MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

A MODEL FOR SUPPLIER SELECTION UNDER ENVIRONMENTAL CONSIDERATIONS

AHMET SELÇUK YALÇIN

MASTER THESIS

Department of Industrial Engineering

Thesis Supervisor

Assoc. Prof. Dr. Hüseyin Selçuk KILIÇ

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MARMARA ÜNİVERSİTESİ
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Marmara Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Öğrencisi Ahmet Selçuk Yalçın'ın **"A model for supplier selection under environmental considerations"** başlıklı tez çalışması, 14 Aralık 2017 tarihinde savunulmuş ve jüri üyeleri tarafından başarılı bulunmuştur.

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ONAY

Marmara Üniversitesi Fen Bilimleri Enstitüsü Yönetim Kurulu'nun 18.12.2017 tarih ve 2017/27-02 sayılı kararı ile Ahmet Selçuk Yalçın'ın Endüstri Mühendisliği Anabilim Dalı Endüstri Mühendisliği Programında Yüksek Lisans derecesi alması onanmıştır.

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ÇEVRESEL DEĞERLENDİRMELER ALTINDA TEDARİKÇİ SEÇİMİ İÇİN BİR MODEL

Günümüzde, medya, sivil toplum kuruluşları ve bilimsel makaleler sayesinde toplumun ve küresel rekabetçi piyasanın çevresel farkındalığı önemli derecede artmıştır. Bununla birlikte, pek çok çevresel sıkı düzenlemeler hükümetler tarafından yürürlüğe konmuştur. Bu, işletmeleri bugünün yok edici iş ortamında ayakta kalabilmek için çevre konularına odaklanmalarını sağlamıştır. Bu nedenle, son yıllarda, yeşil tedarik zincirine olan ilgi artmakta ve yeşil tedarikçi seçimi büyük ölçüde önem kazanmaktadır. Yeşil tedarikçilerin seçimi, çelişkili, nicel ve nitel, geleneksel ve yeşil faktörleri içerdiğinden çok kriterli bir karar verme problemi olarak düşünülebilir.

Bu araştırmada, hem bilim insanlarının hem de üreticilerin dikkatini çeken yeşil tedarikçileri seçmek için kullanılan mevcut yöntemler ve kriterler ayrıntılı olarak incelenmiştir. Uzmanların ve karar vericilerin kararlarındaki bulanıklık ve belirsizlik nedeniyle, bu çalışmada sezgisel bulanık mantıkla bütünleşik bir model önerilmiştir. Bu model kriter ağırlıklarını belirlemek için Sezgisel Bulanık Analitik Hiyerarşi Süreci'ni (IF-AHP) ve tercihlerin son sıralamasının yapılması için PROMETHEE tekniğini içermektedir. Çalışmanın sonunda, önerilen yöntemin doğrulanması için filtreleme endüstrisinde bir uygulama sunulmuştur.

İstanbul, 2017 **Ahmet Selçuk Yalçın**

ABSTRACT

A MODEL FOR SUPPLIER SELECTION UNDER ENVIRONMENTAL CONSIDERATIONS

Today, the environmental awareness of the society and global competitive market increases considerably thanks to the media, non-governmental organizations and scientific articles. However, many environmental strict regulations have been put into effect by governments. This has forced corporations to focus on environmental issues in order to stand in modern destructive business environment. Therefore, in the recent times, caring in the green supply chain is on an increasing trend and green supplier selection becomes majorly significant. The selection of green suppliers can be considered as a MCDM problem because it includes conflicting, quantitative and qualitative, traditional and green criteria.

In this research, the current methods and factors for selecting green suppliers, which attract the attention of both scientists and manufacturers, have been examined in detail. Owing to ambiguity and uncertainty in stakeholders' and decision makers' judgments, an integrated model with intuitionistic fuzzy logic was proposed in this study. This model includes Intuitionistic Fuzzy Analytical Hierarchy Process to determine the criteria weights and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) technique to carry out a final ranking of alternatives. At last, an application in filtration industry is presented for the validation of the proposed method.

İstanbul, 2017 **Ahmet Selçuk Yalçın**

SYMBOLS AND ABBREVIATIONS

AHP: Analytic Hierarchy Process

ANN: Artificial Neural Network

ANOVA: Analysis of Variance

ANP: Analytic Network Process

ARAS: Addictive Ratio Assessment

CEN: European Committee for Standardization

COPRAS: COmplex PRoportional ASsessment

COPRAS-G: COmplex PRoportional ASsessment of Alternatives with Grey Relations

CWA: Common Weights Analysis

DEA: Data Envelopment Analysis

DEMATEL: Decision Making Trial and Evaluation Laboratory

DM: Decision Maker

DOE: Department of Energy In The United States

ELECTRE: Elimination and Choice Expressing the Reality

EMAS: Eco Management and Audit Scheme

EMS: Environmental Management System

ERP: Enterprise Resource Planning

FAD: Fuzzy Axiomatic Design

FAHP: Fuzzy Analytic Hierarchy Process

FANP: Fuzzy Analytic Network Process

FMOLP: Fuzzy Multi Objective Linear Programming

FST: Fuzzy Set Theory

MLMCDM: Multi Level Multi Criteria Decision Making

GRA: Grey Relational Analysis

GSCM: Green Supply Chain Management

GSC: Green Supply Chain

GSCF: Global Supply Chain Forum

GSS: Green Supplier Selection

HEPA: High Efficiency Particulate Air

HVAC: Heating, Ventilation and Air Conditioning

IF-AHP: Intuitionistic Fuzzy Analytic Hierarchy Process

IFS: Intuitionistic Fuzzy Sets

IFWA: Intuitionistic Fuzzy Weighted Averaging

IFWG: Intuitionistic Fuzzy Weighted Geometric

IVHFRM: Interval- Valued Hesitant Fuzzy Ranking Method

IPA: Importance Performance Analysis

ISO: International Standards Organization

IT2FSs: Interval Type-2 Fuzzy Sets

JIT: Just in-Time

KAM: Kourosh and Arash Method

LT-TOPSIS: Linguistic 2-Tuple Technique for Order Preference by Similarity to an Ideal Solution

MAGDM: Multi-Attribute Group Decision Making

MCDM: Multi-Criteria Decision Making

MCGDM: Multi-Criteria Group Decision Making

MLMCDM: Multi Level Multi Criteria Decision Making

MMAHP: Modified Multiplicative Analytic Hierarchy Process

MOGA: Multi Objective Genetic Algorithms

MOLP: Multi Objective Linear Programming

MOP: Multi Objective Programming

MSGP: Multi Segment Goal Programming

NGOs: Non-Governmental Organizations

OWA: Ordered Weighted Averaging

PROMETHEE: Preference Ranking Organization METHod for Enrichment Evaluations

QFD: Quality Function Deployment

QGDD: Quantifier Guided Dominance Degree

QUALIFLEX: Qualitative Flexible Multiple Method

REACH: Registration, Evaluation, Authorisation and Restriction of Chemicals

ROHS: Restriction of Hazardous Substances

RL: Reverse Logistics

SC: Supply Chain

SCM: Supply Chain Management

SCOR : Supply Chain Operations Reference

SIFWG: Simple Intuitionistic Fuzzy Weighted Geometric

SYIFWG: Symmetric Intuitionistic Fuzzy Weighted Geometric

SWARA: Stepwise Weight Assessment Ratio Analysis

SWOT: Strengths, Weaknesses, Opportunities and Threats

TFNs: Triangular Fuzzy Numbers

TIFN: Triangular Intuitionistic Fuzzy Numbers

TODIM: Interactive and Multicriteria Decision Making in Portuguese

TOPSIS: Technique for Order Preference by Similarity to an Ideal Solution

TOWA: Tuple Ordered Weighted Averaging

TWA: Tuple Weighted Averaging

ULPA: Ultra Low Particulate Air

VIKOR : Vise Kriterijumska Optimizacija I Kompromisno Resenje

WASPAS: Weighted Aggregated Sum Product Assessment

WEEE: Waste Electrical and Electronic Equipment

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1.INTRODUCTION AND AIM

Developments in technology and the industry to meet the increasing needs after the industrial revolution have led to environmental problems and raw material insufficiency. Especially after 1970s, toxic gases and wastes produced by factories have reached serious dimensions which threaten human health. Due to environmental problems, a large number of different species have disappeared and ecosystem balance has been disrupted. Global environmental problems affecting the entire world have emerged. The gases that create greenhouse effect, such as carbon dioxide released into the atmosphere, caused global warming to happen. As a result of global warming, serious environmental disasters such as rising sea level, melting of glaciers, exhaustion of usable water resources, starvation, thirst, desertification and forest fires have occured.

The fact that environmental problems reach these dimensions has led to an increase in public awareness and preparation of tighter environmental regulations by the governments. This has forced businesses to be more environmentally friendly in their supply chain process. Especially in the last thirty years, environmentally conscious companies have become more prominent in the global competitive environment. However, due to enterprises' desire to be ahead of the global competition, they intend to establish long-term cooperation with suppliers. Suppliers with environmental awareness are preferred by firms because they can better adapt to the global environmental trend and create a green image in the eyes of customers. Another reason is that the harmful compounds contained in the raw materials and semi-products supplied by the supplier can bring about considerable environmental influence in the entire process.

Thus, determining the environmentally conscious supplier can be regarded as one of the most significant activity in the SC. As globalization grows, supplier selection problem becomes more complex. This problem has become a multi-criteria decision-making problem that requires many variables, environmental and traditional criteria and alternatives to be jointly evaluated.

The aim of the study is to propose a methodology to determine the most appropriate environmentally conscious supplier considering green and traditional criteria in filtration industry. To achieve this purpose, studies related to procurement processes, green supplier selection processes and the determinants which are effective in this problem were examined.

Furthermore, an implementation was realized in a filtration plant to demonstrate the steps of the proposed method.

First in the following section, various definitions were given regarding the concepts of SC, SCM and supplier selection. The importance of supplier selection was emphasized. It was also mentioned that the importance, objectives, benefits and challenges of SCM.

Then, in the third section, various definitions of GSCM, internal and external factors directing businesses to green practices, green supply chain activities and GSS process were presented. In the fourth section, GSS studies in the literature were examined and application area of this study was presented.

In the fifth section, the working system, types and importance of HEPA filter were observed. Also, the features of HEPA filter media were examined.

In the sixth section, the steps of proposed metholody were examined. Each of techniques was then described in detail. In the seventh section, the explanations of main and sub criteria used in this study were presented and an application in the filtration industry was presented to validate the proposed methodology.

In the final section, the used criteria and techniques were evaluated, the result obtained in the study were shared and opinions about future probable researches were referred.

2. SUPPLY CHAIN MANAGEMENT

2.1. The Concept of Supply Chain

Rapid and unexpected developments in technology and changes in customer requirements lead to alteration of competition conditions. However, due to globalization, products are now sold not only in the places where they are produced, but also in many parts of the world. Moreover, production facilities do not always have the opportunity to be located where raw materials and components are located. When all the current conditions are considered, it is very difficult for enterprises to survive and grow in the face of challenging global competition (Peker, 2010).

Especially after 1970s, the concept SC has become a considerable structure that responds to the requirements of companies in order to be able to adapt to global competition.

Therefore, the issue of supply chain (network administration, decision making mechanisms, planning, etc.) is a robustly improving science field (Banaeian et al., 2015).

Before describing the concept of SCM, it is crucial to consider what the SC means. According to American Production and Inventory Control Association (APICS) Supply Chain Management is a competitive strategy that makes value, a technology that enhances efficiency, and a device that helps corporations grow in an incrementally integrated business world (Url-1).

In accordance with the Supply Chain Council, the concept of SC contains all efforts to produce and distribute the final product. These efforts are; planning (supply and demand management), resource(providing raw material and semi-finished products), production (production and assembly), delivery (Güzel, 2011).

The concept of supply chain is defined according to different scientists. Although definitions seem to be different from each other, the message they want to give is the similar. There are a number of SC definitions in literature as follows:

The SC is a system of manufacturers and deliverers that ensures raw materials, turns raw materials into semi-products and final products, then delivers final products to clients (Lee and Billington, 1992). Another definition of SC is that it is a set of components that include suppliers, logistics service providers, producers, distributors, and retail dealers and has a flow of material, product and data among them (Kopczak, 1997).

In accordance with Beamon (1999) SC is an integrated process that consists of obtaining of raw materials, conversion of raw materials into end products and delivery of end products to retailers and clients as a result of the cooperation of suppliers, producers, distributors and retailers.

In accordance with Banaeian et al. (2015) SC is the worldwide system and its components are in charge of fulfilling the manufacturing and dissemination of a specified commodities from providing raw materials to handing over of products to perform the client's demand.

In accordance with Guo and Tsai (2015) SC is a system that enables a firm to obtain and hand over its commodities and services to its clients. SC network composes of suppliers, producers, dispenders, retail dealers, and clients and each constituent has a large effect on entire operation.

SC concentrates on internal process and the utilization of company's sources. Furthermore, a SC is a considerable operation which highlights significance of exterior links to various businesses. In particular, a SC is a period of change where components are transformed into commodities via production, montage, dispensation and retail trade in diverse businesses and the products are then handed over to the customer (Guo and Tsai, 2015).

2.2. The Concept of Supply Chain Management

The definitions of SC obviously demonstrate that SC is a complicated system and there is a constant exchange of information and interaction among components. It is a very connected system so that the faulty that occurs in one member affects the others negatively. Therefore, careful and attentive planning in SC is very important. This dramatically affects the flow and operation of SC. The result of this planning is the concept of SCM. SCM also means that products and information are monitored and guided throughout the supply chain (Büyüksaatçi, 2009).

Nowadays, customers are the main determinant of business decisions and companies are keen to develop ways of cooperating with all members (suppliers, manufacturers, retailers, distributors) to satisfy their customers. The name of this cooperation period is named Supply Chain Management (Özdemir, 2004).

In accordance with Büyüksaatçi, (2009) the most comprehensive SCM definition is that SCM covers the management of substances from raw materials to delivery of end products and it is a management philosophy that concentrates on how companies can benefit from their suppliers' operations, technological innovations and capabilities in order to support their competitive capacity and also allows to establish commercial partnerships with traditional in-house activities, optimization and effective joint ventures. The classical SCM is illustrated in Figure 2.2.

However, there are some acceptable different definitions of SCM in the literature:

In accordance with Yang et al. (2007) SCM is considered as a concept that performs stock management or cost saving transactions. They also highlighted that, at the beginning of the 90's, significant industries have identified the more important tasks and effects of the supply chain management over company management. It is increasingly taken into consideration to use in business administration and management of organization's transactions (Yang et al., 2007).

In accordance with Tuzkaya et al. (2009), "SCM is the integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes and high levels of information sharing to create high-performing value systems that provide member organizations a sustainable competitive advantage".

In accordance with Hervani et al. (2005) SCM is the arrangement and administration of a complicated group of systems with the task of handing over the end product to the end users or clients. It is also a crucial process involving in the procurement of raw material and necessary fragments, production, assembling and warehousing of products, order taking and follow-up, dissemination by means of several ways and eventually handing over to the end user. The structure of a firm's supply chain composes of exterior suppliers, interior operations of the firm and exterior dealers, alongside clients and end-users.

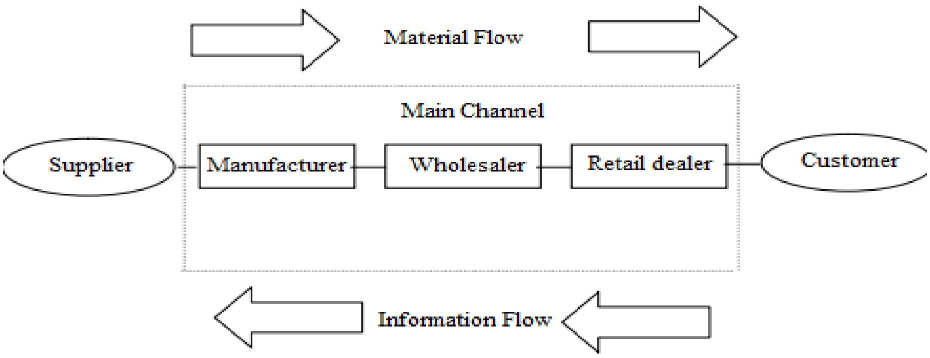

Figure 2.1: Classical SCM (Özdemir, 2004)

Hervani et al. (2005) also highlighted that companies can be a member of more than one supply chain concurrently. However, the administration and coordination of the supply chain is more complex by global determinants spread beyond geographical borders and multiple time periods. The accomplished administration of a supply chain is affected by client's anticipations, globalization, information technology, governmental and non-governmental enforcements, rivalry and the environment.

In accordance with Yazdani (2014), "SCM is the extension of a network of components interrelated together to reach organizational goal, prepare and distribute products and provide services after production".

In accordance with Yazdani et al. (2017) SCM is a process that organizes and integrates various operations, from the client's order to the final product distribution in a well-arranged way. They highlighted that the achievement or unsuccess of any SCM depends majorly on an available process and the suitable suppliers. However, nowadays, the current rapidly varying SCM environment is featured by high quality anticipations with low profit margins and less waiting period for orders.

In accordance with Fıçı (2006), SCM is a combination of material, information and cash flow that enables the customer to obtain the correct product considering both price and time factors. Minimizing the cost within the supply chain is an important issue as supply flow carry out. Another definition is the strategy of unifying basic business processes within the supply chain aiming to enhance client satisfaction.

2.3. The Objectives of SCM

The objectives of the SCM are summarized as follows:

- Enhancing sellings
- Making best use of business
- Increasing firm's profitability
- Increasing customer satisfaction
- Reducing cycle time
- Improving delivery performance
- Decrease in stocks
- Reducing the costs related to storage and storage
- Reducing product flaws
- Protecting product quality
- Reducing operating costs (Banaeian et al., 2015; Hamdan and Chieateou, 2017; Özdemir, 2004)

2.4. Challenges and Advantages of Supply Chain Management

In accordance with Şen (2008), an effective supply chain management positively affects businesses' production and marketing activities and increases customer satisfaction and ensures speed, cost, quality and efficiency.

Fawcett et al. (2008) have examined the benefits of SCM according to clients’ and companies’ point of view.

Client focus

- Enhanced client responsiveness
- More stable on-time delivery
- Client pleasure
- Shorter order times

Firm focus

- Decreasing procurement costs
- Better wealth use
- Capability to manage unforeseen events
- Decreasing inventory costs
- Company productivity
- Decreasing entire product cost

However, reduction in time of reaching the market, reduction in stock levels, obtaining better market information, increase in forecast accuracy, increase in quality, more focus on core competencies, providing competitive advantage in the market are among other benefits of the supply chain.

The supply chain provides advantages for all members in case it is effectively managed. But ineffective management of the supply chain causes to lose businesses' competitiveness. Possible losses, however, can be listed as follows:

- Profit losses due to excessive and dysfunctional inventory
- Income losses due to unexpected claims and mis-executed transactions
- Customer losses resulting from not meeting their demands and expectation
- Loss market share against competitors using effective supply chain activities
- Loss of production time due to plenty of time to remove uncertainties
- Missed opportunities due to inadequacy of product delivery on time and in desired quantity (Şen, 2008).

2.5. Supply Chain Management Processes

The eight processes defined by the decision of attendants of the GSCF are generally accepted.

These processes are as follows (Özdemir, 2004):

- Client Relations Administration
- Client Service Administration
- Request Administration
- Order Fulfillment
- Production Flow Administration
- Purchasing
- Product Improvement and Commercialization
- Revenues

2.6. Supplier Selection

In modern business world, any organization does not have the whole essential goods or cover all demands by utilizing its respective sources. For this reason to take competitive advantage in the increasing worldwide and complicated rivalry, corporations are bound to do business in close connection to external collaborator. Concurrently the external association ability of a corporation has major impacts on its abilities to improve novel innovations on its products or services and on communicating appropriate suppliers (Acar et al., 2016).

In accordance with the last prediction, the mean US producer spends about half of its income to buy product and merchandise. In this respect, the selection of suppliers and how they perform is an important issue for producers because they invest a lot in suppliers. The supplier selection is a difficult MCDM problem because of comprising both concrete and abstract elements. The supplier selection problem is intended to choose the most sutiable suppliers from a range of potential suppliers to meet specific requirements and customer demands considering their constraints (Hosseini and Barker, 2016).

However, the achievement of SCM is largely dependent on visibility along the SC. The reason for this is that the capability to respond swiftly to abrupt, unexpected alteration rises as visibility in the supply chain goes up. An influential supplier selection in SCM is required to create a trustworthy and sustainable relationship between supplier and purchaser. In addition, the choice of the correct supplier is vital to provide cost-effective manufacturing and to gain an accurate quality in the competitive environment of the production industry (Duman et al., 2010).

Suppliers are the dealers who procure raw materials, substances or services which a corporation itself may not present (Kuo and Lin, 2012). Supplier selection is the process of revision, evaluation and election of suppliers to make them a part of the corporation's supply chain. The supplier selection problem comprises of examining and evaluating the suppliers' performance to rank and choose them. A sound supplier selection contributes to a crucial distinction in a corporation's future while decreasing organizational and environmental expenses and developing the standard of its final products (Banaeian, 2014).

