1/3
Spr C	3	3	1

Table 3.29. Evaluation results for suppliers due to sub-criteria of IC2.

IC2	Spr A	Spr B	Spr C
Spr A	1	1	1/3
Spr B	1	1	1/3
Spr C	3	3	1

Table 3.30. Evaluation results for suppliers due to sub-criteria of IC3.

IC3	Spr A	Spr B	Spr C
Spr A	1	1	1/3
Spr B	1	1	1/3
Spr C	3	3	1

Table 3.31. Evaluation results for suppliers due to sub-criteria of IC4.

IC4	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

Table 3.32. Evaluation results for suppliers due to sub-criteria of IC5.

IC5	Spr A	Spr B	Spr C
Spr A	1	1/3	1/5
Spr B	3	1	1/3
Spr C	5	3	1

Table 3.33. Evaluation results for suppliers due to sub-criteria of IC6.

IC6	Spr A	Spr B	Spr C
Spr A	1	1	1/3
Spr B	1	1	1/3
Spr C	3	3	1

Table 3.34. Evaluation results for suppliers due to sub-criteria of IC7.

IC7	Spr A	Spr B	Spr C
Spr A	1	1/3	1/3
Spr B	3	1	1/3
Spr C	3	3	1

Table 3.35. Evaluation results for suppliers due to sub-criteria of IC8.

IC8	Spr A	Spr B	Spr C
Spr A	1	1/3	1/5
Spr B	3	1	1/3
Spr C	5	3	1

Table 3.36. Evaluation results for suppliers due to sub-criteria of IC9.

IC9	Spr A	Spr B	Spr C
Spr A	1	1	1
Spr B	1	1	1
Spr C	1	1	1

3.4. MCDM Techniques Used in Greenovative Supplier Selection Process

In this part, MCDM methods that are used in this study are explained briefly.

3.4.1. Analytic Hierarchy Process (AHP)

In 1970s, Thomas L. Saaty was developed Analytic Hierarchy Process (AHP) to handle the complicated decision making problems. The method aims to find the right solution to contribute the decision makers' preferences due to the goal. AHP is widely used in many application areas such as education, agriculture, healthcare, business, transportation etc. (https://en.wikipedia.org/wiki/Analytic_hierarchy_process).

AHP is a comprehensive and a rational method, aims to solve problems, taking goal, criteria and sub criteria into consideration. By using this method, decision makers divide decision problem into sub problems which they are able to be analysed separately in a hierarchical structure. Decision makers generate pair wise comparison matrix, satisfying the gaol at the top the level of hierarchy after hierarchical structure is established. While doing this comparison, tangible concepts are used in addition to aim determination of importance level of elements. AHP converts this evaluation results into numerical values. A numerical value or a priority is calculated for each element in the hierarchy. And high attention is paid on keeping all comparisons consistent (Saaty, 2008).

Models are developed according to the objective and certain data assumption in many studies conducted in the supplier selection problem. However, in real life during the decision process, a lot of information contains ambiguity, inconsistency and subjectivity. But such data types are not used in the classical decision models. So, fuzzy set theory emerges as a valuable method that takes into account these facts. The linguistic variables used in the fuzzy multiple criteria decision making methods provide the inclusion of the decision makers' opinion (subjectivity and ambiguity) into the model (Yılmaz, 2012).

Analytic Hierarchy Process (AHP) is one of the most important approaches for the determination of the best supplier (Senvar, 2014). Although AHP used frequently, it has many shortcomings (Ayağ and Özdemir, 2006). These are:

- This method is generally used in decision making problems for net decisions
- This methods allows and interests with the inequable scale of decisions
- This method does not regard the ambiguity in the decision maker's preference
- This method gives the ranking that has a lack precision
- This method is affected intensely from the decision maker's preference and selection

In AHP method, the decision problem is decomposed into a hierarchy of sub-problems which can be perceived more easily and subjectively evaluated. AHP steps follow as (Triantaphyllou, 2000):

Step 1. The decision problem is formed as a hierarchy that goal at the top level, criteria with sub-criteria at the middle level and alternatives at the bottom level. The formation of hierarchy is the significant step of the AHP method. The hierarchical structure provides a relationship between top, middle and bottom levels. Figure 3.4 shows a generic hierarchic structure (Saaty, 2008).

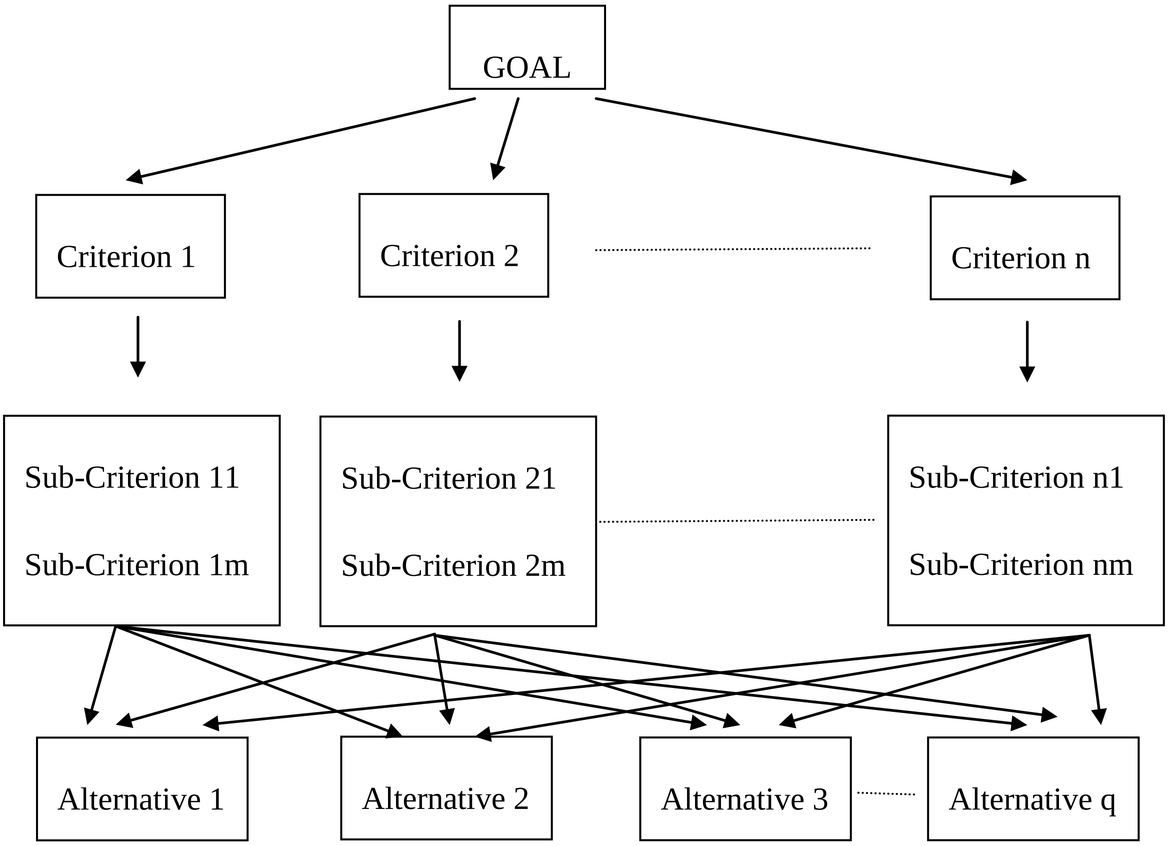


Figure 3.4. Generic hierarchic structure (Saaty, 2008).

The goal or objective of the decision problem is at the root of the hierarchy. The leaf nodes are the alternatives to be compared. In between these two levels are diverse criteria and sub-criteria.

Step 2. Data are collected from decision makers or experts and they can rate the comparison as equal, high importance, strong importance, very strong importance and extreme importance.

Step 3. The square matrix from the pair wise comparisons of various criteria is determined. While preparing comparison matrix, factors in the rows are compared to factors in the columns by their importance levels. Cell value should be 1 when comparing the same factors. For example, if the importance of the first factor at the row has higher importance than the second factor at the column, cell value should be set as 3. The value should be set 1/3 vise versa. Comparison of alternatives is made according to the Table 3.37 (Saaty, 2008).

Table 3.37. Importance value(s) for situations in comparison process (Saaty, 2008).

Situations	Value(s)
Equal importance of both factors	1
Moderate importance of one factor over another	3
Strong importance of one factor over another	5
Very strong importance of one factor over another	7
Extreme importance of one factor over another	9
Intermediate values between two adjacent judgements	2,4,6,8

Step 4. In this step, normalized pair wise comparison matrices are prepared by dividing each column value to column summary. After that, priority vector is determined for each row by calculating rows' average.

Step 5. In this step, the consistency of the matrix is evaluated. Comparisons are subjective in AHP method and it tolerates inconsistency through the amount of redundancy in the approach. The consistency index CI, is calculated below:

$$CI = (\lambda_{max} - n) / (n - 1) \quad (3.1)$$

where λ_{max} is the maximum eigenvalue of the judgement matrix. This CI can be compared with that of a random matrix, RI. The term of consistency ratio is derived from CI / RI and CR value should be less than 0.1 (Saaty, 2008).

Step 6. In this step, the degree of each alternative is multiplied with the weights of the sub-criteria and aggregation is made to obtain local ratings according to all criteria. After that they are multiplied by the weights of the criteria and aggregation is made to obtain global ratings (Triantaphyllou, 2000).

3.4.2. Analytic Network Process (ANP)

Analytic Network Process (ANP) was developed by Thomas L. Saaty in 1996 is a more general form of AHP used in multi-criteria decision analysis and allows for more complex interdependent relationships among elements (Cheng and Li, 2004).

When compared AHP and ANP, AHP forms the decision problem in a hierarchy structure, on the other hand, ANP forms it in a network structure. In two decision making approaches, the weights of the criteria and alternatives are determined by using pair wise comparison matrices for the decision problem. Finally, it allows ordering the alternatives due to their importance level.

In real life, many decision problems cannot be structured in a hierarchy model because there may be interactions and dependences of higher-level elements in a hierarchy on lower-level elements (Saaty, 2005).

ANP is the first methodology to demonstrate systematically all kinds of dependencies and feedback between criteria and sub-criteria influencing the decision making process (Ömürbek et. al., 2013). Feedback lets decision makers to factor the future into the current situation to define what they have to do to reach in a desired future. ANP is also defined systems-with-feedback approach (Meade and Sarkis, 1998).

The biggest difference between analytic hierarchy process and analytic network process is the interaction of both decision points and evaluation factors of analytic network process. In addition, analytic network process is a good solver in cases where it is not a good expression of quantitative factors. Figure 3.5 illustrates the hierarchical and network structures for ANP (Görener, 2012).

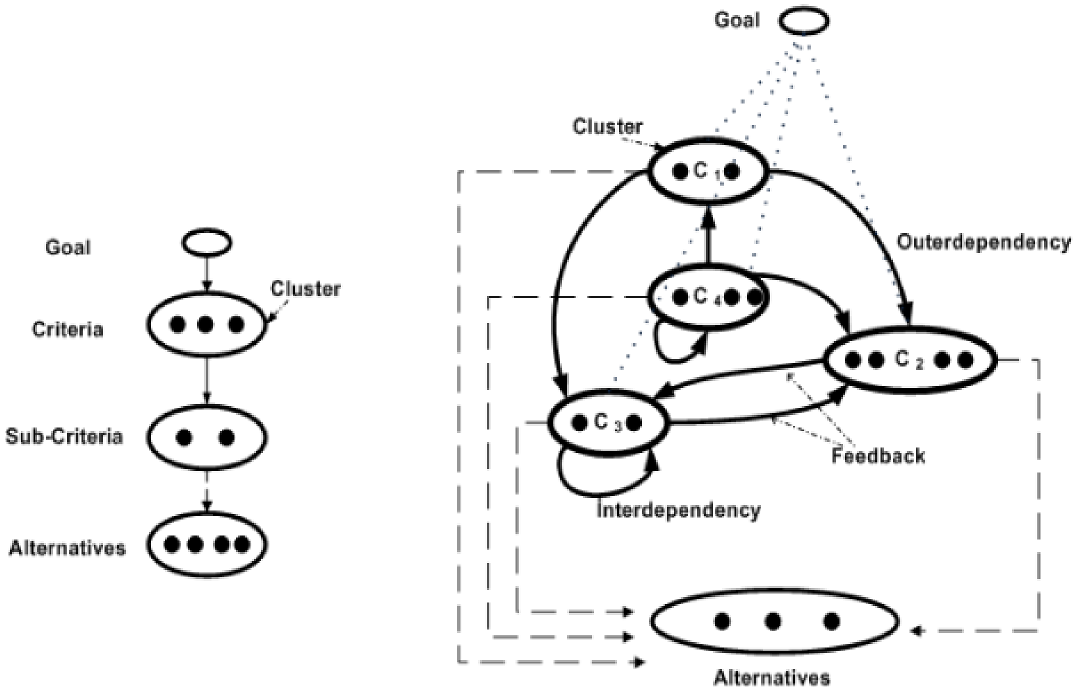


Figure 3.5. Hierarchical and network structures for ANP (Görener, 2012).

The steps of ANP are summarized as follows (Ömürbek et. al., 2013):

Step 1: Problem Definition and Modelling: At the first phase, the decision problem is defined clearly. The goal, main criteria, sub-criteria and alternatives are described. Model of the problem is established into a rational system like a network.

Step 2: Determination of Interaction between Criteria: Internal and external dependencies and if there is feedback between criteria should be associated.

Step 3: Pair-wise Comparisons Matrices and Priority Vectors: ANP is similar to AHP that pair-wise comparisons matrices for the main and sub-criteria are generated by the decision makers and then the relative importance weight of the each criterion is determined. In the ANP as the AHP, criteria that affecting the goal are subjected to pair-wise comparisons and thus the importance levels of criteria are determined. Decision makers in pair-wise comparisons by answering in a number of questions serially compare the two criteria at the same time and determine the contribution of them to the goal. In ANP, Saaty's 1-9 scale is used to determine the relative importance of the weights of the criteria (Table 3.38).

Table 3.38. The scale offered by Saaty (Saaty, 2008).

Importance Level	Situation	Definition
1	Equal Importance	Equal effect on goal for two activities
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Step 4: Determination of Consistency Ratio: Pair-wise comparison matrices are generated by decision makers. After the column normalization of these matrices, the mean values obtained at the rows represent the weight of each component. But the comparison matrices must be consistent for the acceptance of these values (Bulut and Soylu, 2009). Consistency ratio is determined for each pair-wise comparison matrix and it must be equal or less than 0.10 (Ecer et. al., 2009).

Step 5: Super Matrix Formation and Analysis: Super matrix is a pieced matrix and wherein each matrix part illustrates the relationship of two criteria in the system. To determine the long term relative affect on each other criteria the strength of the super matrix is taken. Standard form of a super matrix is shown in Figure 3.6 (Saaty, 2005).

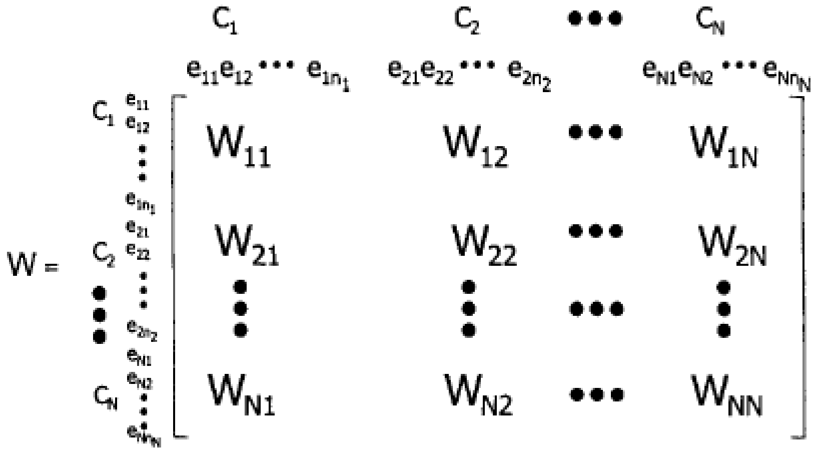


Figure 3.6. Standard form of super matrix (Saaty, 2005).

Step 6: Selection of The Best Alternative: If the super matrix formed in Step 5 covers the whole network, the priority weights of alternatives can be found in the column of alternatives in the normalized super matrix. On the other hand, if a super matrix only comprises of components that are interrelated, additional calculation must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be the one selected (Yazgan and Üstün, 2011).

3.4.3. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a solution method for the MCDM (Multi Criteria Decision Making) problems. TOPSIS was developed by Hwang and Yoon in 1981 and the basic principles of ELECTRE method were used. It is based on the main principle of ideal solution proximity of decision points and it is shorter than the ELECTRE method. TOPSIS determines the best alternative that is the closest to the positive ideal solution and farthest from negative ideal solution (Triantaphyllou, 2000). Figure 3.7 shows the method with two criteria and provides definitions for the positive ideal solution (A^+) and negative ideal solution (A^-) (Karacan, 2015).