Supplier selection process is a decisive factor in a successful green supply. In the past, producers were prone to bargain for lower prices, higher quality, convenient delivery times and special conditions as they had to keep a large number of suppliers. Owing to global rivalry, producers do not incline to build a short-term relations with suppliers to effectively combine the component with data flow throughout the SC and react to rapidly-developing marketplace. Furthermore, middle class corporations want to establish sound relationships with solely a number of suppliers to achieve a consistent supply of components, help them in making innovation for products, share technology and data, and obtain reciprocal success. Provided the chosen supplier does not address the needs, the association can be a calamity. For this reason, choosing available suppliers and shaping an association with them happen a serious topic in green supply (Tsui and Wen, 2012).

Long-term business partnership between supplier and company need to be provided for achievement of SCM. Long-term collaboration with suppliers is more stable and gives the company a competitive advantage. In the procurement process, the processes of the supplier and the firm must be in harmony. In case of incompatibility, resource loss may occur. For this reason, the scientific and strategic supply chain process is a necessity.

Two types of ways are considered when choosing suppliers. In the first type, one supplier may meet purchaser's all requirements and the purchaser need to decide about which supplier is the most appropriate. In the second type, a number of supplier need to be evaluated since a supplier can not meet the all orders of the purchaser (Kannan et al., 2013). The advantages of working with a single supplier can be summarized as follows (Baran, 2012):

- The long dated agreement between client and supplier and the strong relationship between the partners,

- The same responsibility and care in all orders
- Decreasing the differences between the materials
- The possibility of discounts on orders
- Conducting businesses more securely
- Swifter communication between supplier and buyer

Even if working with a single supplier is very beneficial in some cases, it also has major risks. Provided the supplier experiences a financial crisis, the enterprise may stop production or hinder orders even though it is not a fault of its own and in the face of this situation the customers become victim. Because of these reasons, a number of organizations prefer to work with a large number of suppliers. By separating their budgets to a certain number of suppliers and sharing their orders they can reduce the likelihood of presence of any supplier hindering the business. In this case, a financial problem of a supplier does not put business which demands material from supplier in a difficult position (Baran, 2012).

The advantages of working with a multi-sourced supplier can be summarized as follows (Baran, 2012):

- Having more information about the market,
- To benefit from the price competition between suppliers,
- Not being dependent on a single company,
- To be able to respond to the demand in different or very large quantity in a short time

Supplier selection process is often defined as an activity, which involves various tasks. These tasks are shown in Figure 2.2. This usually begins with the process of determining needs. Later the buyers accept the criteria for measurement for the potential suppliers and the tenders are reported to the potential suppliers. An election is carried out after observing the data provided by the candidate suppliers.This process is repeated several times and the final selection is made amongst a few eligible suppliers. Furthermore, it can contain post-election assessment of the performance of supplier. Data obtained as a result of a post-election assessment can be stored and made available for further utilization and developments. Assessment of supplier performance is occasionally called "supplier monitoring" or "application feedback". By adding post-election assessment in supplier selection process, former models of the supplier selection process can be extended without varying the main structure (Igarashi et al., 2013).

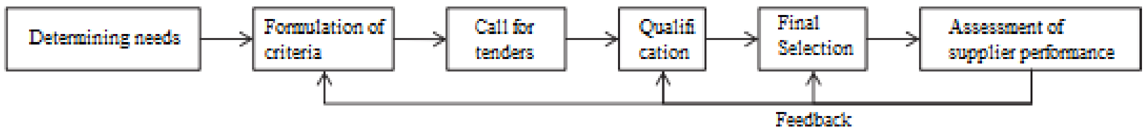

Figure 2.2: Supplier Selection Process (Igarashi et al., 2013)

After obtaining necessary information on the general concept of SCM and its purpose, benefits and processes and supplier selection process, the terms and concepts that related to GSS and GSCM will be evaluated in following.

3. GREEN SUPPLY CHAIN MANAGEMENT

3.1. The Environment

The environment is the physical, biological, social, economic and cultural environment in which people and other living creatures interact between each other throughout their lives. It also refers to the sum of the cultural, economic and physical conditions that affect living things and the life of the society (Url-2).

When considered in terms of enterprises, in accordance with the definition of Istanbul Chamber of Industry, the environment is an economic resource that ensures the necessary resources for realization of manufacturing (Türkay, 2015). In short, the environment is a covering of all living and inanimate things on earth.

The intervention of humankind to nature began with significantly after industrial revolution. This has led to the degradation of the ecosystem and the extinction of living species. Subsequently, such things as population growth and urbanization have led to worsen people's relationship with the environment. This has caused serious global environmental pollution. Environmental pollution, however, has not only been affected by population growth, urbanization and industrialization, while at the same time misconceptions about the environment, lack of education, uncoordination and tourism investments have also caused environmental pollution (Uzel, 2017).

3.1.1. Environmental Pollution and Types

Environmental pollution is the unnaturally disruption of the environment by people. Actions to disrupt this ecosystem are named as pollution (Url-3). Environmental pollution is the intense mixing of air, water and soil with foreign substances which influence negatively the health of entire living things and cause structural damage to inanimate environment items and disturb their qualities (Çepel and Ergün, 2013).

3.1.1.1 Air Pollution

Air pollution is defined as the increase in pollutants that can be found in the atmosphere in the form of dust, smoke, gas, odor and impure water vapor, which may damage people and other living things (Çepel and Ergün, 2013).

Air is a mixture of 78% nitrogen, 21% oxygen, 0.9% argon and 0.04% carbon dioxide and other gases. Air pollution occurs when the amount of gases in the natural composition of the atmosphere changes, and foreign substances enter the atmosphere. As in the nature, there is a precise and perfect balance in the atmosphere. The problem of air pollution arises with destruction of this balance (Uzel, 2017) .

With increasing population and welfare of people, exhaust gases from motor vehicles, whose number are swiftly increasing, constitute the most important factor in air pollution. Nowadays, inconvenient location in the establishment of industrial facilities, failure to take necessary precautions in terms of protection of the environment, utilization of inappropriate technologies and utilization of fossil fuels in energy generating combustion units majorly cause air pollution (Url-4).

3.1.1.2 Water Pollution

Water pollution is the mixing of organic, inorganic, biological and radioactive materials with water. Water pollution is a major danger to human health. Bacteria and virus rate increase in water resources polluted with sewage waters. It causes the spread of typhoid, dysentery, hepatitis, cholera and other infectious diseases. Serious outbreaks may occur when these disease elements are involved in water resources (Güler and Çobanoğlu, 1994). The causes of water pollution include industrial wastes, household wastes, agricultural wastes. However, it is known that many industrial corporations discharge waste water into rivers, lakes and seas. Also, waste oils, detergents used in houses are mixed with water. Apart from these, chemicals used in agriculture also cause water pollution by mixing with ground water (Uzel, 2017).

3.1.1.3 Soil Pollution

With the application of modern agriculture and the acceleration of industrialization from the beginning of the twentieth century, soil pollution has become an environmental problem. There was no pollution in the soil before the industrial revolution due to the lack of power and energy sources used in previous centuries, the lack of population, the lack of industrial development (Url-5).

The main reasons for the pollution of the soil are as follows (Uzel, 2017):

- Leakage of underground storage tanks
- Pesticide utilization
- Infiltrating dirty water into underground layers
- Oil and other fuel leaks
- Waters leaked from landfill sites
- Industrial wastes
- Emission of exhaust gas
- Utilization of fossil fuels

3.1.1.4 Noise Pollution

Noise is undesirable sounds that cause adverse psychological and physiological effects. Noise is an environmental issue that emerges as a consequence of urbanization and industrialization and causes other problems, especially on health of people. Noice can be defined as a voice over a certain level (Peker, 2010).

Noise pollution is the formation of all kinds of human, animal or machine originated voices which negatively affect human or animal life. One of the most common forms of noise pollution is the pollution caused by motor vehicles in particular (Url-6).

The harmful effects of noise pollution on people can be summarized as follows (Uzel, 2017):

- Hearing organs, hearing health and perception are effected negatively.
- If noise exceeds certain level, breathing rate increases, heartbeat weakens, headaches and dizziness can carry out
- Behavior disorders, irritation, general discomfort may carry out.

- The work efficiency reduces and muscular fatigue carry out and body movements are prevented

3.1.1.5 Radioactive Pollution

Nuclear power plants, factories producing nuclear weapons, radioactive material residues are the main sources of "Radioactive Pollution". Radioactive materials damage the air, water, soil and vegetation with the electrons they emit. Animal products (meat, fish, milk, etc.) with radioactive substances and plants carry this harmful substance through the food chain to humans and other living things. As a result, it may stop the immune system and damage people's organs. However, diseases that do not have any treatment may carry out (Çepel and Ergün, 2013).

3.2 Green Approach to Supply Chain Management

Historically, the examination and administration of industrial contamination has been a serious matter for the community since the industrial revolution took place. Particularly in these years, contamination caused by industrialization was not an important research matter for scientists in economics and management (Sarkis et al., 2011).

In the early 20th century, conducting supply chains acquired notority in applications considering management and engineering literature. A number of crucial implementation of contemporary SCs, such as Lean and Just in-Time (JIT) production, may be considered the product of Henry Ford's endeavour for perpendicularly combining the automotive SC with organizational applications. In that period, the application of JIT and SCM just concentrated on increasing operational yield and minimizing waste. The objective of reducing wastes was not for environmental, but financial causes because waste represents a major economic loss (Sarkis et al., 2011). Nonetheless, nowadays, owing to growing environmental problems it has almost become unthinkable to focus only on the economic dimension of industrial waste and pollution.

For many years, especially in the last thirty years, it has not been possible to consider the negative effects of industrial activities on the environment, such as greenhouses gases, chemical substances spouted in water, and solid wastes which harm the environment. Due to growing environmental concerns, in the 90's, the protection of natural resources and the environment have become a very significant global issue in national and international conferences (Büyüközkan and Vardaloğlu, 2008). However, people from all walk of life in the whole world have become more anxious about the environmental problems that threaten the future of the world.

The environment is heavily influenced by production and industrial operations, especially in major developing countries (China and India). This is caused by unconscious consumption of raw material and energy, the emission of hazardous gases and components which lead to air pollution. The corporations may control and even hinder these detrimental environmental consequences by providently utilizing inestimable energy and by implementing safer components and methodologies (Molamohamadi et al., 2013).

Green approach to SCM prominently emerged between the years of 1990 and 2000 and it became both internationally and academically an up-to-date subject (Polat, 2014). In many countries over the past decade, green approach has become a significant part of SC strategies. A number of serious global environmental problems have led to an increase in awareness. The main alarming of these global problems are global warming, melting of glaciers, global climate change, acid rain, rising sea level, depletion of ozone layer and air pollution and so on.

Min and Galle (1997) suggested that waste and emissions emerged in the supply chain activities became the fundamental sources of critical environmental issues such as global warming, acid rain and global climate change. In today’s business world, the conception of "green" is integrated into the whole members of SC to reduce those harmful effects caused by SC activities.

However, apprehending and forming a connection between SCM and the natural environment is crucial issue not only for health and the environment, but also for the prospective achievement of the enterprise. The increasing environmental effects of industrial manufacture are ideally tackled at the supply chain level. However, social requests and physical constraints are growingly creating challenges for companies to tackle the environmental effect of mass manufacturing and consumption. Supply chain management is the most available functional level to carry out industrial reform (Paquette, 2005). In the current market, green approach in supply chain also enables companies to develop green image, to provide more benefits from sustainable energy sources, to adapt more quickly to market changes and to meet customers' environmental requests.

Alterations and developments are generally caused by requirements (Türkay, 2015). The transition from the traditional understanding of supply chain to the present understanding of environmental supply chain emerges due to a number of social, economic and environmental requirements. It is possible to list these requirements in the following way (Türkay, 2015):

- Governmental regulations and legislation
- Customer's demands
- Increasing competition
- Ecosystem degredation
- The desire to catch an advantage
- Providing cost reduction through waste management
- Shortening product life cycle
- Stakeholders' and owners' demands
- Company image and policies
- Increasing consumer sensitivity and awareness
- Sustainable development

As a result of increasing environmental awareness, governments, local and global non-governmental organizations (NGOs) have become more sensitive to environmental problems. There is a pressure on the use of green management practices in businesses. However, green approach can be considered as a necessity for firms to have an environmentally conscious understanding rather than their own choice. By legislative arrangements, constraints can be placed on the operations and the applications which negatively affect the environment (Andic et al., 2012). Nowadays, both legislations and consumer expectations are driven by environmentally friendly products and services. Therefore it is very important for managers to identify and implement environmental sustainability practices in their supply chains (Green et al., 2012).

Growing public awareness in developed and developing countries and stricter governmental regulations, conferences and protest demonstrations on environmental issues organized by global and local NGOs, customer pressure and the desire of companies to be in a more advantageous position in the competitive market has forced corporations to adopt green measures in the supply chain management. Industrial institutions in developed countries have established full-fledged systems in order to comply with these regulations, implement eco-friendly strategies and thereby to reduce their carbon footprint (Xu et al., 2013).

Zhu et al. (2005) examined four types of pressures that directed companies to the green supply chain “supply chain pressure, cost related pressure, marketing and regulations”. Srivastava (2005) has categorized pressures into three groups: economic conditions related to the recovery of consumed resources, directives of governments and associations, and pressures from consumers.

In this respect, Hervani et al. (2005) have gathered the pressures and controls confronted by an organization which integrates green approach into supply chain management under two main headings; internal functions and external shareholders. Internal functions include “health and safety, environment operations, engineering, marketing, accounting, human resources and information systems”. External stakeholders consist of “customers, suppliers, community, regulators and NGOs”.

In the literature, the pressures on GSCM are usually addressed in two groups: external and internal (Güzel, 2011).

3.2.1. Internal Factors

GSCM applications have an entrepreneurial policy focused on expense and waste reduction and quality improvement. The desire to reduce costs refers to a compelling factor for the implementation of in-house environmental projects (Güzel, 2011).

Internal factors of an enterprise's GSCM practices contain individual opinions of leaders, middle management, entrepreneurial policy and investors. Researchers demonstrate that full support of top and middle management is necessary to build up the green supply chain in the enterprises. Internal organizational factors often aim to reduce waste and pollution by focusing on quality improvement and cost reduction (Güzel, 2011). Especially in small and medium scale enterprises, the profits and decisions of the stakeholders and executives become crucial during green supply chain implementation process.

The pressure on GSCM's internal controls is majorly related to cost and profit. Waste needs, disposal costs, general waste and non-recyclability are the main ones of internal factors. There are several internal controls including all forms of old systems, information administration system, total quality management, and alternative industry-based norms. However, internal factors influence the decisions of the enterprises in adapting new applications. A large number of new applications lead to increased environmental and overall business performance (Hervani et al., 2005).

For corporations, waste, emissions, destruction of waste and pollution mean both time and cost. The mismanagement of environmental problems in enterprises creates a serious burden on the operation of monetary penalties. Nevertheless, overcoming the impediments caused by legal obligations lead to serious time losses. With the occurrence of the GSC concept, it is understood by businesses that the generation of waste and pollution can be prevented or reduced to a large extent (Url-7).

3.2.2. External Factors

Increasing environmental problems and the reduction of natural resources make consumers conscious and this situation forces governments to take the necessary precautions. Thus, the green practices in corporations depends on a large number of external factors.

External factors are applied in three ways ; normative, compulsive and imitative. Normative pressures are perceived as more legal. Customer needs can be considered amongst normative pressures. However, for companies where several external stakeholder forces exist, compulsive pressures can be put into force. Governments can implement environmental practices through compulsive regulations (Güzel, 2011).

The pressures arise from penalties for incompatibilities related to the environmental impacts of enterprises, or by public awareness of the environmental effects of businesses. Examples include NGOs, environmental voluntary groups and industrial associations (Güzel, 2011).

3.2.2.1. Government

Formal government structures symbolize one of the most relevant stakeholders. Government pressures to promote green approach in supply chain contains compulsive precautions including penalties, fines, and cancelling of license in case corporations are incapable of meeting specific regulative necessities. However, the action of contamination interception fostered formal government structures to help to improve supportive precautions such as benchmarking, data sharing and green subsidiary as means to help private and civil institutions become greener (Bai and Sarkis, 2010).

As one of the strongest stakeholders of GSC, the government can readily direct the corporations by affecting their internal and external sources. Governments in the supply chain may be regarded as an outer environment that can ensure value, as well as inevitability, seldomness and non-substitutability to the firm. Nonetheless, governments can not only apply normative and restrictive forces to firms, but they can also affect the resources of firms (Nezaketi et al., 2016).

The government agencies can encourage green companies by encouraging clients to purchase eco-friendly products. This situation enhances profit share of eco-friendly products in the market. Then, the government agencies can publish green companies lists to media, this increases fame of green companies in the market and eventually cause an increase in their revenue. The government also can foster media to develop the validity of green corporations. Futhermore, the government agencies can influence NGOs to strenghten their relationship with the green enterprises (Nezaketi et al., 2016).

3.2.2.2. Competitors

Being environmentally friendly is a crucial strategy of differentiating the enterprises from its competitors.The enterprise which does not adopt the green supply chain is under pressure by its competitors. Therefore, the companies are bound to adopt and implement green supply chain regardless of its competitors (Güzel, 2011).

Although some businesses do not attach much importance to environmental research and development activities, they recognize that their competitors on the market considers the environment as a competitive element. The delay in implementing environmental innovations in enterprises means to lose green customers on the market to competitors. In this regard, timing is very crucial because businesses will either be in the first place or they will follow developments back. Top-ranked businesses should place more emphasis on environmental factors in supply chains. Companies that are late in this area should also give importance to environmental factors in supply chains as soon as possible (Url-7).

However, every enterprise may not always have an opportunity to gain competitive advantage by adopting a green approach. In this regard, the top management of the enterprises and shareholders have important responsibilities. They need to help to overcome environmental change pressures the enterprise faces and improve internal policy and management systems to encourage change (Güzel, 2011).

3.2.2.3. Community and Consumer

Human and the environment are naturally constantly interacting with each other. The vast majority of environmental problems are caused by unconscious human behavior.

Increased industrial wastes and rapid pollution of the environment cause climate change, global warming and the extinction of many living species. The human being responsible for this pollution is negatively affected by this pollution like other living species. Today, as the pollution levels increase rapidly, societies understand that this pollution must be precluded (Köse, 2010).

As a result, companies have to be accountable to public on environmental issues. Today, consumers are increasingly aware of environmental protection. When modern-day customers purchase a product, they are generally influenced by green image of the firm and firm's respect for environmental issues. Green products are demanded more. Company stakeholders and managers should have an environmental approach in the supply chain to develop relationships with the consumers.

Nowadays, the community pays more attention to the environmental approaches of enterprises when purchasing products. Even, environmentally conscious community demand the products of environmentally conscious enterprises despite of high price. The media, environmental groups, community pressures and stakeholders, NGOs or green voluntary groups that have the ability to influence an enterprise's perception in society are key factors that cause enterprises to monitor green supply chain activities. These structures also have the effect of directing communities easily. Therefore, these groups should not be ignored because they have serious influence in terms of damaging the image of the enterprises (Güzel, 2011).

3.2.2.4. Regulations

Nowadays, inadequacy of raw materials and resources and the importance of environmental issues lead to innovation programs or stricter environmental regulations for these issues. Government regulations and rules are one of the most important factors contributing to this development. Regulations play a strong role in contributing to product innovation, reducing companies' emissions and recycling the products. Environmental regulations are one of the main factors for enterprises to adapt to environmental practices. Encouragement of innovation has a positive effect on firms' competitive advantage.

3.2.2.5. Environmental Management Systems

EMS is a systematic methodology which may be utilized by a business or corporation to determine and direct its environmental effects. An EMS is a administration means which helps to carry out sustained development by means of a “plan, do, check, act” cycle which may contain best administration applications (Zutshi et al., 2008). The Environmental Management System is also a cycle of continuous development and it can be shown in Figure 3.1.

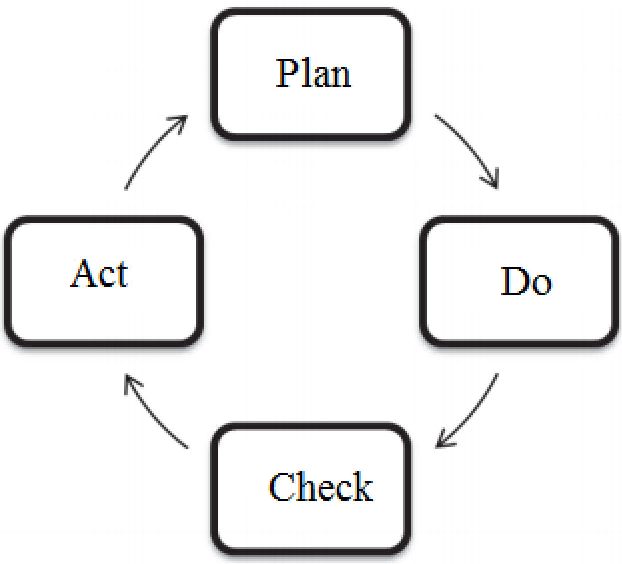

Figure 3.1 : Environmental Management System Elements

In the planning phase, it is necessary to precisely determine the target to be achieved and prepare the implementation plan. The first and most critical step of this cycle is the planning phase. Proper assignment of tasks and targets at the planning stage will reduce the amount of transaction in the final step. In this step, it is very important to inform the people in charge. Tracking the action plan takes place at this stage. The follow-up of implementation results is also included in this phase. It is determined whether the targets can be reached in the control phase. Deviations from the target and their causes are investigated at this stage. The deficiencies identified in the last phase are eliminated and the plan can be revised according to changing circumstances.

Benefits of EMS can be explained as follows (Zutshi et al., 2008):

- Diminished greenhouse wastes
- Developed immediate treatment planning
- Better monitoring of all kinds of permissions (health, fire, etc.)

- Suitability for various encouragement programs presented by state regulatory agencies
- Developed performance and improved management productivity
- Occasions for cost reduction
- Higher level of personel attendance and responsibility;
- Possible savings for risk and debt reduction and payroll tax

The fact that the legislative arrangements for countries, national and regional conditions differ from each other, led to the creation of different environmental standards (Karaer and Pusat, 2002). This has begun to create various trade barriers between countries. An EMS standardization was needed to remove these differences and the obstacles and various standards were developed. The most common of these standards are; EMAS, BS 7750 and the ISO 14000 (Peker, 2010).

3.2.2.5.1. BS 7750

The British Standards Institute constituted, in 1992, BS 7750 as standard for environmental control in the production and service sector. BS 7750 enables corporations to indicate compliance with health and safety arrangements, domestic and national environmental necessities and the latest industry application orders. Compliance to this standard provide significant conservation against allegations about product liability and indictments of unfair omission (Url-26).

Although BS 7750 is a system that can be applied to all types and sizes of enterprises, it is a standard that is difficult and sometimes impossible to use especially in developing countries because it contains very inflexible and special materials for developed countries. BS 7750 is very important because of leading to ISO 14001 and EMAS (Peker, 2010).

3.2.2.5.2. EMAS

EMAS is a senior administration tool improved by the European Commission to assess, report and develop the environmental performance of corporations and other organizations. EMAS is available for any organization that wants to develop its environmental performance. This certificate covers all economic and service sectors and is valid all over the world (Url-8).

The objectives of EMAS can be listed as follows (Peker, 2010):

- Creating and implementing environmental policy, programs and management systems
- Monitoring environmental performance in a systematic and objective way
- Providing continuous amendment and improvement by informing the public and relevant sections on environmental performance

The benefits of EMAS can be listed as follows (Url-9):

- Increased reliability, transparency and dignity
- Advanced environmental risks and opportunity management
- Improved environmental and financial performance
- Strengthening and motivating employees

3.2.2.5.3. ISO 14000

ISO 14000 has been improved to assist any corporation all across the world to carry out the target of sustainable improvement and environmental companionship. The ISO 14000 standards family were issued as formal document in 1996. The ISO 14000 series targets to improve an extensive approachment to environmental management and to guide a number of the crucial environmental analysis instruments such as labeling and life cycle assessment (Quazi, 1999).

The benefits of ISO 14000 to businesses can be listed as follows (Url-27) :

· Facilitates compliance with national and international legal regulations.
· Improves environmental performance.
· Provides competitive advantage in national and international markets.
· Improve business reputation and increase market share.
· Provides reduction of cost and increase in productivity by improving cost control
· Helps to reduce incidents like accidents
· Provides control and reduction of pollution starting from the source.
· Provides savings in raw materials, components and energy used as input.
· Reduces the amount of waste
· Makes it easier to obtain permission and authorization documents.
· ISO 14001 is a globally recognized common language and is accepted in national and international markets.

- Reduces costs which take place due to environmental impacts
- Helps to increase environmental awareness in employees due to environmental training

3.2.2.6. Directives

The directive is a commercial regulation consisting of instructions. The directives issued by the organizations are legally entitled, although they are not law (Türkay, 2015).

It is the responsibility of the EU directives to companies that are members of the European Union and / or export to the European Union countries. These countries are obliged to implement and carry out these directives. Today, the European Union Directives have published a number of different regulatory directives related to environmental problems (Türkay, 2015). In the scope of the study, the directives dealing with HEPA filter media will be examined. These directives are RoHS and REACH.

3.2.2.6.1. RoHS

The RoHS directive stipulates that certain materials can not present in electronic cards or materials. On 7 January 2003, it is a directive restricting the use of harmful substances accepted by the Council of Europe in electronic products. It prohibits the use of substances harmful to human health such as lead, cadmium, mercury and brominated components (Url-10).

Directive 2011/65 / EC (RoHS 2) on the limitation of accurate dangerous materials in electrical and electronic devices has been put into practice as of 2 January 2013, while taking place in the former EU directive (RoHS 1). RoHS2 is regulated in accordance with the REACH Regulation.

Heavy metals and compounds in accordance with RoHS directive, such as chromium mercury and cadmium are seriously harmful for both the environment and the living,as well as human health when they are not recycled and controlled. These heavy metals lead to miscarriage in pregnant women, or they interfere with blood and cause cells to die. They can also lead to serious illness such as cancer (Url-11).

3.2.2.6.2. REACH

REACH is the acronym of "Registration, Evaluation, Authorisation and Restriction of Chemicals". It went into operation in 2007 in the Europe and takes the place of the previous regulation for the chemical substance in the EU (Url-12).

One of the fundamental causes of improving and implementing the REACH Regulation is that a lot of hazardous chemicals, occasionally in high amount, were manufactured and put onto the market in the Europe for years (Url-13). However, many people do not have adequate data about their harmful impact on the environment.

The essential target of REACH is to conserve the all living things and environment from hazardous impact of chemicals. However, encouragement of various testing methodologies, the unrestricted movement of materials in the interior market, the improvement of competition capacity and novelty are amongst the targets of REACH (Url-12). When the directive and market conditions are examined, it is understood that there are unexplained targets such as protecting the EU market and competitive advantage in its chemical industry.

Lydall Inc. as a major HEPA air filtration media manufacturer suggested that a HEPA filtration media manufacturers need to take necessary precautions to comply with REACH and RoHS and their related regulations. They suggested that HEPA air filtration manufacturers need to undertake the whole costs, prices and expenses related to REACH and RoHS.

3.2.2.7 Environmental Pollution and Protection of Natural Resources

Even if concerns about environmental pollution are based on ancient histories, the general understanding of the harm of environmental pollution to human health and the growing interest in this subject is based on the late 1950s. Especially after 1950, there are various factors which are effective in the importance of the problem (Uzel, 2017). The most important of these factors can be listed as follows:

- Increase in environmental pollution due to technological advances
- The non-recycling of waste materials and therefore the worsening of the pollution problem
- The accumulation of wealth in developed countries as a result of economic growth until the early 1970s; has brought people to a point where they will be distressed and

worried in the events outside of the money. One of the sources of this concern was the negative impact of economic growth on the environment (Uzel, 2017)

Environmental problems, which are thought to be limited by pollution of water, air and soil in industrial areas, actually cover many areas from global warming, pollution of sea and oceans, rapid population increase, erosion and depletion of natural resources. However, natural resources such as oil, natural gas, coal, mines, forests, air, soil and drinking water, which can not be renewed, are rapidly consuming (Url-7).

Thereafter, enterprises must eliminate waste and provide resources that do not cause pollution. To achieve this purpose, the following methods of businesses can be applied (Url-7):

- Redesigning the products
- Redesigning production processes in a way that does not cause pollution,
- Using less material and energy input
- Developing alternative resource utilization methods
- Making distribution systems more effective
- Reconsidering the waste

Peker (2010) summarizes the internal and external factors that direct businesses to green practices, the effects of the factors and the results of effects in Table 3.1 .

Table 3.1: Factors Directing Businesses to Green Practices (Peker, 2010)

	Factors	Effects	Results
External	Reducing risks and liabilities	Eliminating damages to employees and the environment	Avoiding legal regulations
	Reducing damage to employees and the environment	Improving the image of the business in front of society	Maintaining market share
	Customers' demands	Meeting customer demands for environmentally friendly product	Affecting and retaining customers
	Competition	Production of environmentally friendly product and obtaining more market share	Maintaining market share
	Supply chan demands	Implementation of environmentally friendly advancements to improve the environmental performance of all supply chain members	Maintaining market share
	Standards and directives	Setting environmental targets for products to achieve environmental credibility	Affecting customers

	Reducing costs	Reduction of environmental damage and use resources effectively	Improving business performance
Internal	Improving product performance	Improving of product to meet customer satisfaction	Affecting and retaining customers
	Increasing employees' commitment to the company	Shaping a collective cause that specifies employee values	Improving business performance

3.3. The Concept of Green Supply Chain Management

There is no universally accepted description of GSCM in the literature. Nonetheless, the concept of GSCM in the literature changed from green procurement to combined GSCs, environmental supply chain and even reverse logistics (Hashemi et al., 2015). Throughout the years, there are many different definitions and terminology related to the concept of GSCM in the literature. Sarkis et al. (2011) made an extensive list of a number of expressions which define that concept:

- "Sustainable supply network management
- Supply and demand sustainability in corporate social responsibility networks
- Supply chain environmental management
- Green purchasing and procurement
- Environmental purchasing
- Green logistics and environmental logistics
- Sustainable supply chains" (Sarkis et al., 2011)

According to Green et al. (1996) "green supply refers to the way in which innovations in supply chain management and industrial purchasing may be considered in the context of the environment". Narasimhan and Carter (1998) define that "environmental supply chain management consists of the purchasing function's involvement in activities that include reduction, recycling, reuse and the substitution of materials". Klassen and McLaughlin (1996) identified "environmental management encompasses all efforts to minimize the negative environmental impact of the firm's products throughout their life cycle and environmental performance measures how successful a firm is in reducing and minimizing its impact on the environment". In the study of Min and Galle (1997) the effectiveness of green purchasing in reducing resource use and waste disposal have been examined. In their study Murphy et al. (1994) concentrated on the significance of environmental issues in logistics operations. They also focused on strategies to manage and deal with environmental concerns in logistics.

SCM has grown globally and gained importance among suppliers. GSCM has drawn interest from scholars and producers since the 90's because it has environmental objectives such as reducing solid and liquid waste, protecting product and raw materials and natural resources, and providing sustainability of these resources (Fortes, 2009).

GSCM is alike to the traditional supply chain, but executives also take environmental effects into account and endeavours to decrease them in time. While GSCM considers ecology and economy as goals, classic SCM always only concentrates on economy. A number of features and disparities between GSCM and SCM are demonstrated in Table 3.2 (Nielsen et al., 2014).

However, in the last researches, the scope of the green supply chain concept has changed and shaped, taking into account the growing public perception on the environment and the tighter regulations of governments.

Table 3.2: Comparison of Classic SCM and GSCM (Nielsen et al., 2014)

Features	GSCM	Traditional SCM
Objective	Environmental & Economic	Economic
Environmental optimization	High	Low
Criteria	Environmental	Economic
Cost pressure	High	Low
Flexiblity	Low	High
Speed	Low	High

Nowadays, GSCM should be evaluated as a whole. Focusing on manufacturing activities alone is not adequate to decrease the effects of pollution. Environmental management is a considerable matter in SCM and for the achievement of environmental programs, the entire SC should be made greener by applying green supply chain management (Malviya and Kant, 2016).

In accordance with Sahu et al. (2015) green supply chain management (GSCM) is “a systematic and integrated management philosophy for the companies to maintain their sustainability and competitiveness in the recent global market”. Lee et al. (2009) suggested that “GSCM emerged as a way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency”.

In accordance with Srivastava (2007) GSCM is that ‘‘integrating environmental thinking into supply chain management, including product design, material procurement and selection, manufacturing processes, delivery of the final product to the consumers and end-of-life management of the product after useful life of the product.’’

In accordance with Malviya and Kant (2016), GSCM is an environmental philosophy which contains “internal environmental management, green design, green procurement, green manufacturing, green packaging, green marketing, green information systems, investment recovery, customer cooperation, product life cycle assessment, reverse logistics etc”.

In accordance with Ma and Liu (2011) GSCM may be considered as part of SCM. However, there are some differences from traditional SCM. Green supply chain is more careful on supply of environmental metarial and environmental effects of its complete lifecycle. Other green supply chain management definitions are listed in Table 3.3.

Table 3.3 : Green Supply Chain Management Definitions (Aksoy, 2014)

Author(s)	Definition
Hervani et al. (2005)	“Green Purchasing + Green Production / Materials Management + Green Distribution / Marketing + Reverse Logistics”
Andic et al. (2012)	Reducing or even destroying the hazardous environmental impacts of the supply chain
Sarkis et al. (2011)	The integration of environmental issues into inter-organizational practices where reverse logistics is involved in supply chain management
Azevedo et al. (2011)	Entire activities which occur throughout the supply chain that aim to reduce or eliminate any negative environmental impact

Min ve Kim (2012)	The integration of eco-friendly enterprises' entire supply chain activities such as resource discovery, product design and improvement, manufacturing, transport, packaging, warehousing, destruction, after-sales services and product end-of-life management.
Handfield et al. (1997)	Implementation of environmental design, procurement, production, assembly, packaging, logistics and distribution activities throughout the entire customer order cycle.

The modern corporations realized that GSCM plays a crucial role in making the difference and attracting green customers in today's excessively destructive global market. In the literature, there are many advantages for the corporations to manage the green supply chain. Therefore, a large number of companies struggle to produce innovations in the supply chain in order to improve their green image, to make the best use of raw materials and to save even more.

Nonetheless, product improvement and environmentally conscious product or service generation strategies can be integrated by GSCM approach. Then, it is observed that companies that implement green supply chain management from tactical decisions to strategic decisions realized that decreasing negativities in operations, reinforcing control mechanisms, enabling recycling and resource utilization. While this approach makes a value in the company's supply chain, it also expresses the significance of the environment (Büyüközkan and Vardaloğlu, 2008).

This approach also improves the ecological effectiveness of the organizations and also achieves the win-win strategy by helping to reach the target profit and desired market share. While this approach enhances job satisfaction and the quality of life of the society, it also plays a key role in making value within the company by providing customer satisfaction (Büyüközkan and Vardaloğlu, 2008).

3.3.1. Green Supply Chain Management Activities

GSCM can be defined “as the integration of green procurement, green production / materials management, green distribution / marketing and reverse logistics processes” (Hervani et al., 2005). It is demonstrated in Figure 3.2.

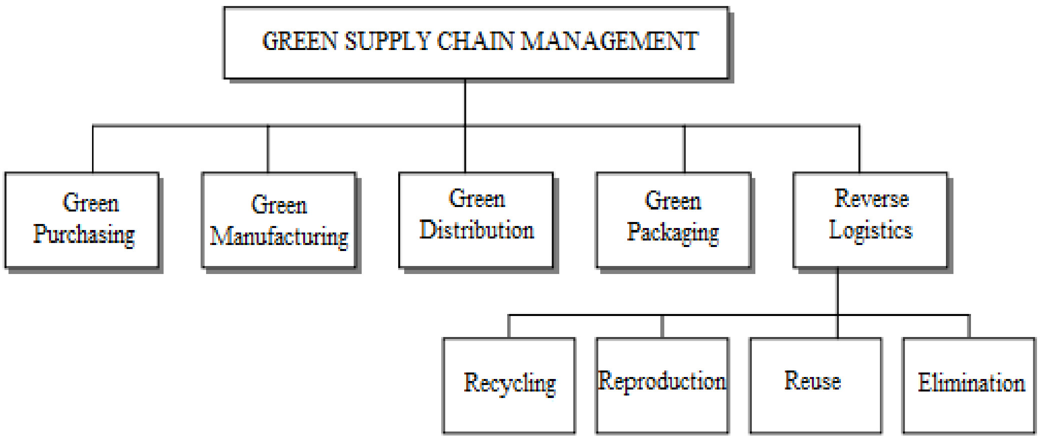

Figure 3.2: Green Supply Chain Management Activities (Büyüközkan and Vardaloğlu, 2008)

3.3.1.1. Green Purchasing

Purchasing can be evaluated as one of the most crucial operations in a corporation and supplier performance assessment is one of the most significant operations of the purchasing function (Büyüközkan, 2012).

Green purchasing may be identified as the choosing process of commodities and services which have less harmful effect during the life cycle amongst others. It is also defined as an environmentally friendly procurement practices that reduce waste sources and encourage the recovery of recycled materials (Min and Galle, 2001).

Green purchasing activity occurs at the starting of GSC and is identified as a procurement application that takes environmental factors into account when selecting commodities and services (Freeman and Chen, 2015).

Some of the advantages of green purchasing are mitigation of waste resources, waste minimization of harmful components, recycling and improvement of bought materials and environmental material substitution (Holt and Rao, 2005). Therefore, corporations are bound to be concerned with the environmental performance of their suppliers and provide that the bought components environmentally friendly for cleaner manufacturing (Kumar et al., 2017).

The main role of green purchasing is to select suppliers by taking environmental criteria into consideration and to supply environmentally friendly raw materials. By providing green products from suppliers, a company can enhance not only customer pleasure but also competitive advantages (Govindan et al., 2017).

3.3.1.2. Green Production

The green product is identified as products that do not harm the environment, reduce the consumption of natural resources, and can be recycled or protected (Özesen, 2009).

Green production is a business strategy that concantrates on eco-friendly production processes and lucrativeness. While green production and eco-friendly production processes are constituted, lucrativeness also increases thanks to the waste and resource reduction policy (Türkay, 2015). Nevertheless, green production can make a contribution to companies in lowering raw material expense, increasing production effectiveness, decreasing job security costs and improving corporation green image (Ninlawan, 2010).

Green production is interested in the substitution of harmful or nonrenewable components with less harmful or regenerable ones, respectively. Better monitoring of operations with high productivity, equipment amendment, technology adaptation and product amendment to reduce waste and emissions are amongst the benefit of green production (Kumar et al.,2017).

Reduction of scrap and waste in manufacturing operations and decrease in the amount of total used material are the characteristics of green production. Nowadays, a number of enterprises are almost in rivalry for integrating green philosophy into their production system. Becauase manufacture with less resources and environmental impact will be the main objective of enterprises in the near future (Korkankorkmaz, 2012).

Nevertheless, green production should not be considered as an independent process. In order to obtain green production objectives, both forward and backward supply chain activities need to be evaluated. Therefore, green production should be considered as interacting with other activities in the green supply chain (Büyüközkan and Vardaloğlu, 2008).

Benefits of green production processes can be listed as follows (Url-7) :

- Consuming less natural resources
- Less energy for production
- Less greenhouses gases emission
- Utilization and occurence of Less toxic material

- The emergence of less waste

3.3.1.3. Green Distribution

Logistics activities for a product include procurement of necessary raw materials for the manufacturing of the products, packaging after the production, transportation, storage and delivery of the products to the customers (Türkay, 2015). Distribution and logistics operations can be considered as one of the most basic reasons of hazardous gas emissions in SC. (Paksoy et al., 2011).

Green logistics deals with the reduction of the environmental impacts of the activities from raw material procurement to manufacturing, packaging, transportation and storage before products reach the customers.

The fuel used by the vehicle carrying the products, the transport frequency, the characteristic of packaging material and the transportation distance are most the significant factors on the performance of green distribution activities (Sarkis, 2003).

Reducing storage areas, keeping out unnecessary inventories, determining and using shorter ways are the main objectives of green distribution. Utilizing clean fuel is quite important in logistics activities. However, the use of hybrids or electric vehicles is very important in terms of air quality (Korkankorkmaz, 2012). More information related to this issue will be given in the green transportation heading.

3.3.1.4. Green Packaging

Packaging is a valuable material that protects the product in according to its shape and structure, ensures the product's cleanliness, makes it easier to transport, and also advertises the product. (Url-13). Packaging does not only provide information but also provides some sort of superiority to the product. Packaging is also one of the main sources of environmental pollution. Most of the green marketing debates are on both the packaging and the material on which the packaging is made. Today there is a high demand for recycled and recyclable packaging (Ayyıldız and Genç, 2008).

The attributes of green packaging are as follows (Ayyıldız and Genç, 2008) :

1- Conservation and warranty attribute

2- Selling attribute; directing the client to purchase

3- Service attribute; informing about commodities

4- Eco-friendly attribute; minimization of environmental impacts

5- Arrangement attribute; labeling, hygiene, expiry date, etc.

6- Warehousing and selling attribute; conservation of service standard

7- Division attribute; preservation of fresh produce

The package's structure directly affects the environment. In some countries, the legislation on the withdrawal of packages that are harmful to nature has brought the packaging process and planning to a critical position in terms of environmental logistics (Sarkis, 2003). This resulted in the need for some environmental remediation in the packaging process. The utilization of nature-friendly, reusable and recyclable packaging materials and reduction of the number of deliveries are important packaging improvements.

For instance, thanks to improvements in packaging dimensions, it is possible to fit more products into the transportation vehicles during transportation of the products. In this way, indirect transportation costs and emissions from transportation can be reduced. This also helps to minimize fuel consumption and support less noise generation (Sarkis,2003).

However, to summarize the benefits of green packaging:

- Material reduction ; Redimensioning of products to suit the content of the packaging
- Increasing recycled substance ; Using definitely PCW paper and obtaining recycled plastic pipes
- Waste reduction ; Utilization of slim plastic packaging, lighter paper and shivering old paper
- Increasing recycling ; Redesigning to leave out non-recyclable materials such as plastic caps and putting informative recycling labels on the packaging
- Cleaner production ; Making sure that the compounds used in the materials do not harm the environment
- Energy conservation ; Using green power certified components and obtaining product from energy efficient plants
- Efficient transport ; Working with a packaging manufacturer close to product manufacturer and supply companies located in the primary market

- Increasing utilization of renewable material ; Using fibrous paper instead of wood-based paper and designing for reuse of packaging (Plushbeds, 2017)

3.3.1.5. Green Marketing

The concept of green marketing, which was first debated in 1975, became popular at the beginning of the 90s. Green marketing was first described as a practice of the positive and negative sides of marketing operations related to contamination, power consumption and power-free source consumption (Armağan and Karatürk, 2014).