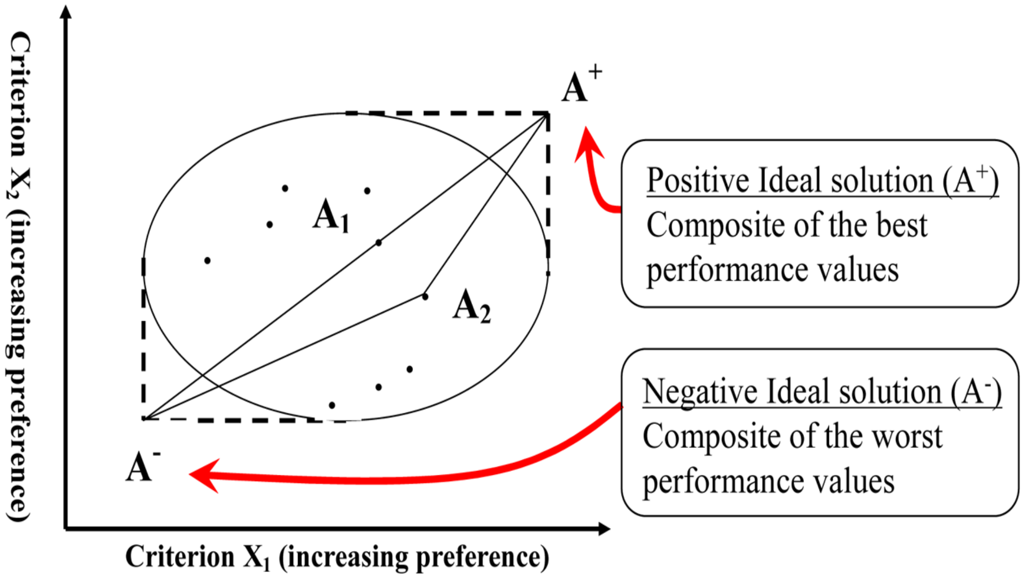


Figure 3.7. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Karacan, 2015).

The TOPSIS method accepts that each criterion has a propensity of increasing or decreasing benefit. That's why; it is easy to express the positive ideal and negative ideal solution. The Euclidean distance approach was used to judge the relative closeness of the alternatives to the ideal solution. So, the preference order of alternatives can be determined according to the series of comparisons of these relative distances (Bhutia and Phipon, 2012).

General TOPSIS method includes 7 steps and these steps are listed below (Triantaphyllou, 2000; Bhutia and Phipon, 2012):

Step 1. Construct the decision matrix: The decision matrix is formed with m alternatives and in terms of n criteria.

$$D = \begin{bmatrix} X_{11} & X_{12} & X_{13} & \cdots & X_{1n} \\ X_{21} & X_{22} & X_{23} & \cdots & X_{2n} \\ \vdots & & & & \vdots \\ X_{m1} & X_{m2} & X_{m3} & \cdots & X_{mn} \end{bmatrix} \quad (3.2)$$

where X_{ij} denotes the performance measure of the i^{th} alternative in terms of the j^{th} criterion.

Step 2. Construct the normalized decision matrix: The normalized decision matrix (R) is calculated by using the following formula.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}} \tag{3.3}$$

Step 3. Construct the weighted normalized decision matrix: The weighted normalized matrix (V) is constructed by multiplying the normalized decision matrix by its associated weights. A set of weights W = (w_1, w_2, w_3, ... , w_n) (where $\sum w_i = 1$) defined by the decision maker. The weighted normalized decision matrix (V) as follows:

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & w_3 r_{13} & \cdots & w_n r_{1n} \\ \vdots & & & \vdots & \vdots \\ w_1 r_{21} & w_2 r_{22} & w_3 r_{23} & \cdots & w_n r_{2n} \\ \vdots & & & & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & w_3 r_{m3} & \cdots & w_n r_{mn} \end{bmatrix} \tag{3.4}$$

Step 4. Determine the positive ideal and negative ideal solutions: A^* refers to the positive ideal solution and A^- refers to the negative ideal solution. Both of them are calculated as follows:

$$A^* = \{(\max{}_i v_{ij} |\ j \in J), \ (\min{}_i v_{ij} |\ j \in J'), \ i = 1, 2, 3, \ldots, m\} \tag{3.5}$$

$$= \{v_{1*}, v_{2*}, \ldots, v_{n*}\}$$

$$A^- = \{(\min{}_i v_{ij} |\ j \in J), \ (\max{}_i v_{ij} |\ j \in J'), \ i = 1, 2, 3, \ldots, m\} \tag{3.6}$$

$$= \{v_{1-}, v_{2-}, \ldots, v_{n-}\}$$

J = 1,2,3,...,n where J is associated with the benefit criteria and J′ = 1,2,3,...,n where J′ is associated with the cost/loss criteria.

Step 5. Determine the separation measure: The separation distances of each alternative from the positive ideal solution and the negative ideal solution are determined due to the principle of the n-dimensional Euclidean distance method.

The separation distance of each alternative from the positive ideal solution is given by:

$$S_{i*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j*})^2} \text{ where i = 1, 2, ...,m.} \tag{3.7}$$

The separation distance of each alternative from the negative ideal solution is given by:

$$S_{i-} = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_{j-}\right)^2} \text{ where i = 1, 2, ...,m.} \quad (3.8)$$

Step 6. Determination of the relative closeness to the ideal solution: The relative closeness of an alternative A_i with respect to the ideal solution A^* is defined as follows:

$$C_{i*} = \frac{S_{i*}}{S_{i*} + S_{i-}} \quad (3.9)$$

where $1 \geq C_{i*} \geq 0$, and i = 1,2,3,...,m. Obviously, $C_{i*} = 0$ if $A_i = A^*$ and $C_{i-} = 1$, if $A_i = A^-$.

Step 7. Ordering the preference: Finally, the best alternative can be determined by using the preference rank order of C_{i*}. So, the optimal alternative is the one that has the shortest distance to the positive ideal solution. Any alternative which has the shortest distance from the ideal solution is also guaranteed to have the furthermost distance from the negative ideal solution (Triantaphyllou, 2000).

3.4.4. VIKOR (VIseKriterijumslca Optimizacija I Kompromisno Resenje)

VIseKriterijumslca Optimizacija I Kompromisno Resenje in Serbian means that multi criteria optimization and compromise solution (Liu and Wang, 2011). The VIKOR method was developed for the optimization of the complex systems with the multi criteria. It was originally developed by Serafim Opricovic to solve decision problems with contradictory and different unit criteria in 1998 (Opricovic, 1998). The alternatives are assessed due to the all criteria to determine the compromise solution that is the closest to the ideal solution (Karacan, 2015).

The researchers Yu and Zeleny (1973) introduced the compromise solution in MCDM problems in their studies. Opricovic and Tzeng (2004) also adapted the VIKOR method in MCDM problems. The VIKOR method has also been described as a multi criteria ranking index that aims to find the decision which is the closest to ideal solution (Yılmaz, 2012).

It is assumed that each alternative is evaluated due to each criterion. After that, the compromise ordering solution may be done with the alternative closeness measure to the ideal solution. For the determination of compromise ranking, Lp-metric that is multi criteria measurement method was developed. In here, Lp-metric is used as an aggregation function as with compromise programming. Development of the VIKOR method is started with the Lp-metric expression that is defined in below (Karacan, 2015):

$$L_{(p,j)} = \left\{ \sum_{i=1}^{n} \left[\frac{w_i (f_i^* - f_{ij})}{(f_i^* - f_i^-)} \right]^p \right\}^{1/p} ,1 \leq p \leq \infty; j = 1, 2, ..., J. \quad (3.10)$$

The steps of the VIKOR method are shown below (Karacan, 2015):

Step 1. The best f_i^* and the worst f_i^- values of all criterion functions are determined where i = 1, 2, ..., n is the index number of the criterion function. If i^{th} function represents a benefit or a maximization than $f_i^* = \max_j f_{ij}$, $f_i^- = \min_j f_{ij}$, where j = 1, 2, …, m is the index number of alternatives. If i^{th} function represents a loss or a minimization than $f_i^- = \max_j f_{ij}$, $f_i^* = \min_j f_{ij}$.

Step 2. Sj indicates the maximum group utility and the minimum individual regret of the opponent Rj are calculated by using the weighted and normalized Manhattan distance formula and the weighted and normalized Chebyshev distance formula, respectively.

$$S_j = \sum_{i=1}^{n} \frac{w_i (f_i^* - f_{ij})}{(f_i^* - f_i^-)} \quad (3.11)$$

$$R_j = \max_i \left[\frac{w_i (f_i^* - f_{ij})}{(f_i^* - f_i^-)} \right] \quad (3.12)$$

Step 3. The Q_j values are calculated to rank the alternatives as follow:

$$Q_j = \frac{v\,(S_j - S^-)}{S^* - S^-} + \frac{(1-v)(R_j - R^-)}{R^* - R^-} \quad (3.13)$$

where;

$$S^* = \max_j S_j \, , \; S^- = \min_j S_j$$

$R^* = \max_j R_j$, $R^- = \min_j R_j$ for benefit criteria, and v is the voting rule and it should be between [0,1].

Step 4. The decreasing sorting order of the alternatives is made according to the Q, R, and S values. As a result, there are three different ranking lists.

Step 5. The results satisfy the two following conditions:

C_1: "Acceptable Advantage"

$$Q(a'') - Q(a') \geq DQ \tag{3.14}$$

where a' and a'' are the first alternative and the second alternative in the rank list according to the Q value, respectively. DQ is defined like that:

$$DQ = \frac{1}{j-1} \tag{3.15}$$

where j is the number of all alternatives.

This condition indicates that the best alternative is obviously the most advantageous alternative according to the other alternatives.

C_2: "Acceptable Stability in Decision Making"

Alternative (a') must also be the best alternative in the rank lists due to the S and R values. This compromise solution will provide a stability in the decision making process which may be ballot by majority rule (if v>0.5), by consensus (v=0.5) or with vote (if v<0.5).

If none of the conditions are met, a compromise solution set is recommended like that in below:

- Alternative a' and alternative a'' if only condition 2 (C_2) is not met,
- Alternative $a', a'', a''', .., a^m$, if condition 1 (C_1) is not satisfied, where a^m is determined by the formula:

$$Q\ (a^m) - Q\ (a') < DQ \tag{3.16}$$

where m is the maximum number that satisfies the condition. With this inequality, a compromise set will be revealed. In this evaluation result, a increasing rank is made according to Q values and the alternative that has the lowest Q value will be chosen.

3.4.5. Goal Programming (GP)

In 1961, Charnes and Cooper started to study with Goal Programming subject and in 1970s it was developed by Lee and Ignizio. In real life, actually, all problems have several objectives not only one. For example, in an automobile industry, if a manufacturer focuses on only cost issue, it will disregard environmental and social concerns of the community. With different perspective from the Linear programming, goal programming minimizes the deviations from the defined target values in the framework of constraints instead of maximization or minimization of objective function (Yigit, 2014). There is no feasible solution for the model if the constraints are inconsistent in both of LP and GP problems. In this study, the steps of the weighted GP model are formulated below (Karacan, 2015). Weighted GP ensures a way of striving toward several objectives simultaneously.

$$Min\, Z = \sum_{i=1}^{m} w_i^+ . d_i^+ + w_i^- . d_i^- \qquad (3.17)$$

Subject to:

$\sum_{i=1}^{m} a_{ij} . x_j - d_i^+ + d_i^- = g_i$ j = 1, 2, ..., n

$x_j \geq 0$; j = 1, 2, ..., r

$x_j \in Z$; j = r+1, r+2, ..., n

$d_i^+, d_i^- \geq 0$, i = 1, 2, ..., m

where;

Z : the sum of weighted deviational variables

w_i^+ , w_i^- : the positive and negative relative weight of i^{th} deviation

d_i^+ , d_i^- : the positive and negative deviation variable from the i^{th} goal

a_{ij} : the j^th decision coefficient of the i^th goal or hard constraints

x_j : the j^th decision variable and g_i : the i^th goal or target value.

The deviation variables can also be expressed like this:

$$d_i^- = \left[g_i - \sum_{i=1}^{n} a_{ij}x_j\right]^+ \quad (3.18)$$

$$d_i^+ = \left[\sum_{i=1}^{n} a_{ij}x_j - g_i\right]^+ \quad (3.19)$$

where $[x]^+ = max(0, x)$

In here, constraints display the positive or negative deviation of the alternatives related to the criteria from the intended goal g_i. There is the deviation to be minimized with relevant weights (w_i^+ , w_i^-) in the objective function. An optimal solution of the problem is achieved if the sum of both positive and negative deviations is to be minimized. If the target value of a goal should not be exceeded, then the respective positive deviation variable should be minimized. Similarly, the minimization of the negative deviation variable of goals should not be underachieved. The GP problems are NP-hard problems and some algorithms such as branch and bound can be used to find satisfactory solutions in GP method. In addition, with some adjustments such as removing integer constraints of variables, the problems are transformed from GP to linear programming and so they are solved with well-known algorithms like Simplex. GP may propose multiple optimal solutions, so one of them is selected arbitrarily or we can re-adjust some weights to find a different solution.

3.5. Fuzzy MCDM Techniques Used in Greenovative Supplier Selection Process

In this part, fuzzy MCDM methods that are used in this study will be introduced shortly.

3.5.1. Fuzzy AHP and Fuzzy ANP

Fuzzy Analytic Hierarchy Process (F-AHP) is used widely in multi criteria decision making process because of fuzzy nature of comparisons of the selection criteria and alternatives. Decision makers prefer to express for their bilateral comparisons in a range instead of in absolute terms.

The most important point of criticism against the AHP method is that using Aristotle logic in the bilateral comparisons process. This deficiency was corrected by fuzzy AHP that was developed by Van Laarhoven and Pedrycz in 1983. They used the triangular fuzzy number in their study on the other hand; Buckley (1985) used trapezoid fuzzy numbers in his study. The extended analysis method that was developed by Chang (1996) is widely used for the bilateral comparisons in the literature (Yılmaz, 2012).

In literature, there are many methods using different types of fuzzy numbers, however Chang's Extent Analysis method is the most used for both FAHP and FANP. This method derives crisp priority vector from a fuzzy comparison matrix. And in the methods FAHP and FANP the all other calculations are same as in the AHP and ANP (Yanar, 2011).

According to Chang's extended analysis method, each evaluation criterion will be subjected to analysis for each target, respectively. Thus "m" extended analysis values will be obtained for each criteria.

$$M_{g^i}^{1}, M_{g^i}^{2}, \dots, M_{g^i}^{m}, \qquad i = 1,2,\dots,n.$$

All $M_{g^i}^{j}$ values (j = 1,2,…, m) are assumed as triangular fuzzy numbers:

The phases of the extended analysis method according to Chang's study are listed below:

Step 1: Based on criteria i, fuzzy synthetic expanded value will be calculated as follows:

$$S_i = \sum M_{g^i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g^i}^{j}\right]^{-1} \tag{3.20}$$

By using fuzzy sum up operation, $\sum_{j=1}^{m} M_{g^i}^{j}$ values are calculated as follows:

$$\sum_{j=1}^{m} M_{g^i}^{j} = \left(\sum_{j=1}^{m} l_j \ \sum_{j=1}^{m} m_j \ \sum_{j=1}^{m} u_j\right) \tag{3.21}$$

Calculation of;

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g^i}^{j} = \left(\sum_{i=1}^{n} l_i \ \sum_{i=1}^{n} m_i \ \sum_{i=1}^{n} u_i\right) \tag{3.22}$$

Calculation of;

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\ \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{3.23}$$

Step 2: Two triangular fuzzy numbers of M_1 and M_2 are defined as $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ respectively.

Probability of $M_2 = (l_2, m_2, u_2) > M_1 = (l_1, m_1, u_1)$ are described in below.

$$V(M_2 \geq M_1) = \sup \lfloor \min(\mu_{M1}(x), \mu_{M2}(y) \rfloor\ y \geq x \tag{3.24}$$

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2(d)} \tag{3.25}$$

$$\mu_{M2(d)} = \begin{cases} 1, m_2 \geq m_1 \\ 0,\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, others \end{cases} \tag{3.26}$$

Both of values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ are needed for the comparison of $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. Ordinate of the highest point of intersection between μ_{M1} and μ_{M2} is shown in Figure 3.8 (Chang, 1996).