In accordance with Özesen, (2009) green marketing is defined as organizations' efforts for designing, introducing, pricing and distribution of eco-friendly products. Green marketing is also defined as the design of all activities to create and facilitate any kind of barter that tends to environmentally satisfy the needs and desires of people (Jain and Kaur, 2004).

According to the definition given by the American Marketing Association, green marketing is a science that examines the marketing activities on pollution, the energy consumption and the positive and negative aspects of the use of consumable resources (Fırat, 2008).

The market share of companies implementing the green marketing program increased. Swedish paper maker Svenske Cellulose has increased its sales by 10-13% when it enters the UK market with its non-toxic chlorine-free product. Especially in the western countries, awareness of the consumer makes the manufacturing of environmentally friendly product obligatory. The main role of marketing is to make more people willing to be environmentalists (Güzel, 2011).

3.3.1.6. Reverse Logistics

The concept of Reverse Logistics arises from the need to recycle materials to be used instead of raw materials, due to the rapid increase in the world population and the decrease in the amount of raw materials. Nowadays, the importance of environmental legislations, modern business and management approaches, businesses' sensitivity to the environmental issues and companys' desire to fulfill social responsibility principles have increased the importance of RL activities (Şengül, 2011).

RL is identified by the American Reverse Logistics Executive Council as the schedule, implementation and control process of the influential and low-priced raw material flow, inventory in process and used products from consumption stage up to the stage in which recovery will begin or will be properly destroyed (Rogers ve Tibben-Lembke, 1999).

In order to have a GSC, it is essential to minimize environmental effects of the SC. This situation is closely related to the utilization of eco-friendly substances and to the reduction of hazardous gas emissions in the SC process, as well as the reverse logistics that enable to minimize waste and to protect natural resources (Andic et al., 2012).

Reverse logistics transforms the open-ended supply chain into a closed cycle by adding reusing, recycling and converting materials into other products with marketable or market value. (Büyüközkan and Vardaloğlu, 2008). Closed loop SC includes forward and reverse SC. The key point of the closed SC is the client . The producer includes a stream of feedback to the client. In the reverse SC, the client assumes the role of a supplier. Products flow from this supplier to producers who reproduce. The main difference between the traditional SC and the closed loop SC is that the client becomes the supplier (Östlin et al., 2008).

The reasons for the return of products from the consumer to the manufacturer can be listed as follows (Türkay, 2015; Ayvaz et al., 2013):

- Product malfunction
- Damaged product
- Owing to the fact that the product is seasonal, it cannot be used or sold
- Serious faiulres in the product
- Containing hazardous substances in the product
- Damages arising during transportation
- New model products in the market
- Replacing the product with another product
- Returning of product
- Repairing of product
- Recalls
- Incorrect delivery

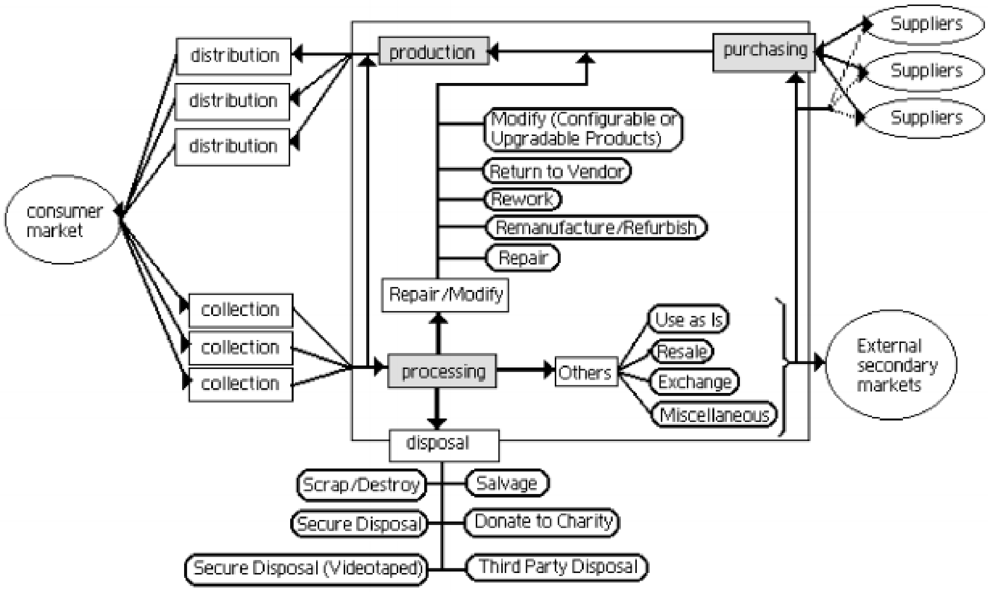

Figure 3.3: The Reverse Logistics Network (Zuluaga, 2005)

As can be seen in Figure 3.3, the product entering the reverse logistics network can be recovered by using one or more of transactions such as repair, refurbishment, reuse, reproduction and recycling. In the absence of any of these processes, used products are burnt or buried and destroyed in an appropriate manner. Different delivery alternatives, such as donations to institutions, are also applied for some returned products (Şengül, 2011). However, the functions of recycling, reproduction, reuse and disposal, which are categorized as RL activities, may be explained as follows :

Disposal: The uselessness of a waste or scrap derives from the fact that its technical or economic reuse does not make any value. This phase begins with the excluding of the goods that have completely occupied the time of use and which are not in the potential for sale and available wastes for production are separated at the stage of recovery and control. Then, it ends with transport, landfilling and burning or any form of destruction (Şengül, 2011).

Reproduction: It is the process of remanufacturing the same product by replacing the damaged, lost parts of the used and obsolete products with new ones to protect the features and functions of the original product (Türkay, 2015). In this case, the original product features and functionality are protected. Then, the remanufactured product is examined and tested to achieve or even exceed the specifications of a new product. In some cases, products that exceed the qualities of the original product can also take place (Büyüközkan and Vardaloğlu, 2008).

Reuse: It is the process of distributing and selling the used materials, products and components after being assembled from the production site (Büyüközkan and Vardaloğlu, 2008). Reuse of a product is the expansion of its life span with little or no improvement. No novel value is added to the product (Kumar et al., 2017). More information related to this issue will be given in the design for dissambly and reuse heading.

Recycling: It is the process of using usable products and parts from used products in the manufacturing of the original product. In this process, the material is recycled without conserving the structure of the product (Şengül, 2011). More information related to this issue will be given in the design for recyclability of raw material heading.

3.4. Green Supplier Selection

Especially after the 90s, community is growingly becoming conscious on the robust relationship between the economy and the environment. Utilizing energy between them is a prerequisite for maximizing prosperity and economic growth. Therefore, a large number of countries have begun to implement environmental regulations and enforcements to monitor the utilization of products, processes and wastes that may have environmental impact (Lee et al., 2009). Particularly, implementation of EU environmental regulations such as RoHS, WEEE, ErP and REACH have been effective in European Union in consequence of increasing global warming and environmental awareness. The supply chains and products of the corporations are enforced to be more sensitive to the environment (Chen et al., 2016). In the face of this condition, the corporations are obliged to reduce harmful environmental impacts in their supply chains while reducing dangerous impacts of products, manufacturing and transportation processes (Noci, 1997).

Organizations concentrate upon their own internal environmental precautions for waste mitigation, pollution control and harmful components in order to comply with present arrangement and fulfill their social liabilities. Recently, a large number of organizations have begun to notice that they need to do more than these interior controls. This situation has led to an increase in environmental apprehension for organizations in the selection of suppliers (Banaeian et al., 2015).

However, the supplied green substances are defined as crucial for the improvement and production of green products. Harmful ingredients in raw materials which are ensured by suppliers may bring about critical environmental effects in the SC. Nevertheless, the corporation's environmental performance may be understood by the corporation's respective environmental endeavour and the environmental performance of the supplier. In this respect, collaborative and environmental relationships with suppliers enable corporations to develop their environmental performance (Akman, 2012).

An effective supplier selection is an indicator of a successful organization and a strong SCM. The success of the supplier selection has a crucial effect on the productivity and success of the entire SC. However, a large number of previous studies on this subject have indicated that the supplier selection is most important factor in the achievement of SC. Because it affects directly the environmental performance of the producer. Nonetheless, as companies increasingly depend on their suppliers, structure and results of green supplier selection problem have become critical (Gurel et al., 2015).

The supplier selection problem is formed by investigating and surveying the productivity of a group of suppliers to develop the competition capacity of all system. The selection of a decent supplier provides an important advantage to the future of a company while decreasing operational and environmental expenses and enhancing the product quality (Banaeian et al., 2014).

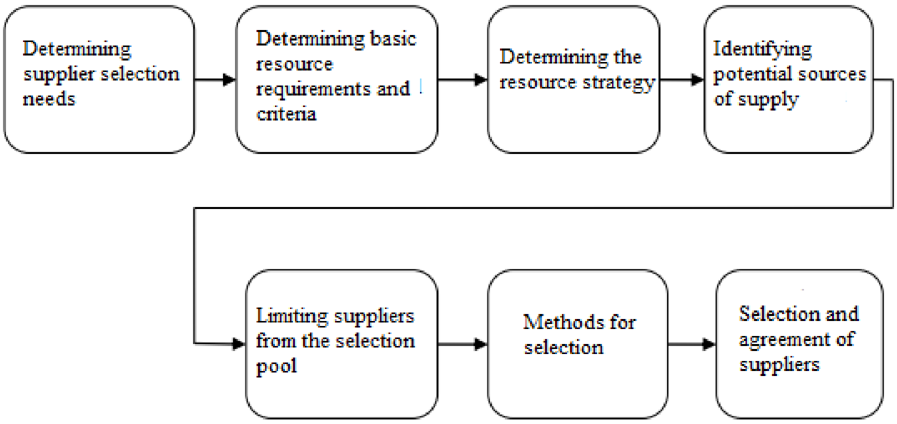

Figure 3.4: Supplier Selection Process (Çakın, 2013)

The blend of quantitative and qualitative criteria and the wideness and variety of suppliers make the supplier selection and assessment process more complicated. However, rising outsourcing and offshoring tendency, complicated and strict civil and territorial politics and different institutional and competitive targets caused to increase importance and intrication of supplier selection decisions (Bananeian et al., 2016).

GSS process necessisates the combination of environmental criteria with the traditional criteria (Banaeian et al., 2016). The process of selecting the most suitable supplier requires the companies to pay attention a number of traditional and environmental elements (Yazdani et al., 2016). However, the structure, process and characteristic of GSS problem are the same as the classic supplier selection problem.

The most frequently used environmental criteria in the literature, after 2008, are as follows:

- Quality
- Delivery
- Price
- Cost
- Service level
- Technology capability
- Flexibility
- References
- Financial status
- Industrial knowledge and experience

Noci (1997) who is one of the first scientists to publish on GSS problem reviewed the criteria under four main headings. Three of them are environmental, one is traditional. In this study, the author evaluted the criteria within a pro-active green strategy. This study was applied in a automobile company. There are two alternatives to supply bumper. One of them produces a cheaper bumper, the price is $ 150. The other produces from a single material, the price is $ 200. The writer suggests that it is logical to choose the first when considered briefly. However, when considering recyclability, the second option is more reasonable nowadays.

In the last twenty years, it can be realized that there are a large number of researchers and publications on environmental issues. A number of new environmental criteria have been added to the traditional supplier selection criteria. Thus, GSS issues have been reviewed by a large number of scholars and scientists.

The most frequently used environmental criteria in the literature, after 2008, are as follows:

- Environmental Management System (EMS)
- Pollution Control
- Green Image

- Green design
- Solid or water waste
- Green competencies
- Energy consumption
- Recycling
- Green technology
- Green product

4. LITERATURE REVIEW

The GSCM literature has intended to foster available suppliers to develop their environmental understanding and productivity by forcing them to obtain essential certificates and promote green applications. In making decisions, the selection of suppliers in GSCM is defined as important. A large number of scientists have examined the criteria and indicators of green supplier assessment to meet environmental arrangements and customer expectations (Kannan et al., 2013).

In the literature review, the green supplier selection studies published after 2008 are examined. The techniques, environmental and traditional criteria and fields of activity are examined in the literature, then they are tabulated and summarized.

The studies on green supplier selection in the literature are as summarized below.

The integration of AHP and genetic algorithm was applied to select the most appropriate alternative in the study of Yan (2009). The eigenvector was utilized to determine the weight of the criteria and to make pairwise comparison between criteria. The genetic algorithm flow and AHP was combined to select the best supplier. In the end, the best one was determined amongst two alternatives in accordance with the result of judgment matrix.

Lin And Juang (2009) implemented AHP to evaluate the significance of diverse green criteria in biotechnology industry. A criteria hierarchy was provided to calculate the weights of each criterion through normalized pairwise matrix. At the end of the study, an evaluation form was prepared to guide decision makers to evaluate green suppliers.

Tsui and Wen (2012) suggested the integration of AHP and PROMETHEE to overcome GSS problem. This proposed model was applied in TFT-LCD industry in Taiwan.

Initially, the weights of each criterion was calculated by using AHP. Afterwards, PROMETHEE I and PROMETHEE II methods were applied to determine the best alternative.

In the study of Yu and Hou (2016), modified multiplicative analytic hierarchy process (MMAHP) was utilized to choose the most environmentally conscious supplier. The criteria were determined by making use of literature review, professionals' review and scientific journals. The weights of criteria were calculated by utilizing the pairwise comparison matrix, then the ranking of suppliers was carried out by considering criteria. The authors compared the proposed method with the traditional AHP and also suggested that MMAHP was available to avoid reversal ranking.

AHP- Entropy based TOPSIS method was applied in electronic sector in the study of Freeman and Chen (2015). Significant specialities and criteria were determined by evaluating experts' views. The subjective and objective criteria weights were obtained by using AHP and entropy weight method, respectively. Due to compromised weight method, objective and subjective method were integrated. Finally, TOPSIS method was implemented to rank alternative suppliers. The authors suggested that the proposed model in this study was available to overcome the issues which happened in reality.

Genovese et al. (2013) examined the study on the two phases. In the first phase, the aim of the authors was to demonstrate the evolution and application of GSC by exemplifying from scientific journal. In the second phase, an empirical analysis was investigated under horizontal and vertical subdivisions. In the horizontal analysis, the green supplier measures were determined through SCOR model. The questionnaire and AHP model were applied for two different firm in vertical analysis. Lastly, the hardship of applying theory which was used in the study and the possibility of implementation of applied method into real case were discussed.

The integration of AHP, fuzzy GRA and TOPSIS was utilized to select green suppliers in the study of Banaeian et al. (2015). Ten criteria were evaluated under conventional and green dimensions. The set of criteria was determined by reviewing the literature and this study was implemented in edible oil company. Pairwise comparison and the ranking of criteria were reckoned by using the integration of AHP and TOPSIS. In supplier selection process, decision makers' view was taken into account. The final ranking of alternatives was carried out by utilizing the integration of AHP and fuzzy GRA methods.

AHP based MCDM model was utilized to select green suppliers in the study of Heung et al. (2013). Ten criteria were evaluated under four categories and this study was implemented in the trading sector in Hong Kong. Environmental and corporate social responsibility necessities were considered to determine the criteria and alternatives in the study. As to application section in the study, priority weight of each criterion and alternatives were detected by using AHP method. Then, final ranking of alternatives was carried out by evaluating the weights they had.

In the study of Banaeian et al. (2015), fuzzy GRA and linear programming were used to determine the best green suppliers in an edible oil production company. Green criteria were extracted from literature review and previous studies. A data base was constructed to collect the aligned and weighted green criteria by using Delphi and AHP methods respectively. Finally, fuzzy GRA and linear programming were applied to select the best suppliers.

Li and Zhao (2009) used GRA and AHP together in electronics sector. Twenty one sub-criteria under seven main criteria (Quality, Technology, Service, Innovation, Management, Environment) were evaluated. AHP was utilized to compute the weights of the criteria. The alternatives were ranked in accordance with the relational coefficient and relational degree.

The integration of AHP and ANN was utilized in the study of Thongchattu and Siripokapirom (2010). Seven sub-criteria under five main criteria (Company reliability, Material quality, Material price, Environmental, ISO 14000) were evaluated. AHP was implemented to assist decision makers to get through complicated problems. After applying AHP, the final solution was obtained by utilizing artificial neural network.

The integration of AHP-entropy and ELECTRE-III method was applied in the study of Tsui and Wen (2014). This study was examined on four stage. The subjective and objective weights of criteria were calculated by AHP and Entropy method respectively. ELECTRE III method was applied to rank the suppliers. If only the AHP was used in the proposed method, the weightings of the criteria would be overly subjective. To prevent this, the entropy method was used to weight the criteria. Also, linear assignment method was implemented to lead manufacturer to choose the most available alternative.

Peng (2012) applied the integration of AHP and GRA to select the best green suppliers in refrigator manufacturing industry. First of all, green supplier index system was constructed under four main factors. Making comparison between criteria and detection of criteria weights were carried out by using AHP model. Afterwards GRA method was implemented to select the best green supplier amongst three candidates.

Chaghooshi et al. (2015) applied the integration of AHP and VIKOR to select the best green supplier. Five criteria were selected after researching literature review. AHP method was applied to determine criteria weights. Afterwards, VIKOR was implemented to align the five candidates. An experimental case was applied to illustrate the process of the proposed model.

Wen and Chi (2010) applied the integration AHP/ANP and DEA to select the best green supplier. Collected criteria were evaluated under three aspects (environmental, traditional, partnership). AHP/ANP model was utilized not only to weight the criteria but to evaluate them. DEA was implemented to construct the efficient group for suppliers. After the suppliers was considered with AHP model, then the most available supplier was determined.

Ma and Liu (2011) applied the integration of AHP and DEA to select best green supplier. The criteria weights were calculated by utilizing AHP method. Price, green indicator, quality, geographic location, delivery on time, level of technique, marketing impact, service level were utilized as criteria in the case study. The integration of DEA and AHP was used to select the best green supplier.

Fuzzy TOPSIS was utilized to obtain comprehensive efficiency mark whilst evaluating each supplier's environmental performance in the study of Shen et al. (2013). The supplier which has the highest mark is the best one in terms of the environmental performance. The authors also highlighted that automobile manufacturing companies need to start to apply green practices in their SCM for making more money by reducing their harmful environmental impacts.

In the study of Hamdan and Cheaitou (2017) the authors implemented fuzzy TOPSIS as a MCDM tool to rank the suppliers while taking both green and traditional criteria into consideration. AHP was applied to perform pairwise comparisons between traditional and green criteria. The ranking of suppliers concerning the criteria was carried out by using fuzzy TOPSIS technique. This study helps the decision maker to decide on which supplier needs to be chosen while taking environmental issues into consideration in facility management company.

Three types of fuzzy TOPSIS methods were utilized in the study of Kannan et al.(2014). They were implemented to align suppliers in terms of environmental condition respectively. Then the distinctions between them were observed. Suppliers were determined considering seventeen criteria. The authors also utilized Spearman rank correlation cofficient to increase reliability of the figures obtained by using three types of fuzzy TOPSIS methodology.

In the study of Büyüközkan and Çifçi (2012), the authors suggested a distinctive hybrid MCDM approach in their study. The integration of fuzzy ANP and fuzzy DEMATEL was utilized to examine the relationship between criteria. Afterwards, fuzzy TOPSIS method was implemented to select the most appropriate green supplier considering criteria. This study was applied in automobile industry.

Kannan et al.(2013) utilized the integration of the fuzzy AHP and fuzzy TOPSIS in their study. Fuzzy AHP was implemented to find out the weight of each criterion. Linguistic variants were utilized to make comparison between criteria. Afterwards, fuzzy TOPSIS was applied to align suppliers. At the end of study, a multi objective linear programming (MOLP) model was made up by using max-min method to appoint orders. However, the authors suggested that the purpose of the mathematical model was not only to increase the total valuation but to decrease total expense in purchasing process.

A fuzzy-MLMCDM approach was applied in the study of Sahu et al. (2014). Fuzzy TOPSIS was also implemented to compare with fuzzy-MLMCDM approach and to approve its validity. The authors used center of area method with triangular fuzzy numbers to determine criteria weights in linguistic scale. Then, at the end of the study, the superiority of the proposed model was confirmed by a comparison table prepared by the authors.

That study prepared by Chen et al. (2016) did not only consider economic criteria but simultaneously evaluate environmental criteria to select the most suitable supplier. Under economic and environmental dimension, twenty sub-criteria were evaluated. The authors combined the fuzzy TOPSIS with fuzzy AHP to detect the significant weights of the aforementioned dimensions. This approach was implemented to solve a real case in the LEF industry.

Duman et al.(2016) suggested that the implementation of integration of fuzzy AHP and fuzzy TOPSIS to determine the most available green one amongst thirteen supplier alternatives. In this study, fuzzy AHP was utilized to determine criteria weights. Afterwards, fuzzy TOPSIS was utilized to array the suppliers. Thirteen potential suppliers were ranked while considering eight decision criteria. The ratings of main criteria values were obtained by making use of professionals' views and were evaluated by utilizing linguistic phrase.

In the study of Büyüközkan (2012) , the integration of fuzzy AHP and fuzzy axiomatic design (AD) was implemented in automobile industry. Fuzzy AHP was applied to demonstrate criteria weights. Then, fuzzy AD was utilized to rank the suppliers. After implementing the proposed model, results were compared with outcome of fuzzy TOPSIS technique.

The integration of fuzzy AHP and fuzzy TOPSIS was utilized to choose the most appropriate green supplier in the study of Yazdani (2014). This methodology was implemented in automobile manufacturing industry. The weights of each criterion were worked out by using fuzzy numbers and linguistic scale during the implementation of fuzzy AHP model. Then, fuzzy TOPSIS was applied to rank suppliers considering the weight of each criterion.

The survey was investigated on two phases in the study of Govindan and Sivakumar (2016). This study was applied in the paper industry with the purpose of decreasing the green gases emissions and cost. Fuzzy TOPSIS model was applied to choose the most appropriate one while taking environmental and traditional factors into consideration in the first phase. Order allocation process was examined by using MOLP in the second phase. The striking point of the study is that the the amount of carbon emission was diminished by %26.2 thanks to recycled materials.

The integration of fuzzy TOPSIS and fuzzy ANP method was utilized to select the best suppliers concerning carbon management in the study of Kuo et al. (2015). The criteria were investigated on the literature review, scientific journals and reference books. Thanks to Delphi method, thirteen criteria under four dimensions (organizational management, process management, procurement management, R&D management) were determined. The weights of each criterion were worked out by using fuzzy ANP. Fuzzy TOPSIS was applied to rank the suppliers considering criteria in the last step of the study.

In the study of Watrobski and Salabun (2016), fuzzy TOPSIS method was utilized to select green suppliers. Seventeen criteria were determined by experts' view. The monthly demand of each suppliers were examined while implementing fuzzy TOPSIS in the study. During implementation of fuzzy TOPSIS the weighted normalized decision matrix was also calculated. Lastly, the steps of fuzzy TOPSIS implementation the rating of alternatives was carried out.

Awasthi et al.(2010) examined the study on three steps. The criteria were defined to evaluate the suppliers' environmental performance. Twelve criteria were evaluated under benefit and cost dimensions. The chosen criteria were aligned by utilizing linguistic assessment. Fuzzy TOPSIS was combined with linguistic ratings to obtain performance score for each supplier. According to the performance scores, the best one was determined.

The study prepared by Gupta and Barua (2017) was formed in three steps. The authors focused on how to choose supplier amongst small and medium enterprises concerning green innovation. Initially, the criteria were determined by examining literature review and consulting DMs. The sorting of the critera is carried out by making use of best-worst method. Finally, the suppliers were aligned concerning the criteria by utilizing fuzzy TOPSIS. Sensivity analysis is applied to supervise the steadiness of the applied methods at the end of study.

The integration of fuzzy TOPSIS-TODIM method was applied in the study of Khamseh and Mahmoodi (2014). Six criteria were determined after taking both professionals' and decision-makers' views. The initial weight of the criteria was determined by using fuzzy TOPSIS, then TODIM was used to determine the final weight of the criteria. During this procedure, FTF (fuzzy time function) was used to align the criteria and candidates. Lastly, the most efficient supplier was detected after implementing the integration of the outcomes of TODIM and fuzzy TOPSIS.

The integration of Delphi model and fuzzy extended AHP was utilized to detect the most appropriate green supplier in study of Lee et al. (2009). There are totally 6 main criteria and 23 sub-criteria obtained by making use of literature review and experts' view in the study. Delphi method was utilized to specify the most significant sub-criteria for classical and green suppliers. Afterwards, main criteria hierarchy was constructed by applying fuzzy extended AHP. It was also utilized to make comparison between criteria. The best alternative considering each criterion was determined by showing graphs.

The aim of the study proposed by Hsu et al.(2013) was to expose the effective criteria considering carbon management in GSC by utilizing DEMATEL. Thirteen criteria were determined under three dimensions. The authors constructed DEMATEL influence matrix to show the relationship and interdepencencies between 13 criteria. The authors also asserted supply chain operations have an influence which should not be underestimated on climate change.

In the study of Grisi et. al. (2009), AHP model was utilized with fuzzy logic to overcome ambiguities happening from human judgment and to select the best green supplier amongst three ones. Pairwise comparison matrices were constructed to compare the criteria between each other. Seven criteria (price, quality of delivery, quality, environmental competences, environmental management system, green image, current environmental impact) were evaluated under traditional and environmental dimensions.

Fuzzy Axiomatic Design method was utilized to choose the most appropriate supplier in the study of Kannan et al. (2015). This study is applied in plastic material manufacturing company. Eleven main criteria and sixty sub-criteria were examined by utilizing Affinity Diagram method.

DEMATEL method was utilized in the study of Guo and Tsai (2015) to select the most convenient supplier under environmental condition. A seven rating scale was implemented to align criteria, “6” means the highest influence and “0” means no influence. During supplier selection evaluation process, fifteen experts were consulted by questionnaires. Twelve main criteria were evaluated by taking their relationship and reciprocal impact between each other into consideration. In the last step, supplier selection procedure was carried out.

Three different fuzzy techniques (TOPSIS, VIKOR, GRA) were utilized to determine the best environmentally conscious supplier in edible oil sector in the study of Banaeian et al.(2016). Four main criteria were determined by investigating scientific journal and literature review. After implementing fuzzy techniques (TOPSIS, VIKOR, GRA) the same supplier emerged for different kinds of oil (olive oil, palm oil, sunflower and soybean oil). The authors also highlighted that there is a pressure to reduce the perilous impact of supply chain in agri-food sector due to global warming and climate change.

In the study of Akman (2015), the aim is to detect green performance of each supplier and to develop their environmental situation. The author applied fuzzy c-method on two step. In the first step every supplier of the company was gathered in accordance with criteria. Thereby best suppliers in terms of environmental condition were detected. Secondly, determined suppliers were considered with green/environmental criteria. VIKOR method was utilized to rank suppliers in poor group to include supplier development programs.

The weight of each criterion was calculated by using DEA and the Common Weights Analysis (CWA) in the study of Dobos and Vörösmarty (2014). The criteria were evaluated under traditional and green aspects. Composite Indicators (CI) were utilized to select suppliers under environmental consideration. The authors also suggested that the integration of DEA and CI method can ease the process for DMs.

The integration of ANP and improved GRA was utilized to evaluate and to determine the most available green supplier in the study of Hashemi et al. (2015). The ANP method was implemented to detect the weights of sub-criteria. Then, improved GRA was employed to rank the suppliers considering economic and environmental criteria. Linguistic evaluation model was utilized in the green supplier selection operation. The authors suggested that the innovation of this study is that decision makers were allowed to take part in the assessment transaction.

Kuo et al. (2010) integrated Artificial Network Analysis (ANN) with DEA and ANP to select the most available green supplier. Six main criteria and twenty four sub criteria were evaluated. Only one of the six main criteria was an environmental criterion. Defining the environmetal criteria was carried out by utilizing Delphi method. Also, determining the criteria weights was calculated by utilizing ANP method.

The integration of (ANP) and multi-objective programming (MOP) methodology was utilized in the study of Wu and Barnes (2016). Ten sub-criteria were determined under four main criteria (cost, pollution control, resource consumption, quality). The authors suggested that the most important innovation of this integration was to be first to implement to select green supplier in the literature.

Yazdani et al. (2017) utilized DEMATEL to determine the relationships between customer requirements by making up relationship table. QFD model was implemented to disclose the relationship between criteria and customer requirements. Lastly, complex proportional assesment (COPRAS) was used to rank alternative suppliers.

Nominal Group Technique (NGT) was utilized to determine the most critical criteria and also to detect the relationship between them in the study of Galankashi et al.(2015). Ten main criteria were determined through experts and NGT. After that transaction, NGT was utilized to find the interdepencency degree of criteria. Then fuzzy ANP method was applied to weight the each criterion. This study contributed to combine classic key performance indicators with green ones while selecting the most appropriate green supplier.

Darabi and Heydari (2016) applied IVHFRM to align the green suppliers nominees. Five criteria (Cost, Quality, Delivery, Technology capability, Environmental competency) which are obtained by experts' opinion were evaluated to align suppliers. Relative importance of criteria which are indicated in linguistic terms tranformed to computational results through interval-valued hesitant fuzzy ranking method. An illuminating instance from automobile manufacturing sector was used to reveal the availability and practicality of the method proposed in the study.

Vague sets group decision-making method was utilized to choose the most environmentally conscious alternative in the study of Yang and Ying-Tuo (2011). The authors attracted attention about that the score function and similarity calculation are obstacles to explain the professionals' views on this subject. The authors suggested that the case results approved the superiority of the proposed model in the study.

The originality of the study of Sarkis et al. (2010) is that ANN was firstly implemented with portfolio analysis to evaluate the performance of each supplier. ANN was initially applied to determine suppliers' relative power by comparing them between each other. Then suppliers' relative power was mapped by using portfolio grid by being scaled from low to high. Lastly, the best alternative was detected.

The integration of COPRAS-G and DEMATEL-based ANP method was utilized in the study of Liou et al. (2016). DEMATEL method enabled to demonstrate the relationship between criteria and also to establish an influential network relationship map (INRM). ANP method was utilized to acquire effective weights of the criteria. The authors applied COPRAS-G to overcome distinctions originating from decision-makers and also to evaluate the alternative supplier's performance.

The hybrid model was utilized in the study of Banaeian et al. (2014) by integrating Delphi and Green Data Envelopment Analysis. Initially, Delphi method was implemented to determine and to score main criteria by taking professionals' opinion on this subject. DEA analysis was utilized to array suppliers in accordance with their character and efficiency. This study was implemented in edible oil sector considering seventeen criteria under financial, delivery & service, qualitative and environmental management system aspects.

In the study of Sahu et al. (2012), five main criteria and thirteen sub criteria were determined after examining literature review and scientific journals. COPRAS-G and Grey-TOPSIS were implemented to choose the most environmentally conscious supplier respectively. Lastly, the results of both technique which were applied in the study were the same.

The integration of ANP and F-MOLP was utilized to determine the most appropriate green supplier and to arrange order assignment in the study of Bakeshlou (2014) respectively. The authors used fuzzy DEMATEL to expose the relationship between criteria regarding economic and environmental issues. Besides, fuzzy ANP was utilized to determine criteria weights. At the end of study, fuzzy MOLP technique was utilized to solve the problem with applying max-min methodology.

Voting analytic hierarchy process method was utilized in 3C industry (computer, communication and consumer) in the study of Juang (2009). To rank the criteria thirty experts on this scope were consulted and with the assistance of LINGO program the weights of each criterion were calculated. Fifteen criteria were evaluated under three categories. An evaluation form was made up to determine the best alternative suppliers in accordance with evaluation scores.

The integration of MCDM approachment based IFS and GRA was utilized in the study of Bali et al. (2013). The scholars suggested that this integration enabled to get through the uncertainty happened by decision-makers in the supplier selection process. IFS method was used to evaluate criteria and alternatives. The entropy weights of criteria were worked out by IF entropy. Then GRA was applied to find out the best alternative. An empirical case was applied to demonstrate this process in automobile industry.

Hu et al. (2015) applied MAGDM along with 2 tuple linguistic assessment while taking commercial and environmental criteria into consideration. 2-tuple averaging (TWA) operator and 2-tuple ordered weighted averaging (TOWA) operator were implemented to align suppliers. Lastly, the implementation of LT-TOPSIS method was carried out to make a comparison with the proposed method.

It was examined that the attributes of building materials in terms of environmental conditions and key factors for green procurement (policy pressure, policy benefits, internal pressure within organizations) for real estate improvement in the study of Shen et al.(2016). Data analysis (one-way ANOVA analysis) was utilized to determine the typical reasons influencing developers' green procurement behaviour and also their purchasing preferences for green building materials. The point of interest of the research is to detect key factors of green building materials as “marketing benefits”, “market pressure” and “international pressure within organizations” in real estate in which rare research is made.

A MCDM model was utilized to choose the best environmentally conscious supplier amongst five ones while taking six criteria into account in the study of Bali and Güreşen (2013). Weight matrix was constructed to evaluate the criteria. Due to dynamic intuitionistic weight analysis, intuitionistic fuzzy sets (IFS) and eucledian distance method optimum solution was determined.

In the study of Kumar et. al (2017) fuzzy ELECTRE approach was utilized to aid administrators to transform linguistic decision of decision makers into quantitative scale. The unique speciality of this study was to outrank the poor performs afterwards thanks to it, the most available green suppliers could be selected. Thirty-eight sub-criteria were gathered into six cluster (cost, flexibility, service, green practice, environmental management and pollution control). Consequently, owing to ELECTRE methodology, decision makers can eliminate poor suppliers and can focus on on high-level suppliers.

The proposed approach consisting of three phase was implemented in the study of Ashlaghi (2014). The fuzzy DEMATEL method was utilized to establish the relationship matrix between criteria (cost, quality, service, environment). Then after implementing fuzzy ANP method, criteria weights were identified. In the last step, linear physical programming model was implemented to choose the most suitable green supplier.

Hashemi et al.(2014) implemented improved GRA to select the most available environmentally conscious supplier. The authors suggested that grey theory is robust tool to consider supplier with vague and uncertain data. The authors also suggested the proposed model is distinctive and could be implemented to another decision-making problems. The authors extracted criteria from reserach literature and those are under three dimensions ; planning, implementation and management.

The integration of DEA and ANP model was employed for supplier selection considering green criteria in the study of Kuo and Lin (2011). The authors concentrated on improving green supplier selection criteria along traditional supplier selection criteria. The criteria were examined under four dimension; organisation structure and manufacturing capability, supplier’s implementation capability, quality system, environmental issues. The criteria weights were calculated by ANP method. DEA method was applied for supplier selection by making use of criteria weights which were calculated by ANP.

Cao et al. (2016) utilized the integration of IFS and TOPSIS method to select green suppliers. An intuitionistic fuzzy judgment matrix was established to detect the weights of each criterion. Then, TOPSIS integrated with intuitionistic fuzzy set was utilized to align suppliers. This study was implemented in an electric automobile company while taking six criteria (environmental cost, remanufacturing activity, energy consumption, reverse logistic program, hazardous waste management, environmental certification) into account.

Green and traditional parameters were investigated by Acar et al. (2014) to select supplier in textile industry. The authors constructed a criteria list by utilizing fuzzy AHP after consulting twenty eight professionals. According to results, the authors suggested that classical decision criteria like cost, quality, service have more influence than green criteria like pollution control, green packaging. The authors also suggested that taking into account the criteria list, could facilitate decision makers to preclude customers' environmental pressure.

In the study of Saeidi et al. (2014), fuzzy Delphi and VIKOR tehniques were utilized to rank green suppliers in an electronic firm respectively. Fuzzy AHP method was used to weight the criteria. Criteria were evaluated under two dimensions; electronic green supply chain and associated with GSC.

Kuo et al. (2014) suggested to apply a hybrid MCDM method to appraise environmentally consious suppliers. The criteria were evaluated under environmental and management dimension. The integration of DEMATEL and ANP (it is known DANP) was utilized to expose the relationship between criteria and to weight each criterion. VIKOR method was implemented to select the best suppliers. A case study was used to illuminate how this process works.

The integration of the attributes of ANP and importance performance analysis (IPA) methods was utilized to select green suppliers in the study of Chen et al. (2016). The criteria were evaluated under three dimensions; operation, competence and environmental conciousness. Due to the attributes of ANP, the relationship between criteria was determined. IPA was also used to demonstrate the criteria's importance and supplier performance. The authors suggested that the integration could ease green supplier selection procedure while rising the supplier management performance. They also suggested the proposed model could constitute a win-win strategy for all system.

The integration of Kourosh and Arash method (KAM) and DEA method was utilized with artificial intelligence model to select green suppliers in garment manufacturer industry in the study of Fallahpour et al. (2016). Six criteria were evaluated under environmental and traditional dimension. Triangular fuzzy numbers (TFN) and graded mean integration method were employed to determine each criterion value. Afterwards, the integration of KAM and DEA was utilized to demonstrate the productivity of alternatives.

An extended qualitative flexible multiple method (QUALIFLEX) was applied to select green suppliers while utilizing probability hesitant fuzzy (PHFE) information in the study of Li and Wang (2010). This proposed model was implemented in the automobile industry by taking nine criteria into consideration. A comperative analysis was employed by using probability hesitant fuzzy information at the end of the study .

In the study of Bai and Sarkis (2016), the integration of TOPSIS and VIKOR method was utilized to rank the suppliers. TOPSIS was applied to consider suppliers for each decision maker. The final ranking of thirty suppliers was carried out by using VIKOR method after evaluating all decision makers' view. Thus, the best alternative was detected. The authors also suggested the main aim of the study was to maximize profit while decreasing risk.

In the study of Feyzioğlu and Büyüközkan (2010), 2-additive Choquet integral methods were utilized to appraise the five candidates. Eighteen sub criteria under five main criteria was evaluated. The mean arithmetic method was applied to demonstrate results without evaluating criteria interactions and to compare with 2-additive Choquet integral methods. The study was implemented in the white goods industry and eighteen criteria were evaluated under four dimensions. The authors suggested that the proposed method which was implemented in the study is more available to obtain more satisfactory results compared to other techniques which are based on aritmetic mean method.

Generic simulation model was used to select green suppliers in the study of Boosothonsatit et. al (2012). The criteria were considered under traditional and environmetal aspects in the study. The authors suggested that the objective of this study was to reduce cost, lead time and hazardous environmental impact. A numerical example was applied in a boat manufacturer in Australia to demostrate the steps of the proposed model.

A hybrid fuzzy ANP and fuzzy PROMETHEE approach was utilized to select the best supplier considering environmental performance in the study of Tuzkaya et al. (2009). Thirty one subcriteria were determined under six main criteria. The evaluation of criteria was carried out by using fuzzy ANP. Then, fuzzy PROMETHEE was used to select the best alternative. Lastly, sensitivity analysis was implemented to confirm and test the outcomes.

The integration FST and GRA was utilized to choose the best environmentally conscious supplier in the study of Tseng and Chiu (2012). Eighteen environmental and non-environmental criteria were considered and their significance and performance were evaluated by using linguistic variables. FST was utilized to weight the criteria and alternatives in the study. GRA was utilized to detect the final sorting of alternatives. This study was applied in original equipment manufacturing sector.

The integration of FAHP and FMOLP was used to find the most environmentally conscious alternative in the study of Shaw et. al (2012). This study was applied in the garment manufacturing company. FAHP was applied to detect the criteria weights. Afterwards, FMOLP was utilized to detect the most appropiate supplier considering the criteria (cost, quality, lead time, green house gas emission and demand). However, carbon emission was considered as a constraint by the authors when choosing supplier.

Sinha and Anand (2017) applied multi preference fuzzy relationship based methodology to evaluate alternatives. It was created a supplier pool by using quantitative techniques and taking experts' view. To create the pool of suppliers five analysis took place and the supplier which has the least hazardous environmental impact was chosen. During supplier selection procedure ordered weighted averaging (OWA) operator was used then quantifier-guided dominance degree (QGDD) was calculated for each supplier alternative considering decision maker's view. Two examples were utilized to indicate the steps of the applied method. The authors suggested that the aim of the study was to develop the quality while decreasing time in decision-making process.

Agarwal and Vijayvargy (2012) used portfolio analysis based ANP method to evaluate the criteria and to select the most environmentally conscious alternative amongst four ones. This study was applied in automobile industry and twenty one criteria under four dimensions. The authors suggested that ANP method was more beneficial in considering quantitative and qualitative criteria and could give more exact outcome compared to other methodologies.

Yeh and Chuang (2011) applied MOGA method to solve the problem. After applying MOGA, the authors obtained a set of Pareto-optimal solutions. The authors evaluated green criteria because traditional criteria do not reflect environmental precision in accordance with them. The authors emphasized that there were four aims in the study; reducing total cost, reducing total time, increasing mean output quality and increasing green evaluation point.

The integration of fuzzy Entropy and TOPSIS was applied to choose the most environmentally conscious supplier in the study of Zhao and Guo (2014). Triangular fuzzy numbers (TFN) were obtained by using fuzzy set theory (FST). Then the criteria weights were seperated to objective and subjective ones. The subjective and objective criteria were calculated respectively. The performance of each supplier was worked out by using TOPSIS.

The integration of SWARA, QFD and WASPAS was utilized in the study of Yazdani et al.(2014). The QFD was used because customer requirements were taken into account in the study. Thanks to SWARA method and the house of quality matrix, the weights of customer requirements were calculated. At the end of the study, WASPAS was utilized to appraise the efficiency of each supplier and demonstrate their score.

Liao et al. (2015) utilized fuzzy AHP, fuzzy ARAS and MSGP to choose the most environmentally conscious supplier in watch manufacturing company. Five main criteria were evaluated and fuzzy AHP was utilized to detect the criteria weights. Fuzzy ARAS technique was used to obtain closeness coefficient after demonstrating the interrelation between alternatives. MSGP was applied with the help of LINGO to choose the best green supplier.

Kuo et al.(2011) used the integration of FAHP and VIKOR to choose the most environmentally conscious supplier in printed circuit board industry. The criteria were determined after reviewing the literature. The weights of each criteria were calculated by applying fuzzy AHP. VIKOR analysis was implemented to consider green suppliers. Lastly, the performance of three kinds of green supplier was compared.

Dehghani et al. (2013) implemented FANP to select the best green supplier with categorizing purchasing items and allocating items respectively. ABC analysis was used to categorize purchasing goods of company. Then the criteria were considered by decision-making team that made use of literature review. Fuzzy ANP was implemented to detect the score of candidates. Due to linear multi-objective programming model, orders were allocated in the last step of the study.