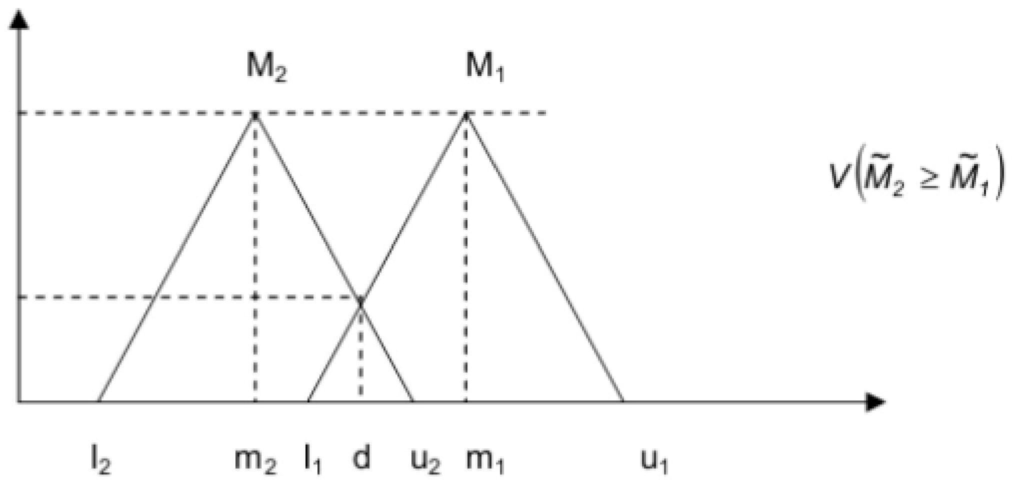


Figure 3.8. The intersection point of M_1 and M_2 (Chang, 1996).

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i = 1, 2 ..... k) can be defined by:

$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1,)$ and $(M \geq M_2)$ and ….and $(M \geq M_k)] = \min V (M \geq M_i)$ i=1,2,…,k. (3.27)

Assumed that $d'(A_i) = \min V(S_i \geq S_k)$ k= 1,2,…,n; k≠i (3.28) and the weight vector is calculated as follows:

$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T$ where A_i (i=1,2.....,n) are n elements. (3.29)

Step 4: For the normalized weight vector;

$W = (d(A_1), d(A_2), \ldots, d(A_n))^T$ where W is a non-fuzzy number. (3.30)

3.5.2. Fuzzy TOPSIS (F-TOPSIS)

The F-TOPSIS method was developed by Chen to solve the MCDM problems under uncertainty. The linguistic variables are used to evaluate the weights of the criteria and the ratings of the alternatives by the decision makers (Junior et. al., 2014). F-TOPSIS procedures are identified due to their way of handling fuzzy numbers. In this F-TOPSIS method, the distance of alternative from Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) is calculated as follows (Karacan, 2015):

$$d(A,B) = \sqrt{\frac{(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2}{3}} \quad (3.31)$$

F-TOPSIS steps define in below (Karacan, 2015):

Step 1. The fuzzy decision matrix is formed.

$$\widetilde{D} = \begin{bmatrix} \widetilde{x_{11}} & \cdots & \widetilde{x_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{x_{m1}} & \cdots & \widetilde{x_{mn}} \end{bmatrix} \quad (3.32)$$

where $\widetilde{x_{ij}}$ is the fuzzy numbers i = 1,2, ...,m (m is number of alternatives) and j = 1,2, ...,n (n is number of criteria).

$$\widetilde{W} = [\widetilde{w_1}, \widetilde{w_2}, \ldots, \widetilde{w_n}] \quad (3.33)$$

Step 2. The normalized fuzzy decision matrix (R) is constructed in this step. The linear scale transformation is used to convert different criteria scales into comparable scale in F-TOPSIS. B and C refer to the sets of benefit criteria (that should be maximized) and cost criteria (that should be minimized), respectively.

$$\tilde{R} = [\widetilde{r_{ij}}]_{mxn} \quad (3.34)$$

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \; c_j^* = \max_i c_{ij} \; j \text{ ò } B \tag{3.35}$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \; a_j^- = \min_i a_{ij} \; j \text{ ò } C \tag{3.36}$$

Step 3. The weighted normalized fuzzy decision matrix is formed.

$$\tilde{v} = \left[\widetilde{v_{ij}}\right]_{mxn}, \; i = 1, 2, ..., m \; ; \; j = 1, 2, ..., n \tag{3.37}$$

where $\widetilde{v_{ij}} = \widetilde{r_{ij}} \otimes \widetilde{w_j}$.

Step 4. Calculate the fuzzy positive ideal solution (FPIS, A^*) and the fuzzy negative ideal solution (FNIS, A^-).

$$A^* = \left(\widetilde{v_1^*}, \widetilde{v_2^*}, \ldots, \widetilde{v_n^*}\right) \tag{3.38}$$

$$A^- = \left(\widetilde{v_1^-}, \widetilde{v_2^-}, \ldots, \widetilde{v_n^-}\right) \tag{3.39}$$

where $\widetilde{v_j^*} = (1,1,1)$ and $\widetilde{v_j^-} = (0,0,0)$, j = 1, 2, ...,n.

Step 5. The distance of each alternative from FPIS and FNIS by using distance operator is determined.

$$d_i^* = \sum_{j=1}^{n} d\left(\widetilde{v_{ij}}, \widetilde{v_j^*}\right), \; i = 1, 2, ...,m \tag{3.40}$$

$$d_i^- = \sum_{j=1}^{n} d\left(\widetilde{v_{ij}}, \widetilde{v_j^-}\right), \; i = 1, 2, ...,m \tag{3.41}$$

Step 6. The closeness coefficient of each alternative is calculated as follow:

$$c_i^* = \frac{d_i^*}{d_i^* + d_i^-}, \; i = 1, 2, ...,m \tag{3.42}$$

Step 7. The ranking order of all alternatives is made due to the closeness coefficient. The closer c_i^* is to 0 means the higher priority of the ith alternative. Now, the alternative sets can be preference ranked due to the ascending order of closeness coefficient.

3.5.3. FuzzyVIKOR (F-VIKOR)

The basis of VIKOR method withstands of the differences from best/worst values on criteria. In fuzzy VIKOR method, the linguistic terms and fuzzy numbers are used to determine the worst/best values in criteria. In the following step, max and min operators are explained.

OPERATOR MAX: $\max_i \widetilde{A_i} = (\max_i a_1, \max_i a_2, \max_i a_3)$

OPERATOR MIN: $\min_i \widetilde{A_i} = (\min_i a_1, \min_i a_2, \min_i a_3)$

Fuzzy VIKOR steps are defined below (Karacan, 2015):

Step 1. The best and worst values $\widetilde{f_{ij}} = (l_{ij}, m_{ij}, r_{ij})$ for every criterion function are calculated. The best and worst values $\widetilde{f_i^*}$ and $\widetilde{f_i^-}$ are the index numbers of the criterion respectively where i = 1, 2, ..., n. When the ith function is the benefit or maximization $\widetilde{f_i^*} = \max_j \widetilde{f_{ij}}$, $\widetilde{f_i^-} = \min_j \widetilde{f_{ij}}$ where j = 1, 2, ..., m is the index number of alternatives. Otherwise for a loss or minimization function than $\widetilde{f_i^-} = \max_j \widetilde{f_{ij}}$, $\widetilde{f_i^*} = \min_j \widetilde{f_{ij}}$.

$$\widetilde{f_i^*} = (l_i^*, m_i^*, r_i^*) \tag{3.43}$$

$$\widetilde{f_i^-} = (l_i^-, m_i^-, r_i^-) \tag{3.44}$$

Step 2. Normalized fuzzy distance $\widetilde{d_{ij}}$ is calculated.

$$\widetilde{d_{ij}} = \frac{(\tilde{f_i} \ominus \widetilde{f_{ij}})}{(r_i^* - l_i^-)} \text{ for } i \in B \tag{3.45}$$

$$\widetilde{d_{ij}} = \frac{(\widetilde{f_{ij}} \ominus \widetilde{f_i^*})}{(r_i^- - l_i^*)} \text{ for } i \in C \tag{3.46}$$

B refers to the set of benefit criteria (it should be maximized) and C refers to the set of cost criteria (it should be minimized).

Step 3. $\widetilde{S_j} = (S_j^l, S_j^m, S_j^r)$ and $\widetilde{R_j} = (R_j^l, R_j^m, R_j^r)$ where j = 1, 2, ..., m are determined as follow:

$$\widetilde{S_j} = \sum_{i=1}^{n} \oplus(\widetilde{w_i} \otimes \widetilde{d_{ij}}) \tag{3.47}$$

$$\widetilde{R_J} = \text{MAX}_i\left(\widetilde{w_\iota} \otimes \widetilde{d_{\iota J}}\right) \tag{3.48}$$

Step 4. $\widetilde{Q_J} = \left(Q_j^l, Q_j^m, Q_j^r\right)$ where j = 1, 2, ..., m is computed.

$$\widetilde{Q_J} = \frac{v\,(\widetilde{S_J} \ominus \widetilde{S_J^*})}{(S^{-r} - S^{*l})} \oplus \frac{(1-v)(\widetilde{R_J} \ominus \widetilde{R_J^*})}{(R^{-r} - R^{*l})} \tag{3.49}$$

where:

v: the weight for the strategy of "the majority of criteria" (or "the maximum group utility")

1–v: the weight of the individual regret. The value of v is assumed 0.5.

$\widetilde{S_J^*} = \text{MIN}_j\, \widetilde{S_J}$, $S^{-r} = \max_j S_j^r$, $\widetilde{R_J^*} = \text{MIN}_j\, \widetilde{R_J}$, $R^{-r} = \max_j R_j^r$

Step 5. Defuzzification of $\widetilde{S_J}$, $\widetilde{R_J}$ *and* $\widetilde{Q_J}$ by using Centroid Defuzzification method (Karacan, 2015):

$$\text{Crisp}\left(\tilde{N}\right) = \frac{m + l + r}{3} \tag{3.50}$$

Step 6. Alternatives are ranked according to the Crisp values S, R, and Q in decreasing order.

Step 7. Two conditions are satisfied. These are:

-C_1: "Acceptable Advantage"

$$Q(A'') - Q(A') \geq DQ \tag{3.51}$$

where A′ is the first alternative and A″ is the second alternative in Q list. DQ is defined as follow:

$$DQ = \frac{1}{J-1} \tag{3.52}$$

where J is the number of all alternatives.

-C2: "Acceptable stability in decision making"

A′ is the best alternative in the Q list and it must also be the best alternative in the S and/or R list. This compromise solution is stable and it is evaluated by majority rule (if v>0.5), by consensus (if v=0.5), or with vote (if v<0.5). v indicates the weight of the decision making strategy. Especially, in numerical examples, v is preferred with the value of 0.5.

If none of the conditions are met, a compromise solution set is recommended such as:

-Alternative A′ and alternative A′′ if only condition 2 (C_2) is not met.

-Alternative A′, A′′, A''', ..., A^m if condition 1 (C_1) is not satisfied, than A^m is calculated as follow:

$$Q(A^m) - Q(A') < DQ \quad (3.53)$$

where m is maximum number that satisfies the condition.

4. RESULTS

In this chapter, results that are acquired from the various MCDM approaches to select the greenovative supplier for company A are examined. After the data entrance, the greenovative supplier selection is determined in AHP, FAHP, ANP, and fuzzy ANP by using DESTEC 1.0 software and the results are shown in the following figures. By using DEMATSEL software, the results of TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP are obtained.

4.1. Supplier Selection by Using AHP and FAHP

In Figure 4.1, there is a graphical representation of weight values for traditional, environmental and innovative criteria for AHP. In Figure 4.2, the weights of the main and sub-criteria are shown as a result of the AHP and FAHP by using DESTEC 1.0. As seen figure, consistency ratio for all the pair-wise matrices is less than 0.1. Main criteria has been examined, the weights of TC, EC and IC are 0.43, 0.14, and 0.43, respectively for AHP and 0.44, 0.12, and 0.44, respectively for fuzzy AHP. For traditional sub-criteria, TC1 (0.23), TC4 (0.18) and TC6 (0.18) are the significant criteria for AHP. Same results have been observed in fuzzy AHP. For environmental sub-criteria, EC3 (0.17), EC2 (0.17) and EC1 (0.13) are the significant criteria for AHP. For innovative sub-criteria, IC5 (0.30), IC6 (0.15) and IC7 (0.12) are the significant criteria for AHP.

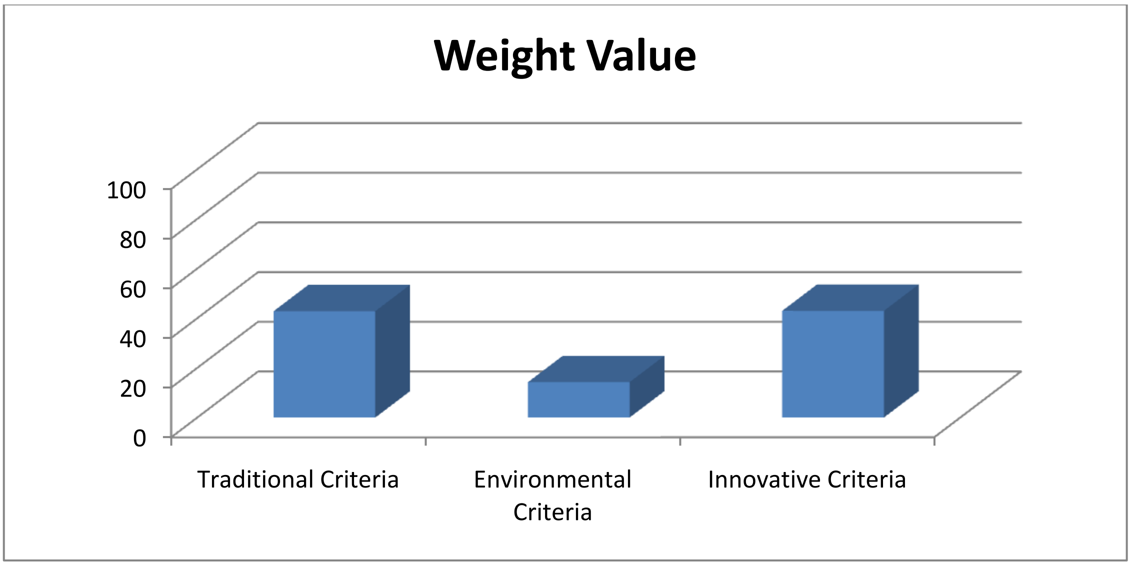


Figure 4.1. Graphical representation of weights for traditional, environmental and innovative criteria.

PLEASE COMPARE THE ELEMENTS.

Seletion	Traditior	Envirome	Inovative	W	Fuzzy W	
Traditional		3	1	0,42816	0,44108	
Enviromental			0,33	0,14224	0,11602	
Inovative				0,4296	0,4429	CR: 0

Traditior	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	W	Fuzzy W	
TC1		5	3	1	3	1	5	7	5	0,22956	0,30936	
TC2			3	0,2	0,33	0,2	1	1	1	0,05647	0	
TC3				0,33	1	0,33	3	1	1	0,06634	0	
TC4					1	1	5	3	5	0,18231	0,24872	
TC5						1	5	3	5	0,14196	0,19319	
TC6							5	3	5	0,18231	0,24872	
TC7								3	3	0,05422	0	
TC8									3	0,05192	0	
TC9										0,03492	0	CR: 0.08

Envirome	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	W	Fuzzy W	
EC1		1	1	0,33	1	5	3	1	1	0,12737	0,13975	
EC2			1	1	3	3	3	1	3	0,1664	0,15932	
EC3				3	1	3	3	1	3	0,16789	0,15932	
EC4					1	3	1	1	1	0,12326	0,12472	
EC5						3	1	1	1	0,09967	0,10862	
EC6							0,33	0,33	0,33	0,03547	0	
EC7								1	1	0,08035	0,09139	
EC8									1	0,11149	0,11626	
EC9										0,0881	0,10062	CR: 0.06

Inovative	IC1	IC2	IC3	IC4	IC5	IC6	IC7	IC8	IC9	W	Fuzzy W	
IC1		5	0,33	1	0,2	0,33	0,33	1	1	0,06525	0,0167	
IC2			0,2	0,33	0,14	0,2	0,33	0,33	1	0,03017	0	
IC3				3	0,33	0,33	1	1	3	0,12227	0,16059	
IC4					0,2	0,33	0,33	1	1	0,0587	0	
IC5						5	3	3	3	0,3039	0,37914	
IC6							1	1	3	0,14756	0,20234	
IC7								1	3	0,1238	0,15028	
IC8									3	0,0992	0,09095	
IC9										0,04915	0	CR: 0.06

Figure 4.2. The weights of main and sub-criteria for AHP and fuzzy AHP.

In Figure 4.3, graphical representation of weights for traditional sub-criteria is shown for AHP.

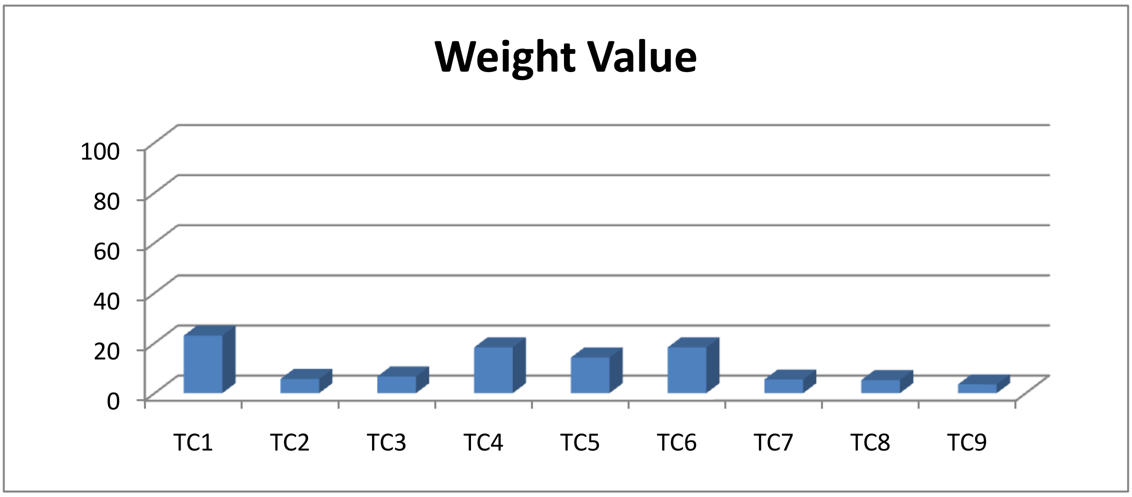


Figure 4.3. Graphical representation of weights for traditional sub-criteria.

In Figure 4.4 and 4.5, there are graphical representations of weights for environmental and innovative sub criteria for AHP, respectively.

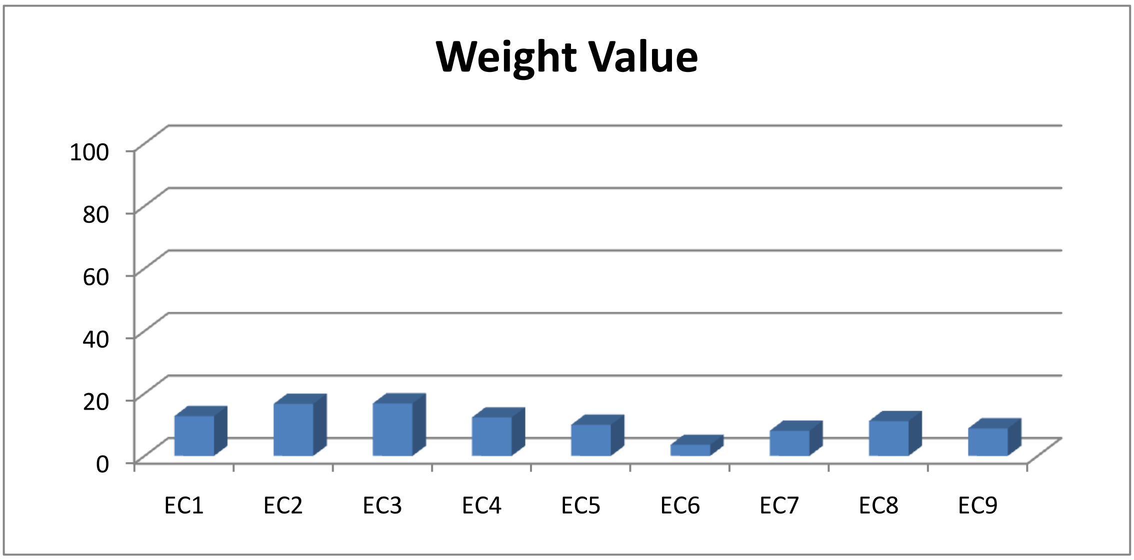


Figure 4.4. Graphical representation of weights for environmental sub-criteria.

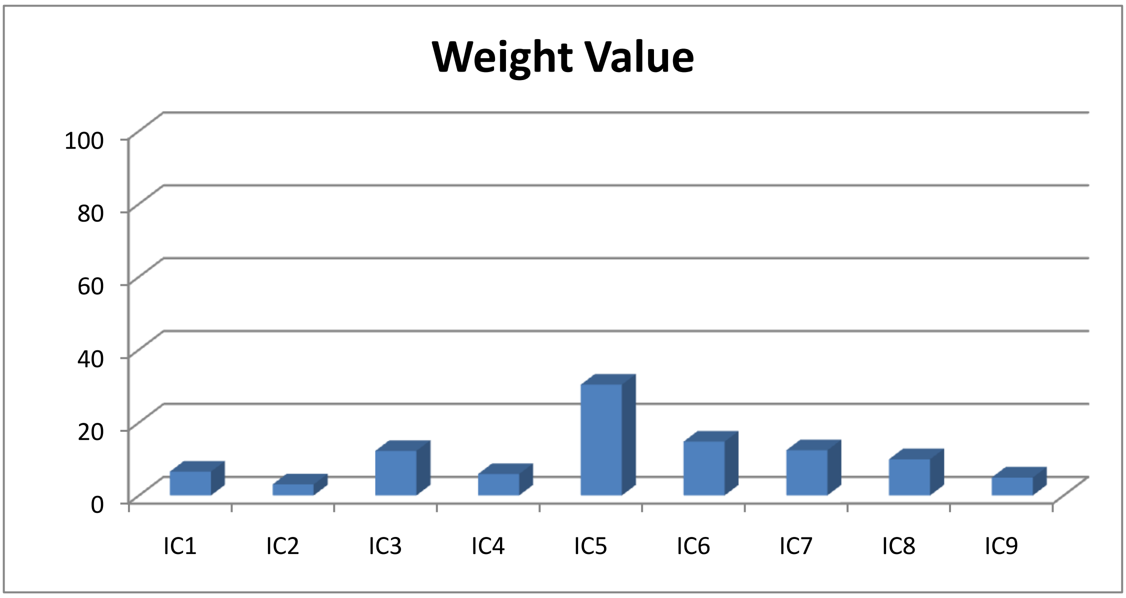


Figure 4.5. Graphical representation of weights for innovative sub criteria.

In Figure 4.6, there are suppliers' evaluation results for the traditional sub-criteria.

PLEASE COMPARE ALTERNATIVES WITH RESPECT TO THE CRITERION ON THE UPPER LEFT CORNER						
TC1	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,2	0,105713	0	
SUPPLIER B			0,33	0,2602	0,295568	
SUPPLIER C				0,634087	0,704432	CR: 0.04
TC2	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,33	0,141631	0,114824	
SUPPLIER B			1	0,429185	0,442588	
SUPPLIER C				0,429185	0,442588	CR: 0
TC3	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0
TC4	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0
TC5	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,33	0,141631	0,114824	
SUPPLIER B			1	0,429185	0,442588	
SUPPLIER C				0,429185	0,442588	CR: 0
TC6	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,2	0,105713	0	
SUPPLIER B			0,33	0,2602	0,295568	
SUPPLIER C				0,634087	0,704432	CR: 0.04
TC7	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0
TC8	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0
TC9	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

Figure 4.6. The weights of traditional sub-criteria for Supplier A, Supplier B and Supplier C by using AHP and fuzzy AHP.

In Figure 4.7, there are suppliers' evaluation results for the environmental sub-criteria.

EC1	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	1	0,199064	0,202254	
SUPPLIER B			3	0,601204	0,594892	
SUPPLIER C				0,199732	0,202853	CR: 0

EC2	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	1	0,199064	0,202254	
SUPPLIER B			3	0,601204	0,594892	
SUPPLIER C				0,199732	0,202853	CR: 0

EC3	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC4	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC5	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC6	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC7	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC8	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

EC9	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

Figure 4.7. The weights of environmental sub-criteria for Supplier A, Supplier B and Supplier C by using AHP and fuzzy AHP.

In Figure 4.8, there are suppliers' evaluation results for the innovative sub-criteria.

IC1	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0

IC2	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0

IC3	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0

IC4	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

IC5	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,2	0,105713	0	
SUPPLIER B			0,33	0,2602	0,295568	
SUPPLIER C				0,634087	0,704432	CR: 0.04

IC6	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0

IC7	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	0,33	0,198795	0,201011	
SUPPLIER B			0,33	0,198795	0,201011	
SUPPLIER C				0,60241	0,597978	CR: 0

IC8	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		0,33	0,2	0,105713	0	
SUPPLIER B			0,33	0,2602	0,295568	
SUPPLIER C				0,634087	0,704432	CR: 0.04

IC9	SUPPLIER A	SUPPLIER B	SUPPLIER C	W	Fuzzy W	
SUPPLIER A		1	1	0,333333	0,333333	
SUPPLIER B			1	0,333333	0,333333	
SUPPLIER C				0,333333	0,333333	CR: 0

Figure 4.8. The weights of innovative sub-criteria for Supplier A, Supplier B and Supplier C by using AHP and fuzzy AHP.

When the problem is solved by using AHP and FAHP approaches, the best greenovative supplier for company A is defined as Supplier C with the 51.9 % for AHP and 59.8 % for FAHP (Figure 4.9). The other Supplier B and Supplier A have 28.8 % and 19.3% of importance for AHP, respectively. These values are equal to 28.9 % and 11.3 % for FAHP. So, the order of suppliers is same in AHP and FAHP approaches. For all calculations, the inconsistency ratio is smaller than 0.10, this signs that all pair-wise matrices are consistent.

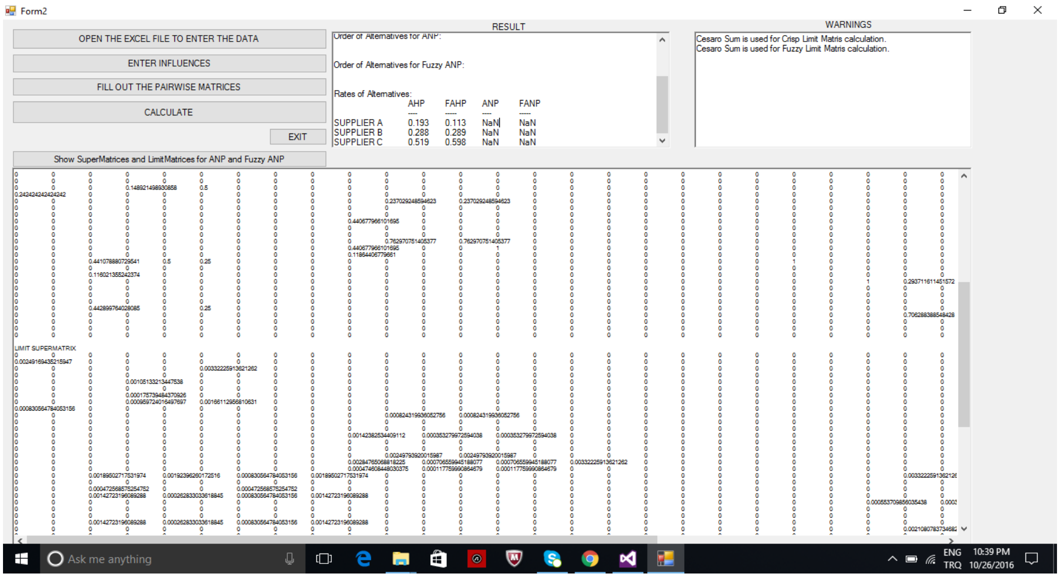


Figure 4.9. Order of alternatives for AHP and fuzzy AHP.

4.2. Supplier Selection by Using ANP and FANP

It is aimed to determine the rank of the best greenovative supplier by using ANP and FANP after the AHP and FAHP. So the same solver DESTEC 1.0 was used to obtain results. For this study, proposed ANP model is represented in Figure 4.10.

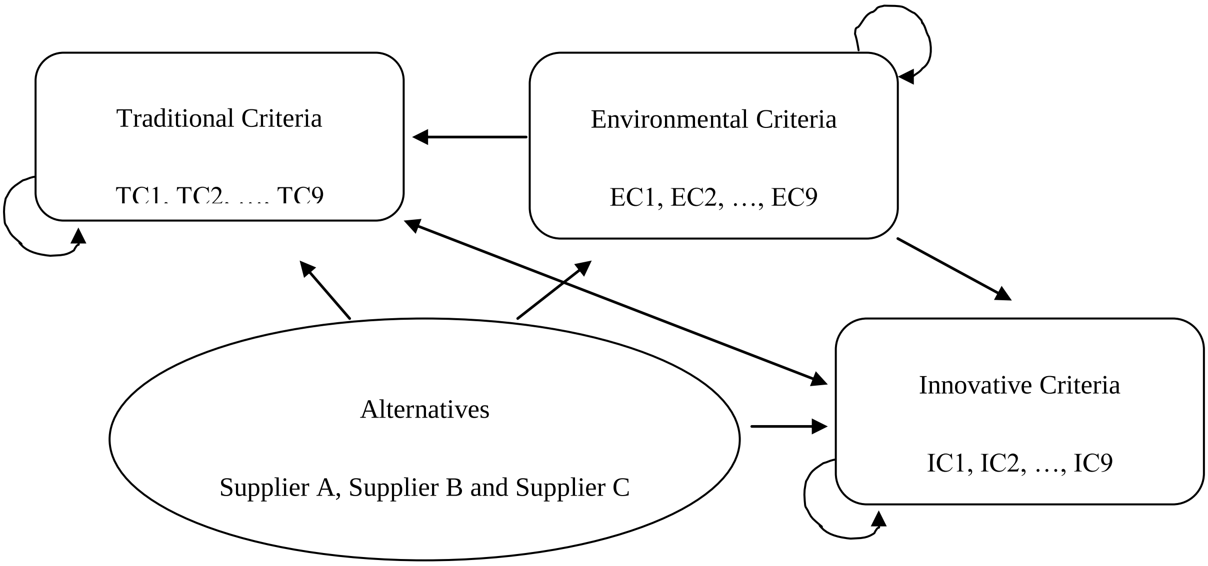


Figure 4.10. Proposed ANP model for the selection of the greenovative supplier.

According to the proposed ANP model, the internal and external dependencies of criteria are defined and comparison matrices are formed again. After the data entrance to the programme, the ranking of best greenovative supplier is obtained (Figure 4. 11).

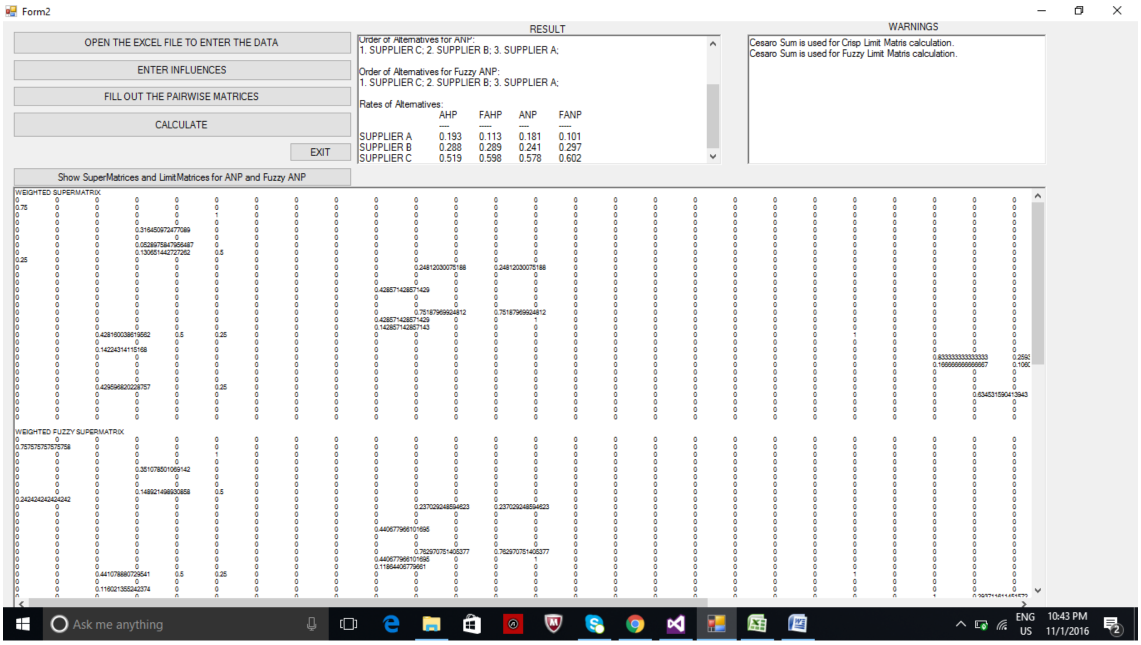


Figure 4.11. Order of alternatives for ANP and fuzzy ANP.

When the figure is examined, Supplier C is identified the best supplier with the highest importance 57.8 % for ANP and 60.2 % for FANP. Supplier B has 24.1 % of importance for ANP and 29.7 % of importance for FAHP. Supplier A has the lowest importance that is 18.1 % for ANP and 10.1 % for FANP. These results are the similar with the AHP and FAHP results.

The numerical values of the solutions for AHP, ANP, FAHP and FANP are summarized in Table 4.1.

Table 4.1. Summary of results for AHP, ANP, FAHP and FANP.

Supplier	AHP	ANP	FAHP	FANP
Spr A	0.193	0.181	0.113	0.101
Spr B	0.288	0.241	0.289	0.297
Spr C	0.519	0.578	0.598	0.602

4.3. Supplier Selection by Using TOPSIS, VIKOR, GP, FTOPSIS and FVIKOR

In this part of the thesis, the results are given that obtained from DEMATSEL tool which solves decision making problems by using TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP.