Ghorabaee et al.(2016) implemented the integration of extended WASPAS method with IT2FSs . Seven criteria were determined and the criteria weights were worked out as objective and subjective. IT2FSs were utilized to compute the weights of criteria and the authors suggested that IT2FSs were used because it dealt with ambiguity of MCDM problems. WASPAS was applied to align the candidates and to choose the most approriate one.

HakimiAsl et al. (2016) implemented the integration of FANP and VIKOR to select the best green supplier in electric power industry. Ten criteria were determined after researching literature review by the authors. The criteria weights and normalization of the criteria weight vector were worked out by using fuzzy AHP. Afterwards, the selection of the best supplier was carried out by utilizing VIKOR method.

Akman and Pışkın (2013) applied the integration of ANP and TOPSIS models to choose the most environmentally conscious supplier. Seventeen sub-criteria were extracted from literature review. Pairwise comparison between criteria was made and the weights of each criterion were calculated by using ANP. The selection of the best supplier in terms of environmental conditions was carried out by using TOPSIS.

Büyüközkan and Çifçi (2012) applied FANP to choose the most environmentally conscious alternative. The criteria and sub-criteria were determined after investigating literature review. The relationship between criteria were demonstrated after consulting experts. Fuzzy pairwise comparison matrices were constructed by utilizing triangular fuzzy numbers (TFNs). Then the weights of the criteria were worked out. After constructing supermatrix by using ANP, alternative one which had the highest score was chosen.

Shaik and Abdulkader (2011) applied a multi-attribute utility theory methodology to choose the most environmentally conscious alternative considering environmental, green and organisational factors. After evaluating options, comprehensive evaluation was carried out by ranking of the alternatives in accordance with the utility values. The alternative which has the highest value was chosen as the best green supplier.

The integration of IT2FSs and TODIM was utilized in the study of Qin et al.(2017). The weights of criteria were determined by using IT2FSs. Then, improved TODIM based on MCGDM model was utilized to select the best supplier alternative. Lastly, the results of the proposed methodology were compared with the results of integration of IT2FSs and TOPSIS. The authors suggested that integration of IT2FSs-TODIM was more applicable and more resilient than IT2FSs- TOPSIS.

Govindan et al. (2017) applied the integration of simos procedure, PROMETHEE methods, algorithm which was available to establish a group compromise ranking and robustness analysis. To show the effeciency and process of the proposed methodology an example was examined in Indian food industry. Five main criteria (cost, quality, delivery, environmental impacts, technology capability) and fifteen subcriteria and five alternatives were determined by decision making team. The criteria weights were detected by Simon procedure. Then, PROMETHEE methodology was implemented to align the alternatives by taking decision makers' choice into consideration. Afterwards, the compromise ranking was established to reduce the interval of each decision makers' alignment from the group solution. At the end of the study, the findings which were determined by decision makers were confirmed versus the results of robustness study.

An elaborative table of the review on green supplier selection is introduced in Appendix A by demonstrating name of authors, publishing year and determined criteria and methodology.

4.1. The Criteria for Green Supplier Selection in the Literature

4.1.1. Green Criteria for Green Supplier Selection

The executives aims to choose the most appropriate supplier from a range of potential suppliers to meet specific requirements while depending on constraints (Hosseini and Barker, 2016). Along with growing awareness of environmental issues, public and governmental pressures, executives have to buy from suppliers who are able to supply commodities and services with "lower price, higher quality, shorter lead time, and at the same time with focus on stronger environmental responsibility" (Hashemi et al., 2015).

GSS is a complicated procedure consisting of several factors "such as environmental management, design, manufacturing and compliance with regulations". For this reason, no world-wide treaty can not be found between surveyor and implementer about what criteria are determinative in the selection process. However, the selection of environmentally conscious suppliers depends on the content and the selection should reverberate the actual working environment of the researching industry or firm in the real world (Liou et al., 2016).

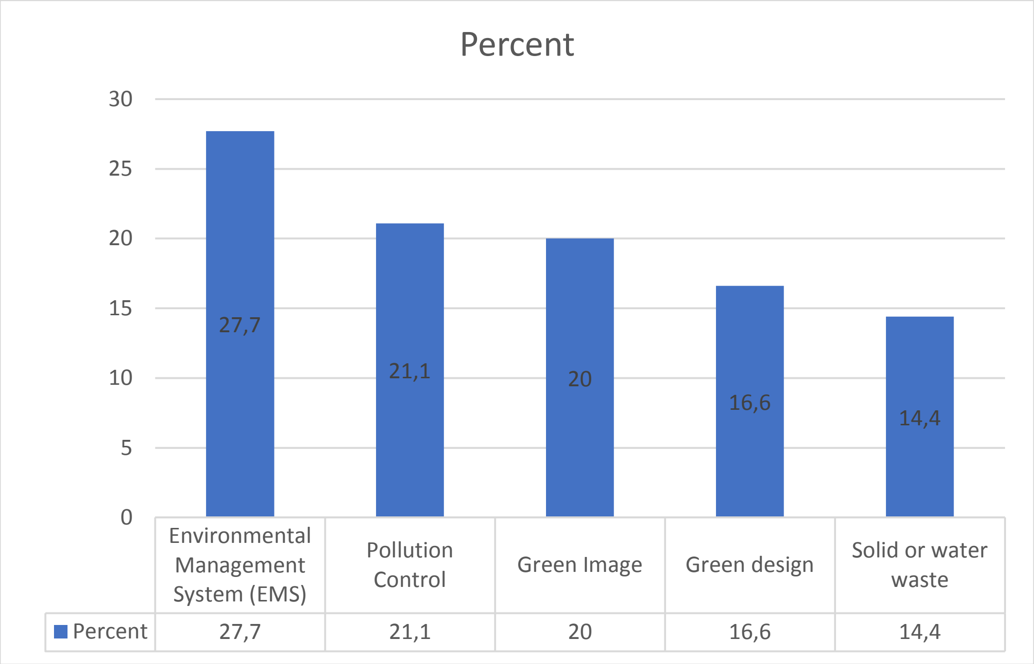

Figure 4.1 : The Percentage of the Most Frequently Used Green Criteria in the Literature

The selection of suppliers is traditionally based only on the price criterion. As mentioned previously, owing to government regulations, the need to protect the environment and growing awareness among the population, organizations can not neglect environmental problems today if they desire to live in global markets (Liou et al., 2016).

Supplier criteria are utilized to determine supplier's compliance with technology and procurement strategy of business (Yazdani, 2014). However, green supplier criteria have a major impact on the supplier selection process. Because opting of environmentally conscious supplier is considerably based on the green criteria, thus determining the appropriate criteria will directly influence the decision maker's findings (Banaeian et al., 2015).

However, the green criteria in supplier selection process have emerged to respond to the need arising from the environmental trend. The green criteria may be improved with the intention of fulfilling governmental legislation, focusing on development of operations and organizations' environmental politics (Liao et al., 2016).

Evaluation of the criteria is the first step of selecting the best alternatives. It is crucial to detect the proper and sufficient criteria for environmentally conscious supplier selection. However, the contingency of obtaining misleading and incorrect results in the study is high as long as the criteria are not properly determined. During the determination of criteria process the researchers made use of scientific journals, experts' views, previous researches and so on.

The relationship between criteria and the weights of the main and sub criteria could be determined by utilizing some techniques such as AHP, ANP, DEMATEL, Delphi method and so on.

Pollution control, green image, environmental management system (EMS), green design, solid and water waste are amongst the most frequent criteria in the literature. Along with those criteria green product, green technology, eco-design, environmental competency are another frequent green criteria. And it was observed that a large number of traditional and economic criteria were evaluated such as cost (direct or indirect in supply chain), delivery, service, quality, technology, management commitment, price, lead time, delivery and so on.

Subcriteria were not utilized in twenty two articles amongst in the literature. Lioua et al (2016) investigated the sub criteria under organisational management, operational management, compliance with regulation, product design. Darabi and Heydari (2016) evaluated cost, quality, delivery, technology capability, environmental competency as main criteria. It means the authors evaluated traditional criteria along with green ones. Govindan and Sivakumar (2016) evaluated cost, quality, delivery, recycling capability and emission of greenhouses gases as green criteria. Chen et al. (2016) observed twenty two criteria to choose the most environmentally conscious supplier in the LEF industry under financial and environmental dimensions. Galankashi et al. (2015) evaluated "price, quality, reputation, service and delivery, distance, use of green materials, air emission level, waste level, energy efficiency, green design capability" as main criteria and did not use any sub-criteria. Chung et al. (2016) evaluated finance, customer service, quality, cost, delivery time, response capability, capacity, technical capacity, environmental specification, green image, environmental benefit as sub-criteria under three dimensions (Operation, Ability, Green). In the study of Hamdan and Cheaitou (2017) the authors evaluated "delivery time, payment term, cost, stock availability, quality, compliance to government regulation, design for environment, environment protection, green image" as sub-criteria under traditional and environmental dimension. Top five green criteria used in the previous studies and their percent are demonstrated in Figure 4.1.

4.1.2. Traditional Criteria for Green Supplier Selection

It is evident that it is not probable to ignore the traditional criteria in green supplier selection studies in the literature. Because it is not realistic to make a supplier selection by only considering the green criteria. The combination of environmental, financial and social performance is a quite crucial subject for the company to obtain sustainable development in this century. To obtain long dated achievement in the modern market, companies and organizations do not only have to focus on economic and traditional terms but also consider several environmental criteria (Lee et al., 2009).

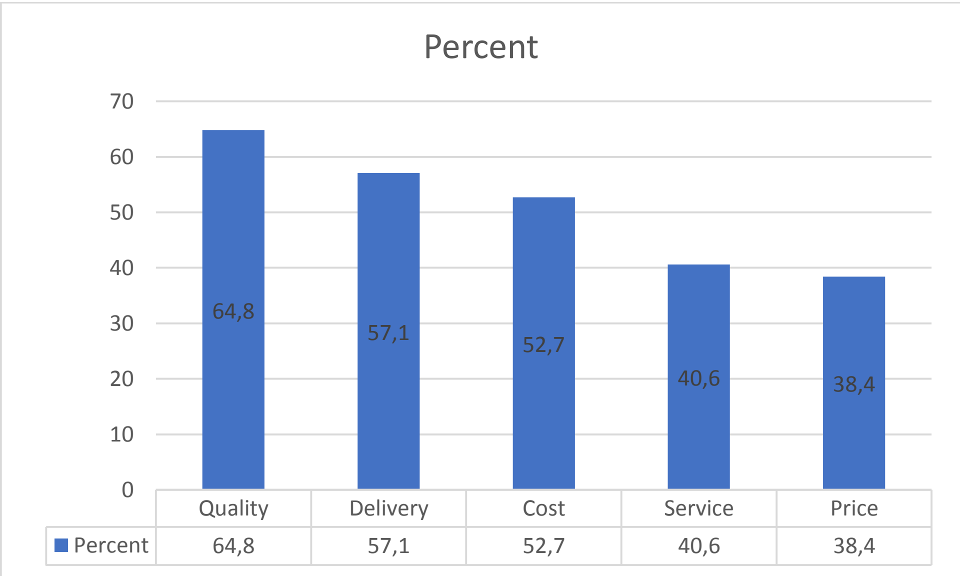

Figure 4.2 : The Percentage of The Most Frequently Used Traditional Criteria in the Literature

However, to choose the most suitable supplier for a company, the executives do not only evaluate the greenness criteria to protect the environment but also take into account classic factors such as quality, price, delivery and so on (Lee et al., 2009). As it is understood from Figure 4.2 delivery, quality, price, service and cost are the most frequently utilized traditional criteria in the previous studies. The quality criterion includes product quality and utilization of quality certificates. Delivery criterion also includes delivery precision and lead time.

The quality criterion was taken into account in about two thirds of the studies in the literature. The delivery criterion is also a traditional criterion used almost as often as the quality criterion. The cost criterion is another traditional criterion that has been used in more than half of the studies. Service and price criterion are another significant traditional criteria used in more than a third of the studies.

To give a number of examples of studies which use the traditional criteria, Lee et al. (2009) investigated seven traditional sub attributes under two traditional main ones; quality, technology capability. The Delphi method was utilized to provide compromise amongst experts and to determine the most significant sub-criterion. Kannan et al. (2015) collected 115 subcriteria under 11 main criteria to evaluate five supplier alternatives in their study. Four of eleven main criteria are traditional criteria. Those are quality, cost, capability of supplier delivery, service. Those are amongst the most frequent criteria in the literature. Jauhar et al. (2016) considered five criteria under managerial and environmental aspects. They have utilized also some of the most frequent traditional criteria under managerial aspects. Those are lead time, quality, price. Fallahpour et al. (2016) also seperated the criteria under traditional and environmental aspects. Those are quality of material, service, delivery and cost. Kumar et al. (2017) utilized the traditional criteria as the main criteria. Those are quality, service, cost and flexibility. Under those main traditional criteria, they collected a number subcriteria such as processing expense, transportation expense, inventory expense, maintenance expense, energy expense, inspecton expense, delivery expense, security expense, materials expense, continuous cost reduction, ISO 9000, certification, fast deliveries, quick response, logistics service, product design, technological change, material change, equipment upgradation, process improvement, volume flexibility, design flexibility. Chen et al. (2016) also seperated the criteria under economic and environmental aspects. Cost, quality, delivery, technology, flexibility, financial capability, culture innovativeness and relationship were considered under economic aspects. Hu et al. (2015) considered traditional criteria under commercial aspect. But most of the subcriteria were considered below the environmental aspect. Quality, price, delivery time, on-time delivery rate, after-sales service and supplier reputation are criteria under commercial aspect. Acar et al. (2014) considered the criteria under classical and environmental dimension. Quality, delivery, service, cost and strategic alliance were considered under the classical dimension.

4.2. Review of Methodology

The present literature offers ideas and debates about the necessity of various supplier management approaches. Selecting an appropriate strategic supplier management approach with quantitative methods considering traditional and environmental criteria were investigated by academicians and researhers. A systematic quantitative research of supplier management strategy in green supply chain may exceedingly benefit the research and application (Sarkis et al., 2010).

However, progress in generating unprecedented supplier selection approaches within the content of GSCM could help organizations avoid the ongoing difficulties of supplier selection process and develop their environmental performance (Kannan et al., 2014). The improvement and widening of a novel green supplier decision making model have crucial importance because the supplier selection directly affects the environmental performance of the producer (Qin et al., 2015).

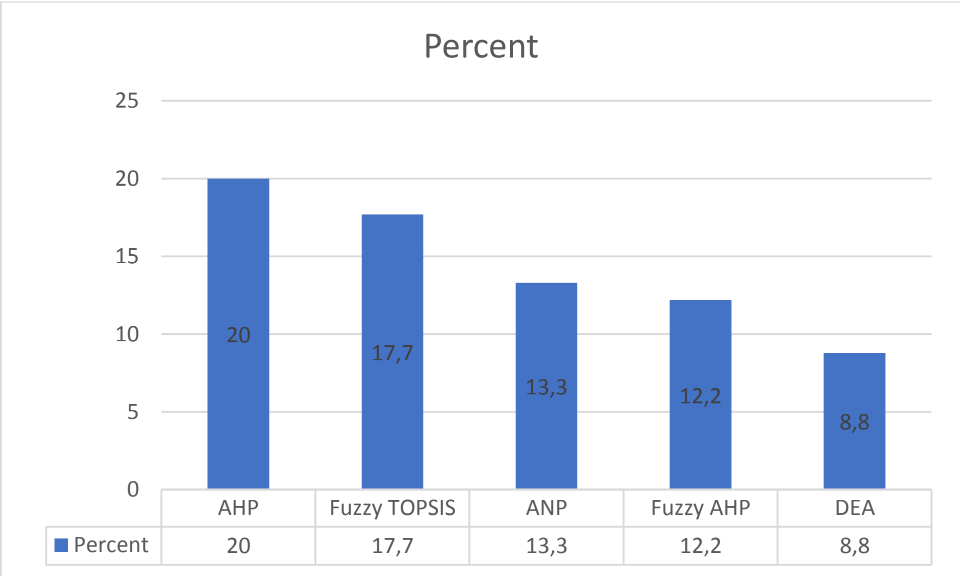

Figure 4.3: Top Five Metholodologies for Green Supplier Selection

A number of methodologies have already been suggested to assess suppliers in the previous studies. The most frequent techniques which are used in the literature are AHP, fuzzy TOPSIS, ANP, fuzzy AHP and DEA in order. Except for aforementioned methods, TOPSIS, GRA, fuzzy ANP and DEMATEL are other common techniques. The percentage of the most frequently used methodologies in the literature is shown in Figure 4.3. However, a number of researchers utilized sensitivity analysis to observe the steadiness and availability of the proposed technique and the outcomes of the model in the study.

Information about the frequently used methodologies in the literature is as summarized below.

AHP is a MCDM approachment and was presented by Saaty in 1970s. The AHP may be utilized to overcome complicated decision problems. However, the AHP drew the attention of a large number of authors due to the robust mathematical features of the method and the necessary input data are pretty straightforwoard to acquire (Triantaphyllou and Mann, 1995). According to Hashemi et al.(2015) “AHP is capable of reflecting the natural preference of the human brain to sort components of a system into distinctive levels and group similar components in each level”.

The ANP method is also one of the most commonly used methods. Because the AHP methodology does not consider dependence of the criteria in the assessment period, ANP is suggested in the cases where it is thought that the criteria are interdependent. ANP is an extent of AHP and is very useful for tackling dependence not only in a cluster but also between different clusters (Hashemi et al., 2015). However, ANP is a sound decision-making method to examine key topics related to GSCM and environmental applications (Sarkis, 2003).

DEA is a mathematical programming method utilized to evaluate the comparative yields of decision-making entities in which the occurrence of numerous entries and outcomes make it difficult to compare. It is a nonparametric method and identifies the nonparametric best application border and the border serves as a reference for supplier assessment (Baskaran et al., 2012).

The TOPSIS algorithm developed by Yoon and Hwang (1981) provides a choice between alternatives, using distances. TOPSIS has a straightforward calculation procedure, a scientific operation and a strong rationale which indicates the logic of people selection. It contains unrestricted set of criteria and performance features and enables obvious exchanges between features (Kannan et al., 2013).

In some mathematical models, it is not possible to use definitive data in some cases. The words that people express their preferences are often uncertain. However, it is difficult for people to make evaluations with strict numerical values. Degrees and weights of the criteria included in the decision making problem in fuzzy environment can be expressed through verbal variables. The fuzzy TOPSIS algorithm has been developed for solving

MCGDM problems that occur in an uncertain environment and that are affected by a large number of people's decision (Öztürk and Başkaya, 2011).

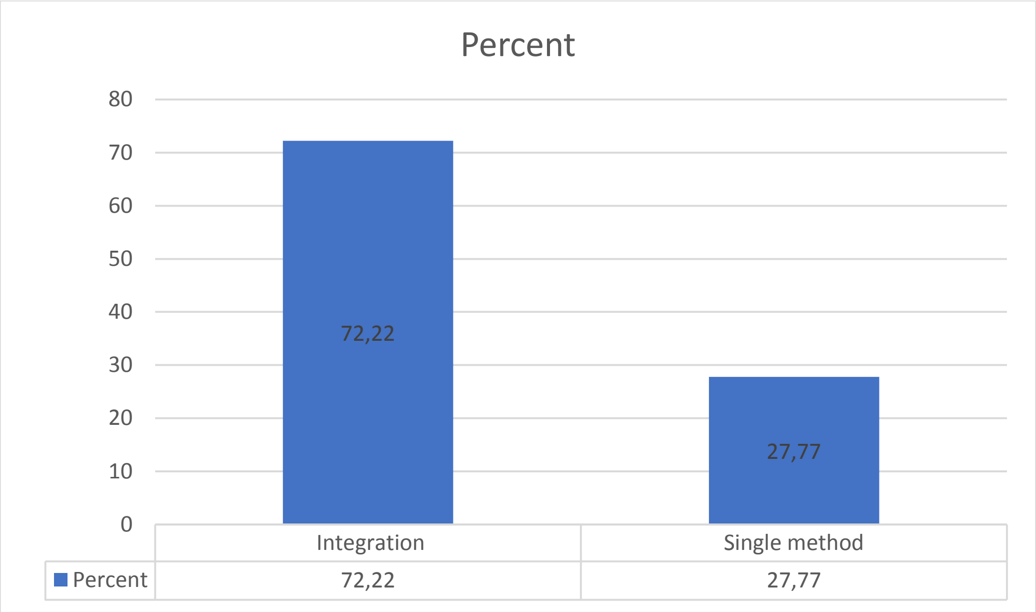

Figure 4.4 : The Percentage of Integration-Single Method in the Literature

Two or more techniques are blended to form an integrated methodology. In recent years, when green supplier selection studies were examined, integrated methods are used in approximately two-thirds of the study. In literature, integration of methodologies (such as TOPSIS and AHP, TOPSIS and VIKOR or fuzzy TOPSIS and fuzzy AHP) were utilized in sixty-six studies out of ninety ones. The percentage of integration-single method in the literature is shown in Figure 4.4.

The significant reason why researchers integrate decision-making techniques in supplier selection problems is that they do not want to be exposed to limitations and constraints of a single technique. However, the researchers desire to obtain more reliable and outstanding results by benefiting from stronger parts of more than one technique.

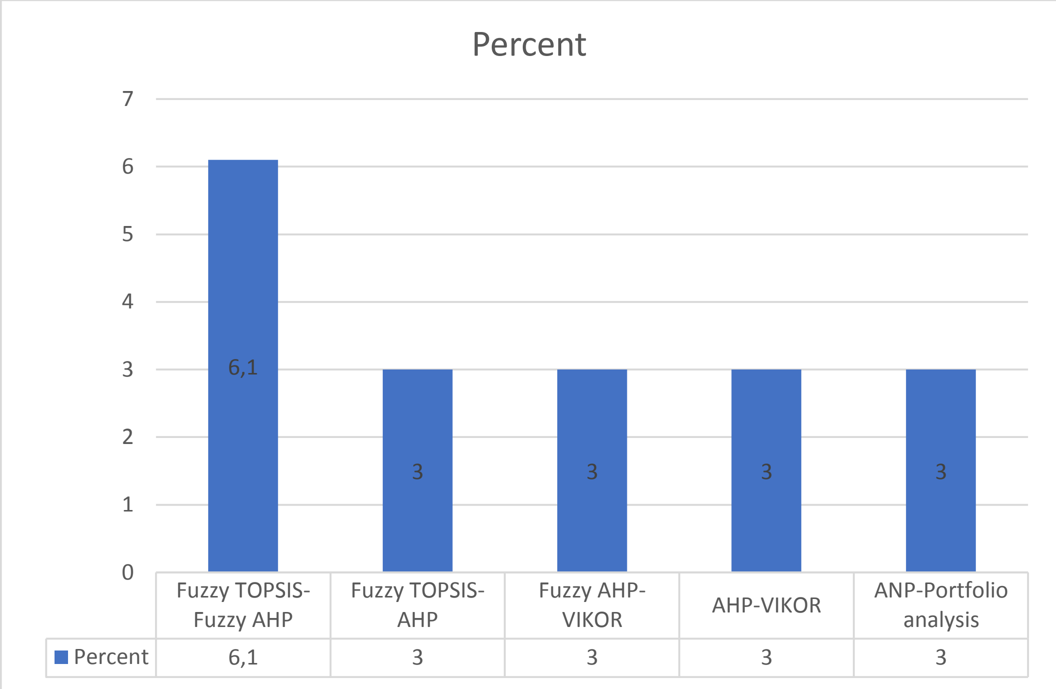

Figure 4.5: The Percentage of The Most Frequent Methods for Integration in the Literature

The integration of fuzzy TOPSIS and fuzzy AHP, fuzzy TOPSIS and AHP, ANP and portfolio analysis, fuzzy AHP and VIKOR and AHP and VIKOR are the most frequent integration models in combined ones in the literature as shown in Figure 4.5. At the same time, fuzzy GRA-AHP, DEA-ANP, fuzzy ANP-fuzzy PROMETHEE, ANP-VIKOR, TOPSIS-VIKOR etc. are utilized once in the literature.

Especially in the last decade, techniques that are up-to-date and capable to remove uncertainties and vagueness arising in decision-making processes are often preferred by researchers. Thus, the researches concentrated on utilizing the techniques which facilitate to overcome subjectivity and ambiguity coming from both experts'and decision makers' view. In the literature, intutionistic fuzzy logic are preferred by a number of authors to come through the vagueness in decision making process. Some researches also preferred to utilize the integration of fuzzy and non fuzzy techniques to evaluate the suppliers.

4.2.1. IF-AHP in the Literature

In the study of Sadiq and Tesfamariam (2009), intuitionistic fuzzy AHP was applied to rank three drilling fluid candidates. Before the illustrative example is examined the authors explained the steps of intuitionistic fuzzy AHP. The structure of comparing general drilling fluids was investigated on six levels. Pairwise comparison was demonstrated in linguistic terms and was improved by utilizing intuitionistic fuzzy judgment matrix. Afterwards, intuitionistic fuzzy weights were computed. Then affinity measurements were used to gather the intuitionistic fuzzy alternative values into a group when they are pretty much similar. At the end of the study, the alternatives were ranked.

Xu and Liao (2016) examined intuitionistic fuzzy AHP on an illustrative example. The authors improved an algorithm to construct perfect multiplicative consistent intuitionistic preference relation matrix. They also utilized distance measurement formula to check the consistency of intuitionistic preference relation matrix. In case of being inconsistent, the authors implemented an algorithm which is more practical and more straightforward to apply to make the matrix consistent. In illustrative example IF-AHP was utilized to align three alternatives considering nineteen subcriteria under five main criteria.

Liao and Xu (2015) observed IF-AHP on the group decision-making problems. The consistency of combined intuitionistic fuzzy preference relation in group decision making problem was investigated. Three examples were evaluated in the study. SIFWG operator was used to agglomerate intuitinistic fuzzy preference relations in a uncomplicated and advantageous manner. Along with that in the examples IFWG, IFWA and SYIFWG operators were utilized in the study.

Kaur (2014) examined IF-AHP method on vendor selection problem. Five main criteria (cost, quality, cycle time, service, reputation) were evaluated to rank the alternatives. The author used the geometric mean method to work out intuitionistic fuzzy priority weights. After obtaining global preference from local preference, the ranking of alternatives was carried out and the highest one was selected.

Nguyen (2016) utilized IF-AHP method on risk prediction in ship systems. The five results of disastrous occurrence (very serious casualty, serious casualty, incident I, incident II, incident III) were compared in intuitionistic fuzzy preference relation matrix. After the ranking of events, the most and the least frequent one were determined. The author suggested providing that the experts to whom were consulted on the topic are competent more objective and reliable outcomes take place in the study.

Tavana et al. (2016) combined SWOT analysis and IF-AHP on outsourcing reverse logistic problem. SWOT analysis was used to characterize main criteria and subcriteria. IF-AHP was applied to compare intuitionistic fuzzy values and to check the consistency of the matrices. Local weights of main criteria and subcriteria were computed by utilizing intuitionistic fuzzy preference programming model. After calculating the global weights of sub-criteria, the final alignment of main criteria and sub-criteria was determined.

Büyüközkan and Güleryüz (2016) combined IF-AHP and IF-TOPSIS to choose partner in product improvement in automotive manufacturing industry. Intuitionistic preference relation matrix was constructed by taking decision makers' view into consideration to evaluate the comparison of criteria and subcriteria. The IFWA operator was utilized to agglomerate singular decision makers' view while evaluating the criteria and alternatives. After that IF-TOPSIS method was applied to align the partner candidates.

Abdullah and Najib (2014) applied IF-AHP to select energy technology in Malaysia. Nine main criteria and seven alternatives were determined in the study. The comparison between criteria was demonstrated in triangual fuzzy numbers (TFNs) and evaluated by three experts. The sigficance of each expert was calculated . Then in accordance with significance weight of decision maker, each criterion's entropy weights and final entropy weights were seperately computed. Nine choices were ranked with respect to the outcome of priority weights of three experts respectively. Nuclear energy was determined the most available one in accordance with the results.

Wang and Sun (2012) applied IF-AHP to consider the risk in energy management contract project. Ten experts were consulted and three projects were examined in three categories (strong, medium, weak) considering experts' view on intuitionistic fuzzy decision matrix. The IFWA operator was utilized to acquire eigenvalue and afterwards total valuation was computed. At the end of study three projects were aligned.

Dammak et al. (2015) applied IF-TOPSIS, IF-VIKOR and IF-AHP to align human capital indicators respectively. Five criteria (talent, strategically integration, cultural relevance, knowledge management, leadership) and four alternatives (creating results by using knowledge, employee skill index, sharing reporting knowledge, succession rate of training program) were determined in the study. Lastly, the outcomes of three different methods were compared and examined. Sorting of alternatives was carried out by utilizing aforementioned methods.

Keshavarzfard and Makui (2015) examined the integration of IF-AHP and IF-DEMATEL on the example of choosing executives of an Iranian automobile manufacturer. Two subcriteria were evaluated with respect to each of three main criteria (conceptual abilities, personal abilities, technical abilities). IF-AHP was utilized to weight the criteria and the IF- DEMATEL was utilized to demonstrate the relationship between criteria. The weights of three alternatives were computed by combining IF- AHP with IF- DEMATEL. After ranking of the alternatives, the best one was selected.

Abdullah and Najib (2014) analyzed IF-AHP on a numerical example. Three main criteria (environmental impact, cost, technical feasibility) and four alternatives were evaluated to consider system index. The criteria were compared by using the new preference measure of triangular intuitionistic fuzzy numbers (TIFNs) judgment matrix. Then, the weights of each decision maker were determined and the agglomerative intuitionistic fuzzy judgement matrix which is depended upon decision makers was created by using IFWA operator. The alternatives were aligned in accordance with the final weights.

Butta and Guha (2015) examined IF-AHP on the four examples. First sample was obtained from Sadiq and Tesfamariam (2009) study to demonstrate that the priority weights which are produced by using geometric mean method diverged from decision maker's views. In the second sample, it is examined that the manner of decision makers for eliminating hesitation on the preference weights by considering three features (pricing, service quality, delivery time). In the third sample, the outcomes of logarithmic preference programming (Wang and Chin) and the outcomes of proposed technique which is prepared by the authors are compared and the outcomes of logarithmic preference programming was found illogical. In the fourth sample, IF-AHP was utilized to choose available site for a company which manufactures engine system by evaluating three criteria (environmental impact, competitive and economic advantages, political risk).

Abdullah et al. (2013) applied IF-AHP to rank human capital indicators. Five criteria and four alternatives were determined in the example. The weights of each criterion's membership and nonmembership were calculated after the criteria were evaluated in pairwise comparison matrix. Then, the alternatives' membership and nonmembership priority were computed by taking each criterion into consideration. After that the total priority value of every alternative was calculated and they were aligned in accordance with total value.

Büyüközkan et al. (2016) applied the integration of IF-AHP and IF-VIKOR to evaluate the performance of hospital web service. Fifteen subcriteria under five main criteria were evaluated in the example. IF-AHP was utilized to determine each criterion's weight. Triangular intuitionistic fuzzy numbers were collected by using the intuitionistic fuzzy weighted averaging (IFWA) operator. Fuzzy VIKOR was used to rank the alternatives. An elaborative table of the review on IF-AHP methodology is presented in Table 4.1 by demonstrating name of authors, publishing year, application type and application year.

Table 4.1.: IF-AHP, IF-DEMATEL, IF-PROMETHEE and IF-ANP Studies in the Literature

Year	Author(s)	Intuitionistic MCDM type(s)	Application Type	Application Area
2008	Saeedi,Malek, Delavar and Tayybi	IF-ANP	Real world application	Geo-spatial information systems (GIS)
2009	Sadiq and Tesfamariam	IF-AHP	Illustrative example	Best drilling fluid selection under numerous environmental criteria
2010	Chang and Cheng	IF-DEMATEL	Illustrative example	Risk evaluation a semiconductor manufacturing factory
2012	Wang and Sun	IF-AHP	Real world application	Evaluation of risks in energy management contract projects
2012	Li, Deng and Kang	IF-DEMATEL	Illustrative example	Numerical example
2013	Abdullah, Jaffar and Taib	IF-AHP	Illustrative example	Human capital indicators
2014	Xu and Liao	IF-AHP	Illustrative example	Global supplier development
2014	Kaur	IF-AHP	Illustrative example	Vendor Selection
2014	Abdullah and Najib	IF-AHP	Real world application	Energy technology selection
2014	Abdullah and Najib	IF-AHP	Illustrative example	Evaluation of system index
2014	Li, Hu, Zhang, Deng and Mahadevan	IF-DEMATEL	Real world application	Optimizing the effectiveness of emergency management
2014	Xie, Duan,Sun and Du	IF-DEMATEL	Illustrative example	Regulation of the cources in a university
2014	Nikjoo & Saeedpoor	SWOT analysis and IF-DEMATEL	Real world application	Insurance company in Iran
2014	Xu and Liao	IF-PROMETHEE	Real world application	Assessment of alternative energy exploitation
2015	Xu and Liao	IF-AHP	Illustrative example	Global supplier development
2015	Dammak, Baccour and Alimi	IF-TOPSIS, IF-VIKOR and IF-AHP	Illustrative example	Human capital indicators
2015	Keshavarzfard and Makui	IF-AHP and IF-DEMATEL	Real world application	Automobile industry in Iran
2015	Butta and Guha	IF-AHP	Illustrative example	Sadiq and Tesfamariam's study
2015	Govindan, Khodaverdi and Vafadarnikjoo	IF-DEMATEL	Real world application	Green supply chain magement application in an automobile manufacturing corporation
2015	Sangaiah, Gao, Ramachandran &Zheng	IF-DEMATEL	Real world application	Assessment of information transfer efficacy
2016	Nguyen	IF-AHP	Illustrative example	Ship system risk estimation
2016	Tavana, Zareinejad, Di Caprio and Kaviani	SWOT analysis and IF-AHP	Real world application	Reverse logistic
2016	Büyüközkan and Güleryüz	IF-AHP and IF-TOPSIS	Illustrative example	Automotive manufacturing industry
2016	Büyüközkan, Feyzioğlu and Göçer	IF-AHP and IF-VIKOR	Real world application	Evaluation of hospital web services
2017	Büyüközkan, Güleryüz, Kapak	IF-DEMATEL and IF-ANP	Illustrative example	Evaluation of customer relationship management partner

4.3. Field of Study in the Literature

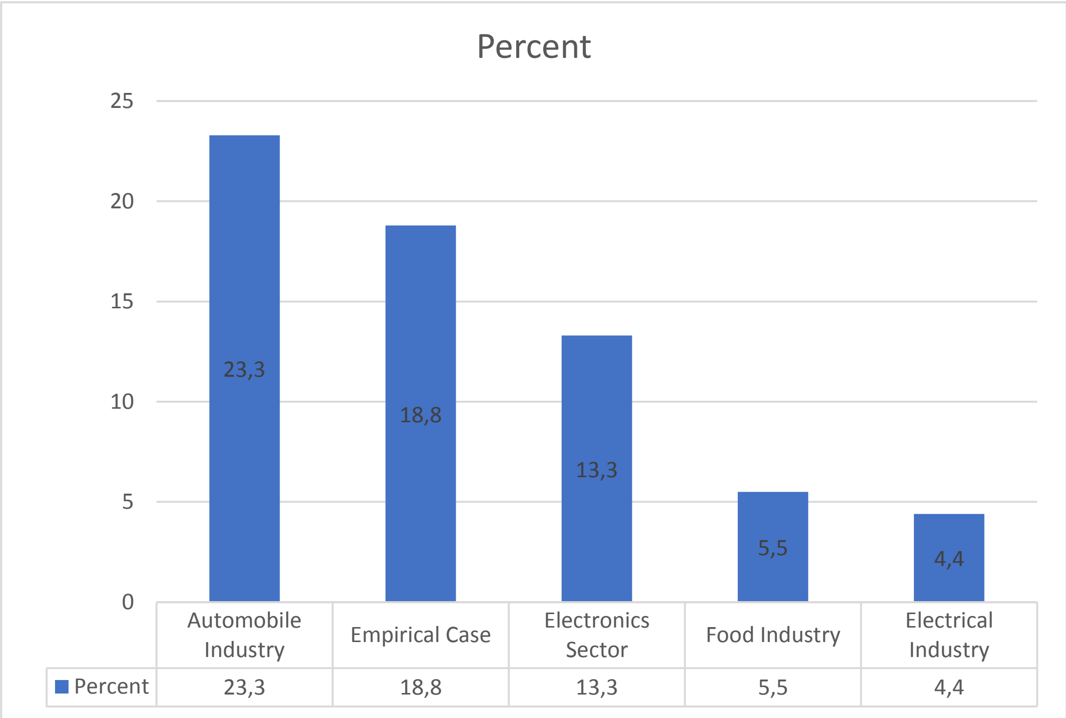

Figure 4.6: The Percentage of the Most Frequent Fields of Study in the Literature

The most frequent application areas in green supplier selection are demonstrated in Figure 4.6. The literature demonstrates that a large number of the study focused on automotive, electronics and food industries. While the automobile industry is the most preferred sector in the literature, empirical analysis is also the second preferred scope to apply the supplier selection process. However, electronics sector and food industry are the third and forth preferred sector by 13,3 percent and 5,5 percent respectively.

4.4. Application Area of the Study

When the literature is examined, it is observed that there is a gap in the filter sector. With today's increasing air pollution, the importance of supplier selection in the filter sector has been recognized. Therefore, the area of this study is determined as the high efficiency particulate air filter (HEPA filter) sector.

5. AIR FILTRATION

5.1. The Importance of Air Filtration

Nowadays in industrialised world, filtration systems are used for human health in various application areas to prevent hazardous particles in liquid or gas phase.

Filters are device or materials which is utilized to remove the harmful gases in the air. Suitable filters need to be utilized in the ventilation systems to trap particulate matters, dust, smog etc. in the air. However, they need to make necessary seperation at the entrance of the ventilation systems to reduce the amount of virus and bacteria (Bulgurcu H., 2015).

The damage of air pollution on human health and world reveals day by day. Air pollution is one of the main causes of very serious environmental problems.

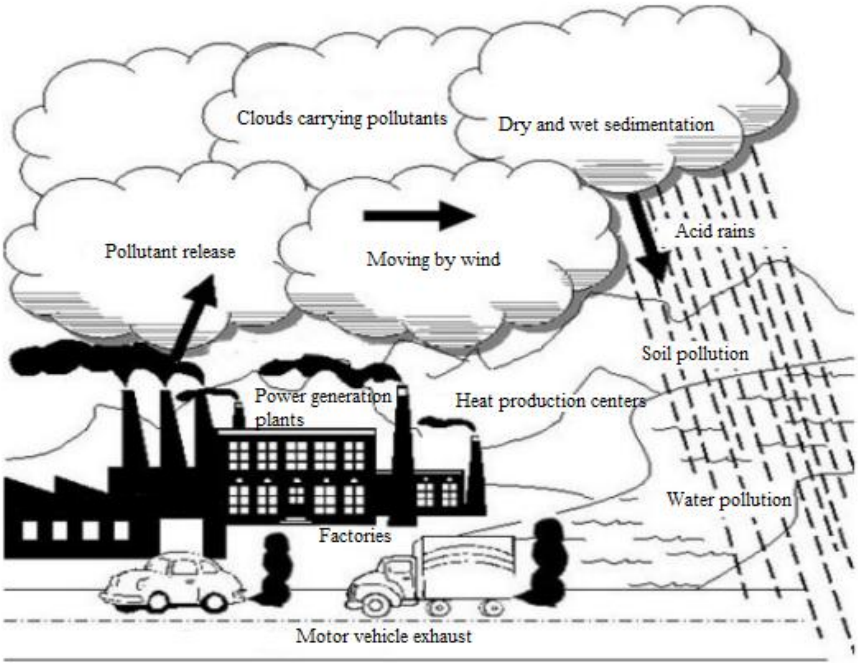

Figure 5.1 : Circulation of Air Pollution (Uzel, 2017)

The transportation of air pollutants and particulates to other areas through clouds and winds means that they are mixed with soil and water by precipitation.This means that not only air but also soil and water are contaminated. Therefore, air pollution affects not only the respiratory system of human, but also the plants growing on the ground and living things in the water. This indirectly damages to human health seriously. There are also global effects of air pollution. These global effects are greenhouse effect, ozone depletion and global warming (Uzel, 2017). However, it indirectly can be reason of global environmental problems such as melting of glaciers, the sea level rise, acid rain, extinction of some species of animals, reduction of potable water resources and reduction in the amount of forest.

Since people have an opportunity to select food or beverage but do not have any chance to choose the air to inhale particularly in urban life. Approximately 5.5 million people pass away every year because of air contamination in the world. (Url-14). The number of deaths is particularly high in regions where urbanization is intensive.

Every year the air pollution is liable for about 350,000-500,000 early deaths in China. It is not surprising that conscious Chinese clients are growingly interested in "green and environmental" economies as the air, water and soil of the country continues to be poisoned by industries (Freeman and Chen, 2015).

The emission of vehicles and production facilities are the fundamental reasons of the air pollution in the world. However, inhaling of small fluid and solid matter enhances the possibility of occuring chronic and serious diseases such as paralysis, heart attack, asthma, lung cancer and so on (Liu et al., 2017).

The implementation of air filtration systems is playing an important role not only to enhance the quality of life but also to degrade the possibility of diseases which occur due to air pollution. In accordance with the WHO report published in 2006 particulate matter, nitrogen dioxide, sulfur dioxide and ozone are the most dangerous ingredients in the air. However, there needs to be a limitation of hazardous gases emission and particulate matter. Table 5.1 demonstrates the limitation of those gases emission (WHO, 2006).