Graphical results from DEMATSEL are shown in the following figures. Figure 4.12 represents TOPSIS solution values. Under the light of the results, Supplier C is the best greenovative supplier because of the shortest distance to the ideal solution. In the ranking, Supplier B is in the second place and Supplier A is in the third place.

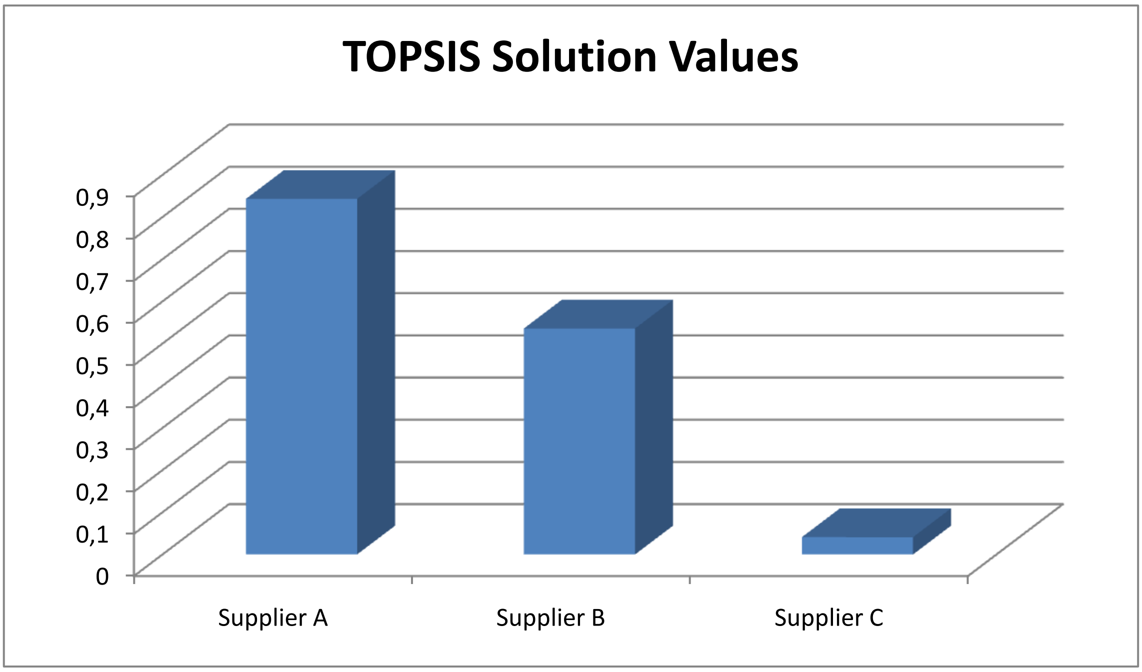


Figure 4.12. TOPSIS solution values.

As seen in Figure 4.13, the best greenovative supplier is identified as Supplier C according to fuzzy TOPSIS results. The worst supplier is identified for company A as Supplier A.

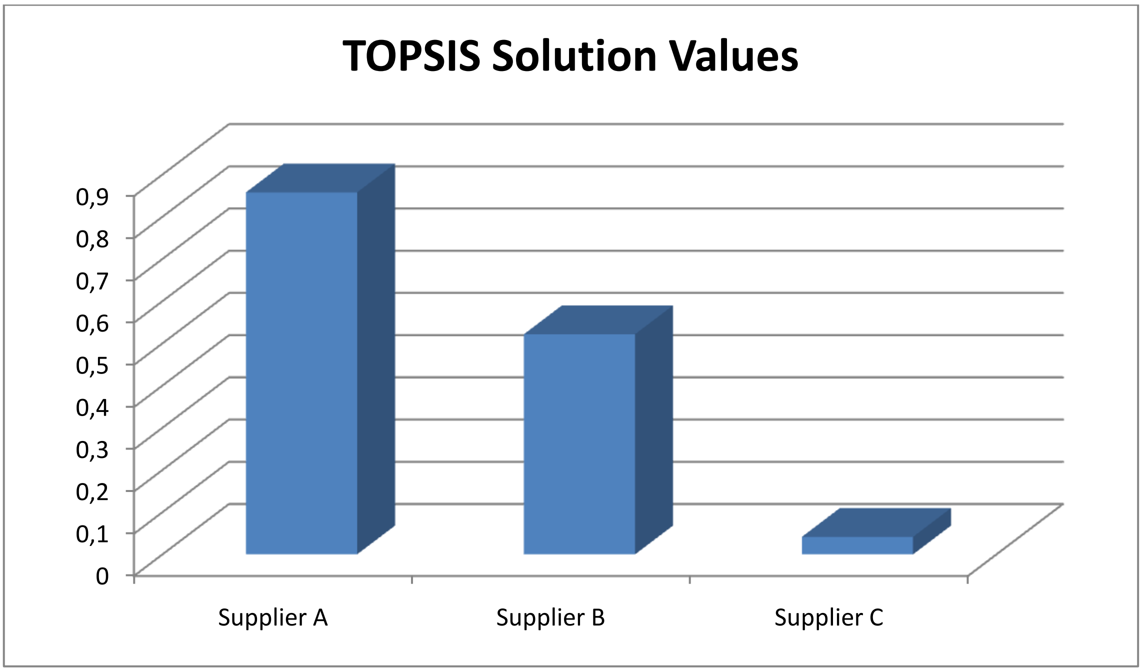


Figure 4.13. Fuzzy TOPSIS solution values.

As seen in Figure 4.14, the same order (Supplier C-Supplier B-Supplier A) can be made for VIKOR method. According to the results, Supplier C is the best greenovative supplier because it has the lowest Q value.

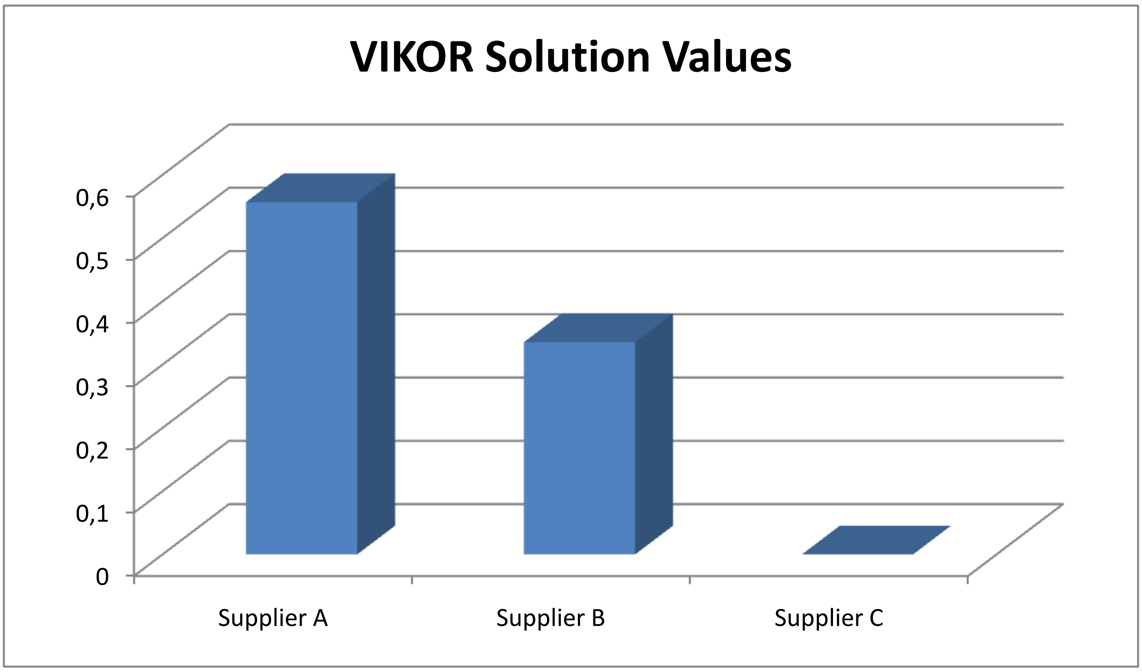


Figure 4.14. VIKOR solution values.

Same ranking (Supplier C-Supplier B-Supplier A) is obtained as a result of the fuzzy VIKOR method (Figure 4.15).

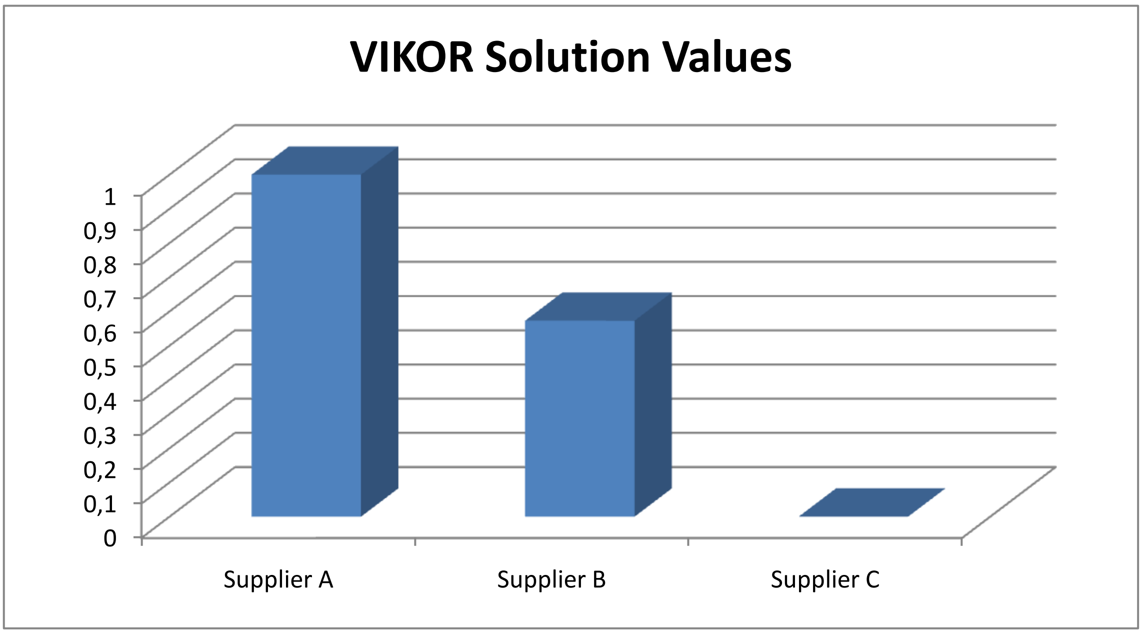


Figure 4.15. Fuzzy VIKOR solution values.

In the Figure 4.16, it can be seen the Goal Programming solution values that gives the same order (Supplier C-Supplier B-Supplier A) for the supplier selection. Supplier C is again the best greenovative supplier due to the lowest deviation variable (d).

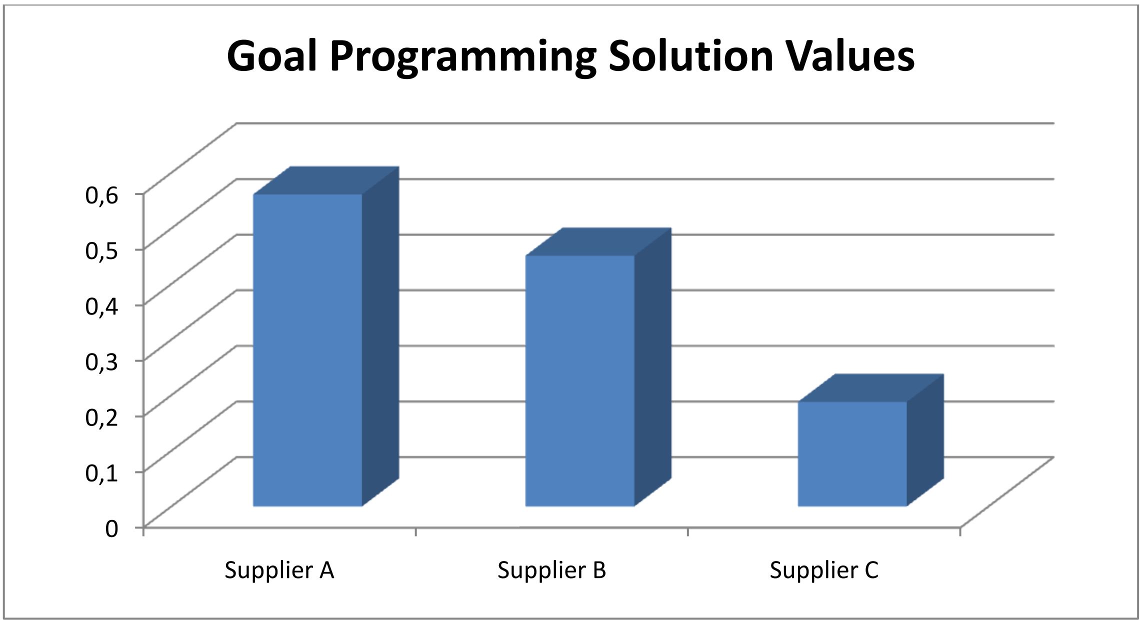


Figure 4.16. Goal Programming (GP) solution values.

The numerical values of the solutions for TOPSIS, VIKOR and GP are summarized in Table 4.2.

Table 4.2. Summary of results for TOPSIS, VIKOR and Goal Programming (GP).

Supplier	**TOPSIS (C)**	**VIKOR (Q)**	**GP (d)**
Spr A	0.795	0.513	0.525
Spr B	0.493	0.307	0.412
Spr C	0.033	0.011	0.151

The numerical values of the solutions for fuzzy TOPSIS and fuzzy VIKOR are summarized in Table 4.3.

Table 4.3. Summary of results for fuzzy TOPSIS and fuzzy VIKOR.

Supplier	**FTOPSIS (C)**	**FVIKOR (Q)**
Spr A	0.801	0.920
Spr B	0.485	0.512
Spr C	0.032	0.008

4.4. Analysis of the Results and Main Findings

As a result of AHP approach, traditional criteria weight is calculated as 42.8%, whereas environmental criteria and innovative criteria weights are determined as 14.2% and 43%, respectively. According to these weights, while the best supplier is determined as Supplier C, the worst supplier is Supplier A.

Different scenarios have been considered for this problem. These are;

- In the first scenario, when we changed the weight of the traditional criteria from 0% to 100%, there is no any difference observed at the ranking result of the suppliers.

- In the second scenario, we repeated the same process on innovative criteria. The result has not changed again and Supplier C became the best greenovative supplier for company A.
- In the third scenario, only the situation of the environmental criteria weight being 100%, Supplier A is chosen as the best supplier. On any other situations, Supplier C became the best one.

In this study, the supplier selection problem is a complex decision making problem that takes place into MCDM problems has been solved by using various MCDM approaches and summary results of these methods have been represented in Table 4.4.

The AHP and ANP models generated using the obtained data were analyzed and the order of alternatives and criteria was determined. For both solution approaches it has been determined that the supplier C is the best preferred supplier. Azizi and Maleki (2014) also found the same ranking by using AHP and ANP to order their suppliers in the automotive industry. Eshtehardian et. al. (2013) made a study for the supplier selection in the construction and civil engineering companies in Iran. They also used AHP and ANP to determine the appropriate supplier. They found that although the ranking of suppliers are similar for AHP and ANP approaches, the values of variation between suppliers are different. On the other hand, Görener (2012) has implemented an application for strategic decision making in a manufacturing firm and compared the results obtained with the AHP and ANP solution techniques in this application. He found that there are significant differences between AHP and ANP outcome derived from interdependencies, outerdependencies and feedbacks. ANP is different from AHP in the solution phase of the problem because of the formation of a super matrix. Here the interactions between the criteria and the alternatives are taken into account and the best alternative is chosen by utilizing super matrix. It is known that the ANP method helps to make more effective and realistic decisions since it also takes into account the interdependence between the criteria. In this study, the ANP method was also applied in addition to the AHP method to support the accuracy of the result.

TOPSIS and VIKOR methods are more suitable for solution of large-scale problems according to AHP and ANP methods. All these techniques give a precise and clear ranking among the alternatives, but inconsistency ratio is not calculated in the TOPSIS

Table 4.4. Summary of results for all MCDM techniques.

Supplier	AHP		FAHP		ANP		FANP	
	Weight	Rank	Weight	Rank	Weight	Rank	Weight	Rank
Spr A	0.193	3	0.113	3	0.181	3	0.101	3
Spr B	0.288	2	0.289	2	0.289	2	0.297	2
Spr C	0.519	1	0.598	1	0.589	1	0.602	1

Supplier	TOPSIS		FTOPSIS		VIKOR		FVIKOR		GP	
	C	Rank	C	Rank	Q	Rank	Q	Rank	d	Rank
Spr A	0.795	3	0.801	3	0.513	3	0.920	3	0.525	3
Spr B	0.493	2	0.485	2	0.307	2	0.512	2	0.412	2
Spr C	0.033	1	0.032	1	0.011	1	0.008	1	0.151	1

and VIKOR methods, but in the AHP and ANP methods. In addition, TOPSIS and VIKOR methods have the ability to use various criteria in different units. The TOPSIS and VIKOR methods operate independently of the unit of measurement, provided that the required data are accurate numbers (Thor et. al., 2013).

In fact, the VIKOR method is based on the TOPSIS method, with minor differences. In the TOPSIS method, the optimum solution is to be determined that is closest to the positive ideal solution and is farthest from the negative ideal solution. This is an appropriate method in terms of decision makers who escaped from the risks (Zhang and Wei, 2013). The same logic also holds for the VIKOR method, but here the relative importance of the distances to the positive and negative solutions is also taken into account. Weighted relation between the maximum group utility and minimum individual regret are considered in VIKOR method. The VIKOR method, when designing the system, is an efficient tool for making multi-criteria decisions in a situation where the decision maker can not explain or know initially (Zhang and Wei, 2013).

Although the same ranking is obtained for different ranking MCDM approaches, TOPSIS and VIKOR methods are more suitable for explaining differences between alternatives. When the TOPSIS and VIKOR method is compared;

- In TOPSIS method the majority rule is considered, on the other hand in VIKOR method the smallest injures is considered.
- In TOPSIS method, weight is added in the distance calculation whereas in VIKOR method, weight is added in the final value.

If the two conditions defined in the VIKOR method are not satisfied, only the order of the alternatives made according to Q values will not be healthy and reliable. Ertuğrul and Özçil (2014) suggested that the obtained results from TOPSIS method for the selection of air conditioning are more reliable and healty than the results from VIKOR method because of in this problem, “Acceptable Advantage” and “Acceptable Stability in Decision Making” conditions could not be satisfied in VIKOR method. The ranking of alternatives is made only due to the Q values. If we have explicit parameters and v value, VIKOR method should be used otherwise TOPSIS should be preferred (Chu et. al., 2007).

In goal programming method, the objective function has more than one goal. In this method, the decision maker is asked to set a target value that he desires to reach for each objective. The weights and priorities of the targets are determined by the decision makers. A solution is found to minimize deviations from these target values. GP provides the user with an opportunity to take the opposite objectives in the objective function while providing an effective solution to the goals' priorities. Constraints that are not absolutely necessary are allowed in GP. On the other hand, in GP, The objective function is created by a combination of multiple success functions. For this reason, it may have a complex structure. Target values, their weights and priority levels are subjective values because these values are determined by the decision makers. In this study, three main selection criteria and each main criterion have nine sub criteria. So, twenty-seven objective functions are evaluated by the decision makers to select the proper greenovative supplier. All objective functions aim to minimize the deviations from the optimal solution. As a result of this method, the same ranking has been found like other MCDM techniques.

Decision making in today's complex environments is a very difficult process. Decision makers are faced with uncertainty resulting from experience and subjective perceptions in the decision-making process. In most of such decision environments it is appropriate to use the fuzzy decision-making theory. Thus, the uncertainty involved in the evaluation of data can be effectively represented with the help of the fuzzy approach, and a more effective decision can be reached. All classic MCDM techniques do not take into account uncertainty arising from human perception when weights and qualitative measurements are determined. Because the exact data are insufficient in modeling applications that appear confused in real life, the weights of subjective qualities and qualifications are often expressed in terms of verbal variables. For this reason, fuzzy logic set theory is widely used in MCDM techniques for solving MCDM problems (Yong, 2006).

Every MCDM technique has its own advantages and disadvantages. Decision makers must aim at the solution of the problem of decision making, choosing the most appropriate decision for themselves, taking into consideration the structure of the problem and the advantages and disadvantages of the techniques used. The same ranking (Supplier C-Supplier B-Supplier A) was found for the most appropriate greenovative supplier selection problem by using all MCDM techniques.

4.5. Managerial Implication

The objective of this research is to select the greenovative supplier for company A that is operating in the automotive industry by taking into account not only traditional criteria but also green and innovative criteria. This research helps to the company owner or manager to understand the greenovative supplier selection and evaluation processes. Three main criteria and twenty-seven sub-criteria are determined according to the results from the literature reviews. Under these conditions, the appropriate greenovative supplier is also determined to satisfy the company's requirements and improve the company's performance. Finally, by this research, the systematic approach is developed to select the greenovative supplier within a number of criteria and it helps to determine the proper greenovative supplier.

5- CONCLUSION

5.1. Summary of Research

Since many years the supplier selection problem emerges as a major problem. Companies are obliged to take account of a number of criteria when selecting suppliers and evaluating. For that, determination of the right supplier is a complicated multiple criteria decision making problem. Working with the right supplier will help to firms to improve and sustain their success. In today, increasing of the global competition and environmental awareness has led to the emergence of new criteria for the supplier selection problem. Academicians and practitioners have studied the new criteria such as environmental, innovative etc. in their projects in the literature. Some researchers consider environmental criteria in their studies, while some researchers also only consider the innovative criteria. Actually these criteria are the important for the successful supply chain management. However, there is a gap in the literature for both environmental and innovative criteria together.

For this reason, in this study, environmental and innovative criteria were taken into account in addition to traditional criteria, while the problem of supplier selection was addressed. In the Marmara Region, supplier selection criteria were determined as a result of the questionnaire conducted in the SMEs operating in the automotive sector. The decision makers created in company A evaluated these criteria and the suppliers they planned to work according to the selection criteria. It was aimed to select the greenovative supplier for company A by using different MCDM techniques.

5.2. Limitations of Research

Yin (2014) defined the limitations of the study as follows: Limitations refer to the weaknesses of the research or the problematic items of the research. In this study also, there are many limitations. The first problem was experienced in the selection of supplier selection criteria. In order to determine the supplier selection criteria, the questionnaire sent to the firm was evaluated by the related persons and it was send back in a period of as long as six months. In addition, this questionnaire is only applied to small and medium-sized enterprises operating in the automotive industry in Marmara

Region, where industrialization is intensive. Among the limitations of this study can be the failure to consider companies operating in other regions of Turkey or large-scale enterprises. In this study, only the green and innovative (greenovative) supplier selection for only the automotive sector was targeted, other sectors were ignored. In addition, the research did not focus on the quality of participants that evaluated the questionnaire.

5.3. Main Findings of Research

In this dissertation, two different solution tools were used to determine the best greenovative supplier. At the first step, data that were collected from the decision makers in company A were entranced into the DESTEC 1.0 software that is developed via C Sharp programming language. This programme gave us AHP, FAHP, ANP and FANP solutions.

When the results were examined, the most important selection criteria was determined as innovative criteria with 43 % of importance for AHP and 44.1 % of importance for FAHP. The traditional criteria took place in the second place with 42.8 % of importance for AHP and 44.1 % of importance for FAHP. Unfortunately, the environmental criteria had the smallest importance weight with 14.2 % for AHP and 11.6 % for FAHP. This suggests that it still not given adequate support for the environment in Turkey. At this point more work is being done by the government and the local municipalities. Environment-related laws should be implemented fully and if necessary, the financial and moral sanctions should be introduced.

In fact, especially small and medium-sized enterprises are aiming to reduce their costs to a minimum level in order to survive in the competitive market. At this point, they see all activities related to the environment as only a source of cost. However, when considered in the long period, these activities will be reflected as an advantage to the firm. For this reason, companies in this size should be informed in more detail about this issue.

Due to these criteria, supplier C was selected the best greenovative supplier with 51.9 % of importance for AHP 57.8 % of importance for ANP. When the fuzzy set theory was applied, the result has not changed and supplier C was selected with 59.8 % % of importance for FAHP and 60.2 % of importance for FANP.

At the second step, same data were entranced into DEMATSEL software is developed via C# programming language. This programme gave us AHP, FAHP, TOPSIS, FTOPSIS, VIKOR, FVIKOR and GP solutions. When all these different solution techniques' results were compared, sorting has always been achieved as supplier C, supplier B and supplier A. Even if we apply many different scenarios, Supplier C is always dominant compared the other ones. As a result, all MCDM techniques have given the same result in solving our problem. At this point, we can say that the decision maker team is making consistent evaluations while evaluating the criteria and alternatives.

5.4. Future Work

As a future work study, the supplier selection criteria should be reviewed and new criteria should be added into the environmental criteria group such as carbon footprint, water footprint and land footprint. In the following days, for example organizations should calculate carbon footprints of their products. New and significant criteria can be added to the model.

Besides, in addition to these solution techniques, the supplier selection problem can be solved by using ELECTRE, PROMETHEE, DEA etc. Also, the obtained results for the same problem can be evaluated when it is handled for different sectors, or when large-scale enterprises are taken into consideration, or when it is addressed for different regions of Turkey.

REFERENCES

Agarwal, P., Sahai, M., Mishra, V., Bag, M., Singh, V. (2011) A review of multi-criteria decision making techniques for supplier evaluation and selection. International Journal of Industrial Engineering Computations, 2, 801-810.

Awasthi, A., Chauhan, S. S., Goyal, S. K. (2010) A fuzzy multicriteria approach for evaluating environmental performance of suppliers. International Journal of Production Economics, 126(2), 370-378.

Ayağ, Z., Özdemir, R. G. (2006) A fuzzy AHP approach to evaluating machine tool alternatives. Journal of Intelligent Manufacturing, Kluwer Academic Publishers, 17 (2), 179-190.

Azizi, A., Maleki, R. (2014) Comparative study of AHP and ANP on multi-automotive suppliers with multi-criteria. Proceedings of The International MultiConference of Engineers and Computer Scientists, 2, March 12-14, Hong Kong.

Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J. and Sorenson, K. (2002) Guidebook to Decision Making Methods, Department of Energy, USA.

Baumann, J., Kritikos, A. S. (2016) The link between R&D, innovation and productivity: are micro firms different? Research Policy, 45, 1263-1274.

Becker, W., Dietz, J. (2004) R&D cooperation and innovation activities of firms-evidence for the German manufacturing industry. Researchy Policy, 33, 209-223.

Benyoucef, L., Ding, H., Xie, X. (2003) Supplier selection problem: Selection criteria and methods. Rapport de Recherche, 4726, 1-38.

Bhutia, P. W. and Phipon, R. (2012) Application of AHP and TOPSIS method for supplier selection problem. IOSR Journal of Engineering, 2(10), 43-50.

Buckley, J. J. (1985) Ranking alternatives using fuzzy numbers. Fuzzy Sets and Systems, 15(1), 21-31.

Bulut, K., Soylu, B. (2009) Öğretim üyelerinin iş yükü seviyelerinin bir Analitik Ağ Modeli ile değerlendirilmesi. Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 25, 150-167.

Büyüközkan, G., Çifçi, G. (2012) A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. Expert Systems with Applications, 39, 3000-3011.

Büyüközkan, G., Erkut, E. (2008) Kalite fonksiyonu göçerimi temelli sürdürülebilir tedarik zinciri yönetimi tasarımı. YAEM 2008 Conference, July, Istanbul.

Büyüközkan, G., Göçer, F. (2017) Application of a new combined intuitionistic fuzzy MCDM approach based on axiomatic design methodology for the supplier selection problem. Applied Soft Computing, 52, 1222-1238.

Büyüközkan, G., Güleryüz, S. (2016) An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey. International Journal of Production Economics, 182, 435-448.

Cao, H. (2011) The study of the suppliers evaluating and choosing strategies based on the green supply chain management. International Conference on BMEI, IEEE, 13-15 May, 3, 788-791.

Chamodrakas, I., Batis, D., Martakos, D. (2010) Supplier selection in electronic marketplaces using satisficing and fuzzy AHP. Expert Systems with Applications, 37(1), 490-498.

Chang, D. Y. (1996) Applications of the extend analysis method on fuzzy AHP. European Journal of Operational Research, 95, 649-655.

Chen, C. C., Tseng, M. L., Lin, Y. H., Lin, Z. S. (2010) Implementation of green supply chain management in uncertainty. International Conference on IE&EM, IEEE, 7-10 Dec, 260-264.

Cheng, E. W. L., Li, H. (2004) Contractor selection using the Analytic Network Process. Construction Management and Economics, 22, 1021-1032.

Chiou, C. Y., Hsu, C. W., Hwang, W. Y. (2008) Comparative investigation on green supplier selection of the American Japanese and Taiwanese electronics industry in China. International Conference on IE&EM, IEEE, 8-11 December, 1909-1914.

Chu, M. T., Shyu, J., Tzeng, G. H., Khosla, R. (2007) Comparison among three analytical methods for knowledge communities group-decision analysis. Expert Systems with Applications, 33, 1011-1024.

Climaco, J. (1997) Multicriteria Analysis, Springer, New York.

Colson, G., Bruyn, C. D. (1989) Models and methods in multiple objectives decision making. Mathematical Computing Modelling, 12, 1201-1211.

Daellenbach, U. S., McCarthy, A. M., Schoenecker, T. S. (1999) Commitment to innovation: the impact of top management team characteristics, R&D Management, 29(3), 199-208.

Dasgupta, M., Gupta, R. K. (2009) Innovation in organizations: a review of the role of organizational learning and knowledge management. Global Business Review, 10(2), 203-224.

Dweiri, F., Kumar, S., Khan, S. A., Jain, V. (2016) Designing on integrated AHP based decision support system for supplier selection in automotive industry. Expert Systems with Applications, 62, 273-283.

Dyer, J. S., Fishburn, P. C., Steuer, R. E., Wallenius, J. and Zionts, S. (1992) Multiple criteria decision making multiattribute utility theory: the next ten years. Management Science, 38(5), 645-654.

Ecer, F., Açıkgözlü, S., Yaman, F. (2009) Analitik Ağ Süreci (AAS) ve web sitelerinden yararlanarak otel seçimi. Hacettepe Üniversitesi, İktisadi ve İdari Bilimler Fakültesi Dergisi, 27 (1), 187-207.

Erciş, A., Can, P. (2013) Tedarik zinciri yönetiminin inovasyon stratejilerine etkisi üzerine bir araştırma. Karabük Üniversitesi, Sosyal Bilimler Enstitüsü Dergisi, 3(2), 95-122.

Ertuğrul, İ., Özçil, A. (2014) Çok kriterli karar vermede TOPSIS ve VIKOR yöntemleriyle klima seçimi. Çankırı Karatekin Üniversitesi, İktisadi ve İdari Bilimler Fakültesi Dergisi, 4(1), 267-282.

Eshtehardian, E., Ghodousi, P., Bejanpour, A. (2013) Using ANP and AHP for the supplier selection in the construction and civil engineering companies; case study of Iranian company. KSCE Journal of Civil Engineering, 17(2), 262-270.

Fallahpour, A., Olugu, E. U., Musa, S. N., Wong, K. Y., Noori, S. (2017) A decision support model for sustainable supplier selection in sustainable chain management. Computers&Industrial Engineering, 105, 391-410.

Famuyiwa, O., Monplaisir, L., Nepal, B. (2008) An integrated fuzzy-goal-programming-based framework for selecting suppliers in strategic alliance formation. International Journal of Production Economics, 113(2), 862-875.

Feyzioglu, O., Buyukozkan, G. (2010) Evaluation of green suppliers considering decision criteria dependencies. Multiple Criteria Decision Making for Sustainable Energy and Transportation Systems Lecture Notes in Economics and Mathematical Systems, 634, 145-154.

Galankashi, M. R., Chegeni, A., Soleimanynanadegany, A., Memari, A., Anjomshoae, A., Helmi, S. A., Dargi, A. (2015) Prioritizing green supplier selection criteria using Fuzzy Analytic Network Process. Procedia CIRP, 26, 689-694.

Galankashi, M. R., Helmi, S. A., Hashemzahi, P. (2016) Supplier selection in automobile industry: a mixed balanced scorecard-fuzzy AHP approach. Alexandria Engineering Journal, 55(1), 93-100.

Gani, A. N., Assarudeen, S. N. M. (2012) A new operation on triangular fuzzy number for solving fuzzy linear programming problem. Applied Mathematical Sciences, 6 (11), 525-532.

Gao, D., Xu, Z., Ruan, Y. Z., Lu, H. (2017) From a systematic literaturereview to integrated definition for sustainable supply chain innovation (SSCI). Journal of Cleaner Production, 142, 1518-1538.

Govindan, K., Rajendran, S., Sarkis, J., Murugesan, P. (2015) Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. Journal of Cleaner Production, 98, 66-83.

Görener, A. (2012) Comparing AHP and ANP: An application of strategic decisions making in a manufacturing company. International Journal of Business and Social Science, 3 (11), 194-208.

Grisi, R. M., Guerra, L., Naviglio, G. (2010) Supplier performance evaluation for green supply chain management. Business Performance Measurement and Management, 4, 149-163.

Güngör, A., Gupta, S. M. (1999) Issues in environmentally conscious manufacturing and product recovery: a survey. Computers and Industrial Engineering, 36, 817-818.

Hamdan, S., Cheaitou, A. (2017) Supplier selection and order allocation with green criteria: an MCDM and multi-objective optimization approach. Computers and Operations Research, 81, 282-304.

Handfield, R., Walton, S. V., Sroufe, R., Melnyk, S. A. (2002) Applying environmental criteria to supplier assessment: a study in the application of the analytical hierarchy process. European Journal of Operations Research, 141, 70-87.

Hoetker, G. (2005) How much you know versus how well I know you: selecting a supplier for a technically innovative component. Strategic Management Journal, 26, 75-96.

Hsu, C. W., Hu, A. H. (2009) Applying hazardous substance management to supplier selection using analytic network process. Journal of Cleaner Production, 17, 255-264.

Hsu, C. W., Kuo, T. C., Chen, S. H., Hu, A. H. (2013) Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. Journal of Cleaner Production, 56, 164-172.

https://en.wikipedia.org/wiki/Analytic_hierarchy_process, June, 23, 2015.

Humphreys, P. K., Wong, Y. K., Chan, F. T. S. (2003a) Integrating environmental criteria into the supplier selection process. Journal of Materials Processing Technology, 138, 349-356.

Humphreys, P. K., Mclvor, R., Chen, F. (2003b) Using case-based reasoning to evaluate supplier environmental management performance. Expert Systems with Applications, 25, 141-153.

Hwang, C. L., Yoon, K. (1981) Multiple Attribute Decision Making Methods and Applications. A State of The Art Survey, Springer-Verlag, Berlin Heidelberg, New York

Igarashi, M., de Boer, L., Fet, A. (2013) What is required for green supplier selection? A literature review and conceptual model development. Journal of Purchasing & Supply Management, 19, 247-263.

Jadidi, O., Cavalieri, S., Zolfaghari, S. (2015) An improved multi-choice goal programming approach for supplier selection problems. Applied Mathematical Modelling, 39(14), 4213-4222.

Jean, R., Sinkovics, R. R. (2010) Relationships learning and performance enhacement via advanced information technology. International Marketing Review, 27(2), 200-222.

Junior, F. R. L., Osiro, L., Carpinetti, L. C. R. (2014) A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection. Applied Soft Computing, 21, 194-209.

Kabak, M., Burmaoğlu, S., Kazançoğlu, Y. (2012) A fuzzy hybrid MCDM approach for professional selection. Expert Systems with Applications, 39(3), 3516-3525.

Kannan, D., Jabbour, A. B. L. D. S., Jabbour, C. J. C. (2014) Selecting green suppliers based on GSCM practices: using fuzzy TOPSIS applied to Brazilian electronics company. European Journal of Operational Research, 233, 432-447.

Kannan, D., Govindan, K., Rajendran, S. (2015) Fuzzy Axiomatic Design approach based green supplier selection: A case study from Singapore. Journal of Cleaner Production, 96, 194-208.

Karacan, İ. (2015) A New Hybrid Decision Support Tool and An Application to Health Technology Selection. A Master Thesis, Turkish Naval Academy, Naval Science and Engineering Institute, İstanbul, Türkiye, 31-33.

Karsak, E., Dursun, M. (2014) An integrated supplier selection methodology incorporating QFD and DEA with imprecise data. Expert Systems with Applications, 41(16), 6995-7004.

Keen, P. G. W. (1980) Decision Support Systems: A Research Perspective, Centre for Information Systems Research, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Kumar, A., Jain, V., Kumar, S. (2014) A comprehensive environment friendly approach for supplier selection. Omega, 42, 109-123.

Kuo, R. J., Lin, Y. J. (2012) Supplier selection using analytic network process and data envelopment analysis. International Journal of Production Research, 50(11), 2852-2863.

Kuo, R. J., Wang, Y. C., Tien, F. C. (2010) Integration of artificial neural network and MADA methods for green supplier selection. Journal of Cleaner Production, 18(12), 1161-1170.

Large, R. O., Thomsen, C. G. (2011) Drivers of green supply chain management performance: Evidence from Germany. Journal of Purchasing and Supply Management, 17, 176-184.

Lee, A. H. I., Kang, H. Y., Hsu, C. F., Hung, H. C. (2009) A green supplier selection model for high-tech industry. Expert Systems with Applications, 36, 7917-7927.

Li, X., Zhao, C. (2009) Selection of suppliers of vehicle components based on green supply chain. International Conference on IE&EM, IEEE, 21-23 Oct, 1588-1591.

Lima Junior, F. R., Osiro, L., Carpinetti, L. C. R. (2014) A comparison between fuzzy AHP and fuzzy TOPSIS methods to supplier selection. Applied Soft Computing, 21, 194-209.

Linton, J., Klassen, R., Jayaraman, V. (2007) Sustainable supply chains: an introduction. Journal of Operations Management, 25, 1075-1082.

Liu, H.C., Wang, M. (2011) An extended VIKOR method for multiple attribute group decision making based on generalized interval-valued trapezoidal fuzzy numbers. Scientific Research and Essays, 6(4), 766-776.

Lo, C. W., Leung, S. W. (2000) Environmental agency and public opinion in Guangzhou: the limits of a popular approach to environmental governance. The China Quarterly, 163, 677-704.

Lopez-Rodriguez, J., Martinez-Lopez, D. (2017) Looking beyond the R&D effects on innovation: the contribution of non-R&D activities to total factor productivity growth in the EU. Structural Change and Economic Dynamics, 40, 37-45.

Lu, L. Y. Y., Wu, C. H., Kuo, T. C. (2007) Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. International Journal of Production Research, 45(18-19), 4317-4331.

Luzzini, D., Amann, M., Caniato, F., Essig, M., Ronchi, S. (2015) The path of innovation: Purchasing and supplier involvement into new product development. Industrial Marketing Management, 47, 109-120.

Mahdiloo, M., Saen, R. F., Lee, K. H. (2015) Technical, environmental and eco-efficiency measurement for supplier selection: an extension and application of data envelopment analysis. International Journal of Production Economics, 168, 279-289.

Mavi, R. K., Goh, M., Mavi, N. K. (2016) Supplier selection with Shannon entropy and fuzzy TOPSIS in the context of supply chain risk management. Procedia Social and Behavioral Sciences, 235, 216-225.

Meade, L., Sarkis, J. (1998) Strategic analysis of logistics and supply chain management system using the ANP. Transportation Research Part E: Logistics and Transportation Review, 34 (3), 201-215.

Mohammadshahi, Y. (2013) A state-of-art survey on TQM applications using MCDM techniques. Decision Science Letters, 2(3), 125-134.

Nazeri, A., Meftahi, H., Shaharoun, A.M. (2011) Supplier evaluation and selection in SCM using Fuzzy AHP. 3rd International Conference on Advanced Management Science IPEDR, 19. IACSIT Press, Singapore.

Omann, I. (2004) Multi-Criteria Decision Aids as an Approach for Sustainable Development Analysis and Implementation, Report, Karl Franzens University, Graz-Austria.

Opricovic, S. (1998) Multi-criteria Optimization of Civil Engineering Systems, Faculty of Civil Engineering, Belgrade.

Opricovic, S., Tzeng, G. H. (2004) Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research, 156(2), 445-455.

Ömürbek, N., Demirci, N., Akalin, P. (2013) Analitik Ağ Süreci ve TOPSIS yöntemleri ile bilimdalı seçimi. Akademik Araştırmalar ve Çalışmalar Dergisi, 5 (9), 118-140.

Önüt, S., Kara, S. S., Işık, E. (2009) Long term supplier selection using a combined fuzzy MCDM approach. A case study for a telecommunication company. Expert Systems with Applications, 36 (2), 3887-3895.

Petersen, K. J., Handfield, R. B., Ragatz, G. L. (2005) Supplier integration into new product development: coordinating product, process and supply chain design. Journal of Operations Management, 23, 371-388.

Petroni, A., Panciroli, B. (2002) Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry. European Journal of Purchasing&Supply Management, 8, 135-149.

Prakash, C., Barua, M. K. (2016) A combined MCDM approach for evaluation and selection of third-party reverse logistics partner for Indian electronics industry. Sustainable Production and Consumption, 7, 66-78.

Pulles, N. J., Veldman, J., Schiele, H. (2014) Identifying innovative suppliers in business networks: an empirical study. Industrial Marketing Management, 43, 409-418.

Rogers, M. (1998) The definition and measurement of innovation. Working Paper, Melbourne Institute of Applied Economic and Social Research, Number: 10/98.

Rouyendegh, B. D., Saputro, T. E. (2014) Supplier selection using integrated fuzzy TOPSIS and MCGP: a case study. Procedia-Social and Behavioral Sciences, 116, 3957-3970.

Saaty, T. L. (2005) Theory and Applications of The Analytic Network Process, PA: RWS Publications, 4922 Ellsworth Avenue, Pittsburgh, PA 15213.

Saaty, T. L. (2008) Decision making with the Analytic Hierarchy Process. International Journal of Services Sciences, 1, 83-98.

Saaty, T. L. (2008) Relative measurement and its generalization in decision making why pairwise comparisons are central in mathematics for the measurement of intangible factors The Analytic Hierarchy/Network Process. Review of the Royal Academy of Exact, Physical and Natural Sciences, Series A: Mathematics (RACSAM), 102 (2), 251-318.

Sanayei, A., Mousavi, S. F., Yazdankhah, A. (2010) Group decision making process for supplier selection with VIKOR under fuzzy environment. Expert Systems with Applications, 37(1), 24-30.

Sarkis, J. (2003) A strategic framework for green supply chain management. Journal of Cleaner Production, 11, 397-409.

Sarkis, J., Hervani, A. A., Helms, M. M. (2005) Performance measurement for green supply chain managemet. Benchmarking: An International Journal, 12(4), 330-353.

Sarkis, J., Talluri, S. (2006) A model for strategic supplier selection. Journal of Supply Chain Management, 38(4), 18-28.

Schiele, H. (2006) How to distinguish innovative suppliers? Identifying innovative suppliers as new task for purchasing. Industrial Marketing Management, 35, 925-935.

Seman, N. A. A, Zakuan, N., Jusoh, A., Arif, M. S. M., Saman, M. Z. M. (2012) The relationship of green supply chain management and green innovation concept. Procedia-Social and Behavioral Sciences, 57, 453-457.

Senvar, O., Tuzkaya, G., Kahraman, C. (2014) Multi Criteria Supplier Selection Using Fuzzy PROMETHEE Method, Supply Chain Management Under Fuzziness Recent Developments and Techniques, 1st Edition., Kahraman, C., Öztayşi, B. Editors; Springer-Verlag Berlin Heidelberg, Germany.

Shemshadi, A., Shirazi, H., Toreihi, M., Tarokh, M. J. (2011) A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting. Expert Systems with Applications, 38, 12160-12167.

Shen, L., Olfat, L., Govindan, K., Khodaverdi, R., Diabat, A. (2013) A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. Resources, Conservation and Recycling, 74, 170-179.

Taha, R. A., Daim, T. (2013) Multi-Criteria Applications in Renewable Energy Analysis, a Literature Review, Research and Technology Management in the Electricity Industry, Green Energy Technology, T. Daim et. al. (eds.), Springer-Verlag, London.

Thor, J., Ding, S. H., Kamaruddin, S. (2013) Comparison of multi criteria decision making methods from the maintenance alternative selection perspective. The International Journal of Engineering and Science, 2(6), 27-34.

Triantaphyllou, E. (2000) Multi-Criteria Decision Making Methods: A Comparative Study, Springer US.

Tseng, M. L. (2011) Green supply chain management with linguistic preferences and incomplete information. Applied Soft Computing, 11(8), 4894-4903.

Turban, E. (1995) Decision Support and Expert Systems, New York: Prentice Hall.

Tuzkaya, G., Ozgen, A., Ozgen, D., Tuzkaya, U. R. (2009) Environmental performance evaluation of suppliers: a hybrid fuzzy multi-criteria decision approach. International Journal of Environmental Science and Technology, 6(3), 477-490.

Upadhyay, A., Baglieri, E. (2012) Innovative supplier selection: Key success factors. International Journal of Innovations in Business, 1, 336-344.

Van Laarhoven, P. J. M., Pedrycz, W. (1983) A fuzzy extension of Saaty's priority theory. Fuzzy Sets and System, 11, 199-227.

Velasquez, M., Hester, P. T. (2013) An analysis of multi-criteria decision making methods. International Journal of Operations Research, 10(2), 56-66.

Wang, J. W., Cheng, C. H., Kun-Cheng, H. (2009) Fuzzy hierarchical TOPSIS for supplier selection. Applied Soft Computing, 9, 377-386.

Weber, C. A., Current, J. R., Benton, W. C. (1991) Vendor selection criteria and methods. European Journal of Operational Research, 50 (1), 2-18.

Welp, M. (2001) The use of decision support tools in participatory river basin management. Physics and Chemistry of The Earth, Part B: Hydrology, Oceans and Atmosphere, 26(7-8), 535-539.

Wen, U.P., Chi, J. M. (2010) Developing green supplier selection procedure: a DEA approach. International Conference on ICMEE, IEEE, 1-3 Aug, 313-316.

Whaiduzzaman, M. D., Gani, A., Anuar, N. B., Shiraz, M., Haque, M. N. and Haque, I. T. (2014) Cloud service selection using multicriteria decision analysis. The Scientific World Journal, 2014, 1-10.

Wu, Y., Chen, K., Zeng, B., Xu, H., Yang, Y. (2016) Supplier selection in nuclear power industry with extended VIKOR method under linguistic information. Applied Soft Computing, 48, 444-457.

Yanar, L. (2011) A Fuzzy Hybrid Decision Support Software Development for Multi Criteria Decision Making Problems and an Application to Abrasive Waterjet. Master Thesis, Turkish Naval Academy, Naval Science and Engineering Institute, Department of Computer Science, İstanbul, Türkiye, 56-66.

Yang, Y., Wu, L. (2007) Grey entrophy method for green supplier selection. International Conference on WiCom, IEEE, 21-25 September, 4682-4685.

Yazdani, M., Chatterjee, P., Zavadskas, E. K., Zolfani, S. H. (2017) Integrated QFD-MCDM framework for green supplier selection. Journal of Cleaner Production, 142, 3728-3740.

Yazgan, E., Üstün, A. K. (2011) Application of Analytic Network Process: Weighting of selection criteria for civil pilots. Journal of Aeronautics and Space Technologies, 5 (2), 1-12.

Yeh, W. C., Chuang, M. C. (2011) Using multi-objective genetic algorithm for partner selection in green supply chain problems. Expert Systems with Applications, 38(4), 4244-4253.

Yılmaz, E. (2012) Bulanık AHP-Vikor bütünleşik yöntemi ile tedarikçi seçimi. Marmara Üniversitesi İ.B.B. Dergisi, 33(2), 331-354.

Yigit, G. (2014) Hedef Programlama. Ankara Üniversitesi, Sosyal Bilimler Enstitüsü, Ankara, Türkiye.

Yin, R. (2014) Case Study Research: Design and Methods, 5th. Edition, Thousand Oaks, CA: Sage.

Yong, D. (2006) Plant location selection based on fuzzy TOPSIS. International Journal of Advanced Manufacturing Technology, 28, 839-844.

Yoon, S. N., Lee, D. H., Schniederjans, M. (2016) Effects of innovation leadership and supply chain innovation on supply chain efficiency: focusing on hospital size. Technological Forecasting&Social Change, 113, 412-421.

You, X. Y., You, J. X., Liu, H. C., Zhen, L. (2015) Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information. Expert Systems with Applications, 42(4), 1906-1916.

Yu, P. L. (1973) A class of solutions for group decision problems. Management Science, 19(8), 936-946.

Zak, J. (2015) Comparative analysis of multiple criteria evaluations of suppliers in different industries. Transportation Research Procedia, 10, 809-819.

Zadeh, L. A. (1975) The concept of a linguistic variable and its application to approximate reasoning. Information Sciences, 8(3), 199-249.

Zeleny, M. (1982) Multiple Criteria Decision Making, New York, McGraw-Hill.

Zeleny, M. (1973) Compromise Programming, Multiple Criteria Decision Making, Cochrane, J. L. and Zeleny, M. (Eds.), University of South Carolina Press, Columbia.

Zhang, N., Wei, G. (2013) Extension of VIKOR method for decision making problem based on hesitant fuzzy set. Applied Mathematical Modelling, 37(3), 4938-4947.

Zhou, P., Ang, B. W., Poh, K. L. (2006) Decision analysis in energy and environmental modelling: an update. Energy, 31, 2604-2622.

Zhu, Q., Sarkis, J., Lai, K. (2008) Green supply chain management implications for closing the loop. Transportation Research Part E, 44, 1-18.

APPENDIX A

The Questionnaire for Determination of Green and Innovative Supplier Selection Criteria

This questionnaire has been prepared to aim that which criteria take into account in order to determine green and innovative (greenovative) supplier in the small and medium-sized enterprises (SMEs). Collaboration with the right supplier is an initial success key to decrease environmental damage and to survive in these competitive conditions. In this context, the answers you give to the questions will be useful for understanding the current situation and for the success of the research. For this reason, the questions in the questionnaire should be answered completely and correctly by the company owners, the purchasing manager or the staff working in the purchasing department.

It is aimed to evaluate the criteria under three main categories; Traditional, Environmental and Innovative Criteria to determine the greenovative supplier.

A- TRADITIONAL CRITERIA

In this section, it will be asked questions about quality, price, availability and delivery.

Questions	**Strongly Disagree**				**Strongly Agree**
	1	**2**	**3**	**4**	**5**
1-The suppliers should have high quality in their products and should have some quality certificate documents (eg: ISO9000, QS9000 etc.).					
2- The percentage of products that are called faulty after the quality control should be zero or at minimum.					

Questions	Strongly Disagree 1	2	3	4	Strongly Agree 5
3- For defective products, the supplier should have return guarantee and return policies.					
4- Poor quality products should be taken back by the supplier and replaced with new quality products.					
5- Without sacrificing quality and guarantee, the supplier should provide the lowest price for the product.					
6- The supplier should provide low cost but high performance products.					
7- The total cost of transportation of the product should be at minimum level.					
8- The supplier should be able to respond and supply quickly to customers' incoming orders.					
9- The supplier should have sufficient technical level in ordering and delivery processes.					
10- The supplier should be able to deliver all of the predetermined orders by the customer completely.					
11- The supplier should have technical equipment and information to meet the current and future needs of the customer.					
12- The supplier should be open and flexible to customer orders and requests.					
13- The supplier's production line and inventory management system should be compatible.					
14- Without compromising on price and quality, the supplier should deliver the product on time, without delay.					

B- ENVIRONMENTAL CRITERIA

In this section it will be asked some questions about environmental management and protection, pollution control, green product and supplier's green image.

Questions	**Strongly Disagree**				**Strongly Agree**
	1	**2**	**3**	**4**	**5**
1- The suppliers should have some environmental certificate documents (ISO 14000, etc.).					
2- Production process should be ecologically productive.					
3- According to product design, energy usage should be at minimum level.					
4- The occurrence of hazardous substances must be at minimum level in the production process.					
5- The supplier should operate in accordance with local environmental policies and regulations.					
6- The supplier must control the emissions of some gases (eg, SO_2, CO, NH_3, and HCl etc.) that are dangerous to the atmosphere and should be disposed them by appropriate treatment methods.					
7- The supplier should treat its wastewater by appropriate treatment methods.					
8- The supplier should take some initiatives in the field of air emissions, wastewater treatment, solid waste disposal, use of hazardous and toxic materials, and energy consumption.					
9- The supplier should have the capability to use a number of systems to reduce pollution.					

Questions	Strongly Disagree				Strongly Agree
	1	**2**	**3**	**4**	**5**
10- The supplier should be able to use its used products or parts of that product when producing new products.					
11- The supplier should choose raw materials and materials that are environmentally friendly during production.					
12- The supplier should choose environmentally friendly recyclable materials during packaging.					
13- The supplier should reduce the cost of product disposal by giving importance to recycling activities after the product becomes unusable.					
14- The supplier should provide a number of green certifications for the product it produces.					
15- The supplier should use environmentally friendly production technologies.					
16- The supplier should design and produce products with reusable properties.					
17- The supplier should separate the useful parts from the used products for future usage.					
18- When the product completes its life cycle, it must be disposed of or burned without damaging the environment.					
19- The supplier should use the materials that will give the least harm to the natural resources while producing the product.					
20- The supplier should have the ability to make changes in product design or production process to give the least amount of damage to the environment and natural resources.					

Questions	Strongly Disagree				Strongly Agree
	1	2	3	4	5
21- It should be important for the supplier that the proportion of the green customers to the total customer should be high.					
22- Suppliers and their business partners should be involved in environmental activities and initiatives.					
23- The supplier should store materials by encoding them as a group of dangerous and non-dangerous materials and the materials should not interfere with each other.					

C- INNOVATIVE CRITERIA

In this section it will be asked about the technical competence of the supplier, new product development, research and development activities, and supplier's organizational and company culture.

Questions	Strongly Disagree				Strongly Agree
	1	2	3	4	5
1- The supplier should have the ability to understand and adapt new technologies easily.					
2- The supplier should have information systems and technical equipment related to demand forecasting, customer service and inventory management.					

Questions	**Strongly Disagree**				**Strongly Agree**
	1	**2**	**3**	**4**	**5**
3- The technical competence and knowledge of the supplier's employees should be at the desired level.					
4- The supplier should give necessary importance to Research and Development (R&D) activities.					
5- The supplier should have the ability to design new products that can respond to the current and future needs of the customers.					
6- The supplier should attach importance to teamwork among departments throughout the new product development process.					
7- It is important for the supplier to allocate sufficient budget to the Research and Development (R&D) activities.					
8- The supplier should maximize the return of investments in Research and Development (R&D) activities.					
9- It is important that the supplier's employees at all levels to have the ability to innovate.					
10- The supplier should be in cooperation with business partners.					
11- The attitude of the supplier firm authorized personnel exhibited in innovative activities is important.					
12- For the supplier the number and success of innovative projects that has done in the past are important.					

D- Please provide your comments and insights about the subject.

E- GENERAL INFORMATION

The information you provided in this section is confidential and will never be used for any other purpose.

1- Surname, name:

2- Gender : □ Male □ Female

3- Age:

□ Under 18	□ 25-34	□ 45-54	□ Over 65
□ 18-24	□ 35-44	□ 55-64	

4- Company name:

5- Your position at current company:

□ Company Owner / CEO	□ Finance Manager	□ General Manager
□ Purchasing Personnel	□ Purchasing Manager	□ Other

6- Total number of employees in your company:

□ 10 or lower	□ 51-100	□ 251 or higher
□ 11-50	□ 101-250	

7- e-mail:

8- Phone number:

This is end of the questionnaire. The answers you gave the endless gratitude for your interest and patience.

APPENDIX B

Yeşil ve Yenilikçi Tedarikçi Seçim Kriterlerinin Belirlenmesi için Soru Ölçeği

Bu anket, Küçük ve Orta Ölçekli İşletmelerin (KOBİ) yeşil ve yenilikçi tedarikçilerini seçerken hangi kriterleri dikkate aldıklarını belirlemek amacı ile hazırlanmıştır. Artan rekabet koşullarında ayakta kalabilmek ve aynı zamanda çevreye verilen zararların minimum düzeyde tutulabilmesi açısından doğru tedarikçi ile çalışmak önemli bir faktördür. Bu bağlamda sorulara vereceğiniz cevaplar mevcut durumun anlaşılmasına ve araştırmanın başarılı olmasına yararlı olacaktır. Bu nedenle anketteki sorular, firma sahipleri, satınalma müdürü veya satınalma bölümünde çalışan personel tarafından eksiksiz cevaplanmalıdır.

Ankette Geleneksel, Çevresel ve Yenilikçi Kriterler olmak üzere üç ana kategori altında kriterlerin değerlendirilmesi hedeflenmektedir.

A- GELENEKSEL KRİTERLER

Bu bölümde kalite, fiyat, tedarik yeteneği ve teslimat ile ilgili sorular sorulacaktır.

Sorular	**Kesinlikle Katılmıyorum**				**Kesinlikle Katılıyorum**
	1	**2**	**3**	**4**	**5**
1- Tedarikçi firma ürünlerinde yüksek kaliteyi sağlamalı ve kalite ile ilgili belgelere (örneğin ISO9000, QS9000 vs.) sahip olmalıdır.					
2- Kalite kontrolünden geçemeyen ürünlerin oranı sıfır veya minimum düzeyde olmalıdır.					
3- Hatalı ürünler için tedarikçi firma iade garantisi ve iade politikalarına sahip olmalıdır.					

Sorular	Kesinlikle Katılmıyorum				Kesinlikle Katılıyorum
	1	2	3	4	5
4- Kötü kaliteli ürünler tedarikçi firma tarafından geri alınmalı ve kaliteli olan yeni ürün ile değiştirilmelidir.					
5- Kaliteden ve garantiden ödün vermeksizin tedarikçi firma ürün için en düşük fiyatı vermelidir.					
6- Tedarikçi firma düşük maliyetli ancak yüksek performaslı ürün sağlamalıdır.					
7- Ürünün toplam taşıma maliyeti minimum olmalıdır.					
8- Tedarikçi firma müşteriden gelen şiparişlere hızlı bir şekilde cevap verip temin edebilmelidir.					
9- Tedarikçi firma şipariş oluşturmada ve teslimatta yeterli teknik seviyeye sahip olmalıdır.					
10- Tedarikçi firma müşterisi tarafından önceden belirlenen siparişlerin hepsini eksiksiz teslim edebilmelidir.					
11- Tedarikçi firma müşterinin şimdiki ve gelecekteki ihtiyaçlarına cevap verecek teknik donanıma sahip olmalıdır.					
12- Tedarikçi firma müşteriden gelen sipariş ve isteklere karşı açık ve esnek olmalıdır.					
13- Tedarikçinin üretim hattı ile stok yönetim sistemi uyumlu olmalıdır.					
14- Fiyat ve kaliteden ödün vermeden tedarikçi firma ürün teslimatını gecikme olmadan zamanında gerçekleştirmelidir.					

B- ÇEVRESEL KRİTERLER

Bu bölümde çevre yönetimi ve korunması, kirlilik kontrolü, yeşil ürün ve tedarikçinin yeşil görünümü ile ilgili sorular sorulacaktır.

Sorular	**Kesinlikle Katılmıyorum**				**Kesinlikle Katılıyorum**
	1	**2**	**3**	**4**	**5**
1- Tedarikçi firma çevre ile ilgili bir takım sertifikalara sahip olmalıdır (ISO14000 vs).					
2- Ürün üretimi ekolojik olarak verimli olmalıdır.					
3- Enerji kullanımını minimum düzeyde tutacak ürün tasarımı olmalıdır.					
4- Üretim sürecinde tehlikeli ürünlerin ortaya çıkması minimum düzeyde olmalıdır.					
5- Tedarikçi firma yerel politika ve yönetmelikler ile uyumlu faaliyet göstermelidir.					
6- Tedarikçi firma atmosfer için tehlikeli olan emisyonların (SO_2, CO, NH_3, ve HC1 vs.) miktarını kontrol altında tutmalı ve bu emisyonları uygun yöntemler ile bertaraf etmelidir.					
7- Tedarikçi firma atık suyunu uygun yöntemlerle arıtmalıdır.					
8- Tedarikçi firma hava emisyonları, atık su arıtımı, katı atık bertarafı, tehlikeli ve zararlı malzemelerin kullanımı ve enerji tüketimi ile ilgili konularda girişimlerde bulunmalıdır.					

Sorular	**Kesinlikle Katılmıyorum**				**Kesinlikle Katılıyorum**
	1	**2**	**3**	**4**	**5**
9- Tedarikçi firma kirliliği azaltacak bir takım sistemleri kullanabilecek yeterliliğe sahip olmalıdır.					
10- Tedarikçi firma kullanılmış ürünlerini veya o ürüne ait parçaları yeni ürün üretirken kullanabilmelidir.					
11- Tedarikçi firma üretim esnasında çevre dostu olan hammadde ve malzemeleri tercih etmelidir.					
12- Tedarikçi firma paketleme esnasında çevre dostu geri dönüşebilir malzemeleri tercih etmelidir.					
13- Tedarikçi firma, ürün kullanılmaz hale geldikten sonra, geri dönüşüm faaliyetlerine önem vererek ürünün bertaraf edilme maliyetini düşürmelidir.					
14- Tedarikçi firma ürettiği ürüne ait bir takım yeşil sertifikaları sağlamalıdır.					
15- Tedarikçi firma çevre dostu üretim teknolojilerini kullanmalıdır.					
16- Tedarikçi firma yeniden kullanılabilir özellikte ürünler dizayn etmeli ve üretmelidir.					
17- Tedarikçi firma kullanılmış ürünlerden işe yarar parçaları gelecek üretimlerde kullanmak üzere ayırmalıdır.					
18- Üretilen ürün ömrü dolduğu zaman çevreye zarar vermeden bertaraf edilmeli veya yakılmalıdır.					

Sorular	Kesinlikle Katılmıyorum				Kesinlikle Katılıyorum
	1	**2**	**3**	**4**	**5**
19- Tedarikçi firma ürünü üretirken doğal kaynaklara en az zarar verecek malzemeleri kullanmalıdır.					
20- Tedarikçi firma çevreye ve doğal kaynaklara en az zararı vermek için ürün tasarımında veya üretim prosesinde değişiklik yapabilme yeteneğine sahip olmalıdır.					
21- Tedarikçi firmanın sahip olduğu yeşil müşterilerinin toplam müşterilerine oranı yüksek olmalıdır.					
22- Tedarikçi firma ve iş ortakları çevre ile ilgili aktivite ve girişimlerde bulunmalıdır.					
23- Tedarikçi firma malzemelerini tehlikeli ve tehlikeli olmayan malzemeler şeklinde kodlayarak depolamalı ve malzemeler birbirine karışmamalıdır.					

C- YENİLİKÇİ KRİTERLER

Bu bölümde tedarikçinin teknik yeterliliği, yeni ürün geliştirme, araştırma ve geliştirme çalışimaları ile tedarikçinin organizasyonel ve firma kültürü ile ilgili sorular sorulacaktır.

Sorular	**Kesinlikle Katılmıyorum**				**Kesinlikle Katılıyorum**
	1	**2**	**3**	**4**	**5**
1- Tedarikçi firma yeni teknolojileri kolaylıkla anlama ve uyarlama yeteneğine sahip olmalıdır.					
2- Tedarikçi firma talep tahminleri, müşteri hizmetleri ve envanter yönetimi ile ilgili bilgi sistemlerine ve teknik donanımlara sahip olmalıdır.					
3- Tedarikçi firma çalışanlarının teknik yeterlilikleri ve bilgileri istenilen seviyede olmalıdır.					
4- Tedarikçi firma Araştırma ve Geliştirme faaliyetlerine önem vermelidir.					
5- Tedarikçi firma müşterilerinin şimdiki ve gelecekteki isteklerine cevap verebilecek yeni ürün tasarımı yapabilme yeteneğine sahip olmalıdır.					
6- Tedarikçi firma yeni ürün geliştirme süreci boyunca bölümler arasında takım çalışmasına önem vermelidir.					
7- Tedarikçi firmanın Araştırma ve Geliştirme faaliyetlerine yeterli bütçeyi ayırması önemlidir.					
8- Tedarikçi firma Araştırma ve Geliştirme faaliyetlerine yaptığı yatırımların geri dönüşümünü maksimum düzeyde almalıdır.					
9- Tedarikçi firmada her kademede çalışan personelin inovasyon yapabilme yeteneğine sahip olması önemlidir.					
10- Tedarikçi firma iş ortakları ile işbirliği içerisinde olmalıdır.					

Sorular	Kesinlikle Katılmıyorum				Kesinlikle Katılıyorum
	1	**2**	**3**	**4**	**5**
11- Tedarikçi firma yetkililerinin yenilikçi faaliyetlerde sergilemiş olduğu tutum önemlidir.					
12- Tedarikçi firmanın geçmişte yapmış olduğu yenilikçi projelerinin sayısı ve başarısı önemlidir.					

D- Konu ile ilgili ilave etmek istediğiniz görüşlerinizi ve yorumlarınızı lütfen belirtiniz.

E- GENEL BİLGİLER

Bu bölümde vermiş olduğunuz bilgiler gizli olup, hiçbir yerde başka amaçlar için asla kullanılmayacaktır.

1- Adınız ve Soyadınız:

2- Cinsiyetiniz : ☐ Erkek ☐ Kadın

3- Yaşınız:

☐ 18 altı ☐ 25-34 ☐ 45-54 ☐ 65 üstü

☐ 18-24 ☐ 35-44 ☐ 55-64

4- Çalıştığınız firma:

5- Çalıştığınız firmadaki göreviniz:

☐ Firma Sahibi / CEO ☐ Genel Müdür ☐ Finans Müdürü

☐ Satınalma Müdürü ☐ Satınalma Personeli ☐ Diğer

6- Çalıştığınız firmadaki toplam personel sayısı:

□ 10 veya daha az □ 51-100 □ 251 veya üstü

□ 11-50 □ 101-250

7- e-mail:

8- Telefon:

Anketimiz sona ermiştir. Vermiş olduğunuz cevaplar, göstermiş olduğunuz ilgi ve sabır için sonsuz teşekkürler…

ÖZGEÇMİŞ

Elif ÇALOĞLU BÜYÜKSELÇUK 17/08/1978 yılında Trabzon'da doğdu. İlk, orta ve lise eğitimini İstanbul'da tamamladıktan sonra 1999 yılında Yıldız Teknik Üniversitesi İnşaat Fakültesi Çevre Mühendisliği lisans diplomasını almaya hak kazanmıştır. 2003 yılında ise Boğaziçi Üniversitesi Çevre Bilimleri Enstitüsü Çevre Teknolojileri yüksek lisans programını tamamlamıştır, 2004-2011 yılları arasında İstanbul Ticaret Üniversitesi Mühendislik ve Tasarım Fakültesi Endüstri Mühendisliği Bölümü'nde Araştırma Görevlisi olarak çalışmıştır. 2006 yılında Marmara Üniversitesi Fen Bilimleri Enstitüsü Mühendislik Yönetimi A.B.D. Doktora Programına kabul edilmiştir.

Kendisi evli ve bir çocuk annesidir.