Table 5.1: WHO Air Quality Standarts

Pollutant	Guideline Values
$PM_{2,5}$	$10\mu g/m^3$ annual mean $25\mu g/m^3$ 24-hour mean
PM_{10}	$20\mu g/m^3$ annual mean $50\mu g/m^3$ 24-hour mean
O_3	$100\mu g/m^3$ 8-hour mean
NO_2	$40\mu g/m^3$ annual mean $200\mu g/m^3$ 1-hour mean
SO_2	$20\mu g/m^3$ 24-hour mean $500\mu g/m^3$ 10-minute mean

Main application areas of air filtration systems:

- Commercial buildings
- Airports and airplanes
- Pharmaceutical industry
- Healthcare facilities/Hospitals
- Manufacturing facilities

- Nuclear industry
- Detached house
- Computer/Electronic
- Food industry
- Transportation

Table 5.2: Summary of Air Filtration Techniques (Liu et al., 2017)

Air filtration technique		Effecient particles (Diameter)	Effectiveness
Fibrous filter	Medium filter	$> 0.3\mu m$	60-90%
	HEPA	$> 0.3\mu m$	>99.99%
	ULPA	$0.12\mu m - 0.17\mu m$	>99.999%
	Glass fibre	$0.12\mu m - 0.10\mu m$	99.00%
	Nano fibre	$< 0.3\mu m$	>99.99%
Trombe Wall		$> 10\mu m$ and $< 0.01\mu m$	99.4% for PM10
Bio filter	Dynamic botanical air filtration system	Blend of volatile organic compound	>33% for toluene and %90 for formaldehyde
	Integrated biofiltration system		%99
Electrostatic air filter	Electrostatic Air filter	$< 0.1\mu m$	82%-94%
	Electrostatic Precipitators	$> 0.1\mu m$	lower than HEPA
Cold plasma air filter		$< 0.1\mu m$ and effective for volatile organic compound	%85-98%

Air filtration systems are categorized coarse, fine, high efficient and ultra high efficient in accordance with EN779 and EN1822 published by CEN (European Committe for Standardization). Types of rough and precise filtration system are used to provide comfort and cosiness in daily life. However, HEPA and ULPA are used with the purpose of protection (Özkaynak, 2007).

In fibrous filter category, HEPA, ULPA and nano fibre technique are the most effective filtration systems. Then glass fibre and medium filter are the other types of fibrous filters. HEPA (High Efficiency Particulate Air) function at %99.97 efficiency and are effective on the hazardous particulate matter whose diameter is up to $0.3 \mu m$. ULPA (Ultra Low Particulate Air) filters take out particles in the air whose diameter in the range of 0.12 and 0.17 μm with 99.99 percent efficiency. ULPA filters are utilized in the semiconductor, healthcare and biology sector (Kte'pi, B., 2011). Nano fibre is more susceptible than others to catch particulate matters whose diameter is smaller than $0.3 \mu m$ (Wang et al.,2013) .

Another techniques are contained of trombe wall, bio filter, electrostatic air filter and cold plasma air filter systems. Meanwhile, trombe wall is preferred in construction industry as an insulation material instead of other insulation techniques. Moreover, it is more useful to make use of the sun energy than another insulation techniques (Doğan and Pırasacı, 2009).

The goal of heating, ventilation, and air conditioning (HVAC) system is to trap flayaway dust. These systems are generally non-returnable and utilized as a pre filter to protect inner filter from big particulate matter in the air. HVAC filters can be used in a large number of application area from nuclear industry to transportation (Anglen et al., 2003).

5.2. HEPA Filter

HEPA filter (High Efficiency Particulate Air) purifies the air from hazardous gases for human health. HEPA filters need to work in the certain standard of effectiveness which is determined by DOE (Department of energy in the United States) and CEN (European committee for standardization). This kind of filters generally works at %99.97 efficiency and are effective on the hazardous particulate matter whose diameter is up to $0.3 \mu m$) in accordance with DOE standarts (Kte'pi, B., 2011).

HEPA filters are also effective on some allergens, some bacteria, viruses, fume and discernible dust whose dimension is between $0.3 \mu m$ and $5 \mu m$. HEPA filters could exterminate particulate matter whose dimension is smaller than $0.3 \mu m$ providing they work in the low effectiveness (Url-15).

The dimension of some particles are defined as follows (Kte'pi, B., 2011):

“Viruses and bacteria : $0.0011 \mu m$

Smoke : $0.011\mu m$

Dust particles : $0.011\mu m$

Pet dander : $0.11\mu m$

Airborne fungi and mold spores : $150\mu m$

Pollen : $10.000\mu m$

Hair of human : $50.000\mu m$"

5.3. HEPA Filters Working System

HEPA filter does not fuction like colander or griddle, it traps a particulate whose dimension is over a specific extent whilst rest of other gets through the bores. HEPA filter characteristically has shirred sheet based on solid floor which consist of fixed fiberglass fibres whose diameter is in the range of 0.2 and $0.5\mu m$. And there are aluminium wavy traps amonst shirred sheets. An engined fan helps to pass the gas through in which particulate matter in the air are caught whilst sticking on fibres. (Kte'pi, B., 2011)

Some HEPA filters have pre filter to eliminate bigger particulates before the inner filter is utilized. Due to prefilter, the inner one can be long-lived. For example a gauze is used in vacuum cleaner to catch larger particles before arriving HEPA filters. The utilization of pre-filter is arbitrary to protect HEPA filter. Inner filter is utilized to catch the finer pollutant in the air (Url-15).

Though HEPA filters exterminate particles which are larger than $0.3\mu m$ many particles and gases (smoke, chemical gas) are smaller than $0.3\mu m$. To catch thin particles HEPA filters can be equipped with carbon filter. The more carbon filters are used the more smoke and bad smell disappers. The utilization of carbon filter is also arbitrary (Url-15).

HEPA filters can be equipped with ultraviolet light or antiseptic matter to eradicate microorganism. In fact, ultraviolet light and antiseptic matter can not be useful providing the other filters do not work well to trap particles. However, the harmful environmental effect of using ultraviolet light is to generate ozone. The utilization of ultraviolet light and antiseptic matter is also arbitrary (Url-15). For instance, type of H14 filter in the Europe is more effective because of ultraviolet lights and antiseptic matter (Kte'pi, B., 2011).

5.4. Usage Areas of HEPA Filter

Hepa filter is a type of filter commonly used by people in everyday and business life. HEPA filter has a wide usage areas ranging from hospitals to cars.

5.4.1. Healthcare Application

HEPA filters plays a critical role to intercept the spread of the bacteria and viruses in the air. Two different filters (HEPA and ULPA) are used in the vantilation systems of hospitals. The effectiveness of former filter needs to be at or over 30 percent and the effectiveness of the latter one needs to be at or over 90 percent. However, HEPA filters are suitable with its 99.97 percent efficiency in the hospital's special department such as: orthopedic operating rooms and the units for immunosuppressive patients (Kılıç, 2012).

Ventilation systems can be a warehouse for pathogenic germs unless essential periodic maintenance is implemented. Ventilation systems' maintenance including HEPA filters needs to regularly carry out by technical team and filters have to be changed every 6 months or once a year and temperature, moisture and current control should be carried out (Kılıç, 2012).

5.4.2. Vacuum Cleaners

Two varied operations are utilized in vacuum cleaner HEPA filtration system. Firstly an external filter is utilized as a griddle to take out particles in the air or dust big enough not to pass through. The inner filter is created by using glass fiber. It also works with three different ways (inertial impact, interception, diffusion). Along with that, three mechanisms are not only utilized to trap bigger but also to snatch smaller particulate matters from a specific dimension (Url-16). The mechanism is illustrated in Figure 5.2.

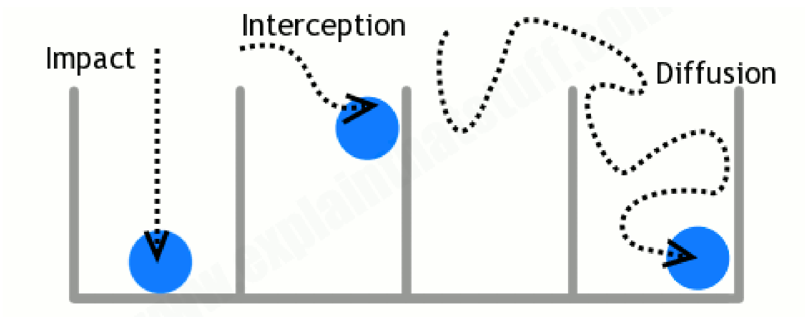

Figure 5.2 : The Working Mechanism of Inner Filter (Url-16)

5.4.3. Automotive Industry

New model electric automobiles started to use HEPA filter and they are designed to make use of HEPA filters effectively. HEPA filters do not to allow bacteria, viruses and other harmful particles in the car at 99.97 percent efficiency.

5.4.4. Airlines

Fifty percent of the cabin air is consists of fresh air, the other fifty percent of the air consists of filtered and reused air. HEPA filters can catch particulate matter such as dust, insects, bacteria, viruses up to $0.3\mu m$. The cabin air is changed in every 3-4 minutes, and the filtration process reiterates 15-20 times per hour. It means excellent hygiene and it is the same condition in the hospitals' operation rooms (Url-17).

5.4.5. Nuclear Industry

The efficiency of hepa filters used in the nuclear industry need to be over 99.99 percent. A number of tests are implemented to monitor the availability of HEPA filtres in nuclear industry. Airflow resistance, dust holding capacity, shock and blow strength, resistance against heat from fire and explosion, resistance against moisture, corrosion and radiation are taken into consideration to monitor the strength and availability of HEPA filters in nuclear industry in accordance with DOE (Anglen et al., 2003).

5.5. Types of HEPA Filters

HEPA filters are divided into two groups (panel type and box type) in accordance with their structure as shown in Figure 5.3.

PANEL TYPE HEPA **BOX TYPE HEPA**

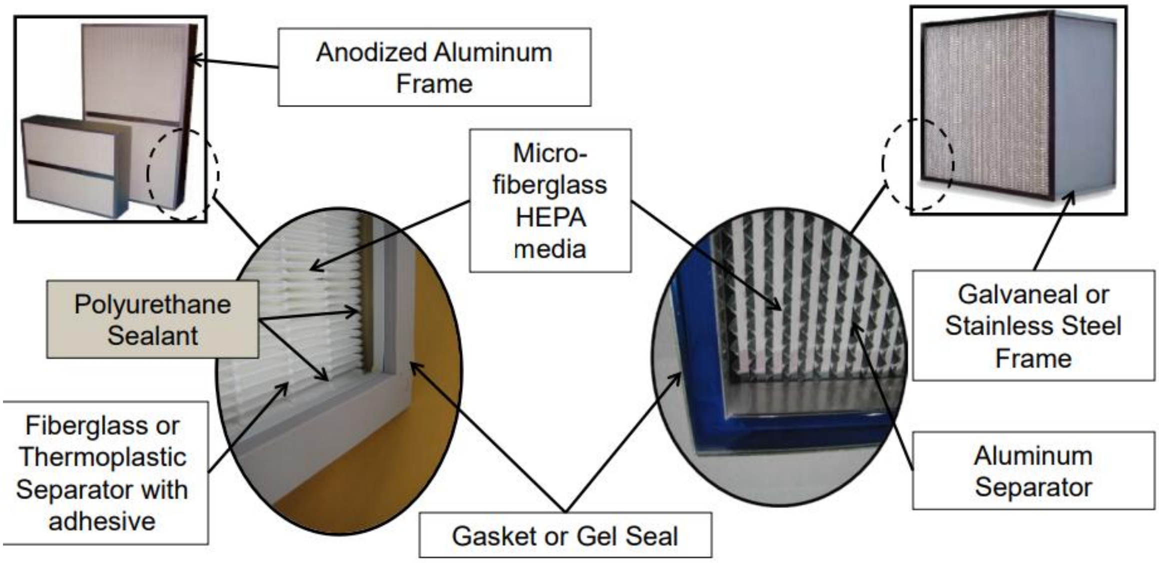

Figure 5.3 : Types of HEPA Filters

HEPA filter can also be seperated in accordance with their raw material and creation of frame, filter media, efficiency and technical data.

5.6. HEPA Filter Media

The HEPA filter media is considered to be the most important component of HEPA filtration, as it undertakes the task of blocking particulate matter.

There are a number of filter media for filtration system such as membranes, plastics, paper, woven and nonwoven fibrous media (Butler, 2000).

Table 5.3: Types of HEPA Filtration Media (Himstedt et al., 2014)

Filtration Technology	Particle Size Removed	Best-suited Media
Coarse Screening	> 2000	Mechanical Sieves
Coarse Filtration	70 – 2000	Nonwovens
Fine Filtration	0.1 – 70	Nonwovens
Microfiltration	0.1 – 1	Nonwovens, Membranes

Ultrafiltration	0.005 - 0.1	Membranes
Nanofiltration	0.001 - 0.005	Membranes
Reverse Osmosis	~0.001	Membranes

Types of HEPA filtration media is demonstrated in Table 5.3. According to research of Himdstedt et al. (2013) nonwovens or membranes are the most suitable alternatives for the fine and microfiltration. Since HEPA filters trap the particles in the air whose dimension over 0.3 micrometers the most suitable media for HEPA filters is nonwovens media and in some cases membrane filter media is also utilized. For example during the recent years polytetrafluoroethylene membrane filtres are utilized.

Table 5.4: Utilized Raw Materials for Nonwoven Filter Media (Himstedt et al., 2014)

Type	Raw material
Natural/Bio Fibers	Cellulose, jute, wood pulp, cotto
Synthetic Polymers	Polyesters, polypropylene, polyethylene, polyamides, polyimides, acrylics
Inorganic Fibers	Glass, metals

The nonwoven filter media is created by layer or weaving of fibers which are clamped together by attraction, tortuosity or glue (Himstedt et al., 2014). The raw material used for creating it demonstrated in Table 5.4.

Figure 5.4: Manufacturing System of HEPA Filter Media

The production phase of air filtration media is not rather simple. The manufacturing system of it is shown in Figure 5.4. Inorganic polymers such as synthetic polymers, glass, and metal are used to form the HEPA filter media. The use of many chemical substances and particular raw materials are necessitated to obtain essential substances to create HEPA filter media. During this production, several types of synthetic paint harmful to the environment, long recycling of solid waste and harmful gas emissions come to exist. There may be substances which may cause serious harm to human health and environment in solid materials such as lead, mercury, aluminum. Serious damage to human health and the environment occurs if necessary environmental measures are not taken in the production process. Nevertheless, a number of materials which have harmful environmental effects can be found in raw materials obtained by suppliers and this could influence negatively every stage of production.

6. METHODOLOGY

6.1. Proposed Techniques Used in the Proposed Methodology

More than 100 articles have been reviewed under the heading of GSC and GSS. There are many different MCDM methods used in the previous studies for the choices of alternatives by considering more than one criterion. Thus, several MCDM methodologies and techniques are presented in the literature.

The MCDM group demonstrates ambiguity and vagueness due to the characteristic of the DMs and the nature of qualitative criterion. For this reason, the process of selecting environmentally conscious suppliers involves uncertainty (Bali and Güreşen, 2013).

It is noticed that there is a gap in the literature as intuitionistic fuzzy logic was rarely researched. In this study, IF-AHP is regarded as a suitable method to weight main and sub criteria since it is easy to implement under ambiguous and uncertain circumstances. Afterwards, PROMETHEE method is applied to rank the alternatives by taking the criteria weights into consideration.

Thus, the integration of IF-AHP and PROMETHEE MCDM methodologies were opted for this research. All steps of the proposed methodology are presented in Figure 6.1.

Nonetheless, the uniqueness of this integration is that it is used for the first time in green supplier selection problem.

The methods and their steps are elaborated as follows.

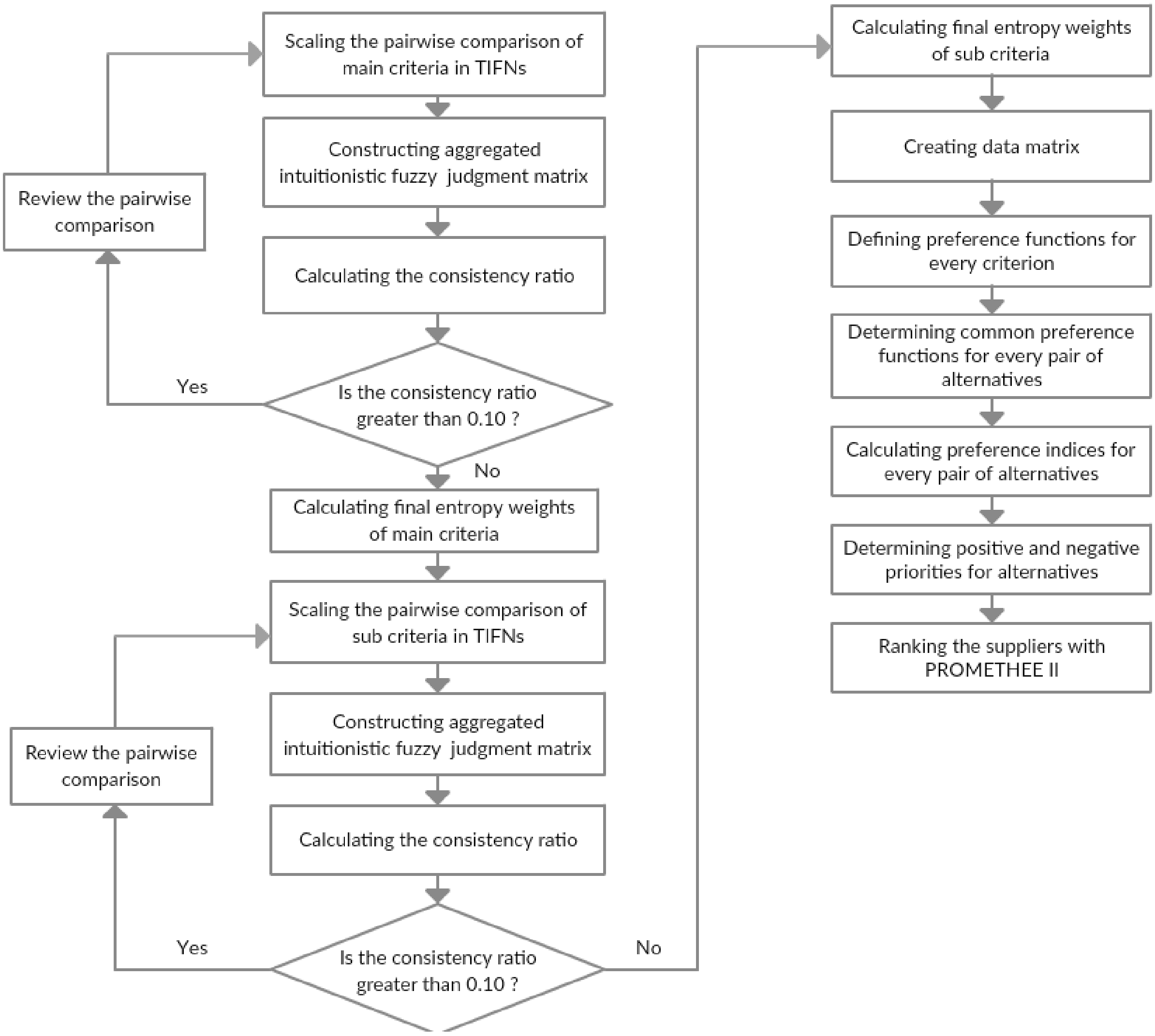

Figure 6.1: Flow Chart of Methodology

6.2. The Concept of Intuitionistic Fuzzy AHP

In real life, a large of number of situations are often ambiguous in a lot of ways. Fuzziness is part of everyday life and can be encountered in any area of work life. Those areas of study can range from engineering to meteorology. However, fuzziness is especially prevalent in the whole area where human judgment, assessment and decision are significant. Those areas are related to decision making, questioning, investigation and so on (Zıngıl, 2009).

Because the selection process comprises of criteria, alternatives and DMs, GSS is regarded as the MCDM problem. The MCDM group demonstrates ambiguity and fuzziness due to the character of the decision-making process and the subjectiveness of criterion. For this reason, the process of choosing environmentally conscious suppliers involves uncertainty (Bali and Güreşen, 2013).

However, people generally have some ambiguity in determining preference evaluation values, if the problem is regarded as uncertain or insufficiently informative. This situation reveals the confirmation, negation and hesitation property of cognitive performance decisions. For instance, when decision makers appraise an alternative, they do not only offer "deal" or "negativeness", but also at the same time "hesitation" that specifies hesitation and uncertainty on the alternative (Xu and Liao, 2014)

As a result of that, as decision makers are inquired to compare the criteria between each other, their answers are linguistic, thus immeasurable and vague. Owing to the character of immeasurable responses, judgments become uncertain and vague (Kannan et al., 2015). However, definite data are insufficient for real conditions since individual verdict and attitude are mostly subjective, fuzzy, vague and can not be predicted with precise numerical values (Kannan et al., 2013).

To describe such practical situations and to pattern human sense and cognition in a more extensive way, intuitionistic fuzzy logic involved hesitancy condition. In realistic implementations, during supplier evaluation process, decision makers can not be able to state their preferences correctly because they may not have adequeate information about the alternatives or they are incapable or reluctant to specify which alternative is better than the others. It means, there is some hesitation. In such cases, decision makers can supply a certain degree of preference for the alternatives and it is not possible to be sure of this. Therefore , it is available to state the preference knowledge of decision makers in intuitionistic fuzzy logic (Xu and Liao, 2014).

Hence, decision maker's subjective decisions and individual options can cause a major ambiguity in supplier selection process. It has become necessary to utilize intuitionistic fuzzy logic to overcome the vagueness in the problem. It is useful for decision maker to include imponderable, unattainable, disregarded knowledge into decision-making structure.

AHP method is a MCDM method proposed by Saaty. He examined a MCDM problem by comparing the criteria between each other. "The hierarchical structure of the AHP model can enable users to imagine the problem in terms of criteria and sub-criteria". Nevertheless, the DMs can be indecisive on pair-wise comparison (Kannan et al., 2013).

The AHP method which is largely utilized to resolve multi-criteria problems in the literature, is incapable to apprehend the uncertainties and vagueness that emerge in detecting the priority of varied features when taking advantage of qualitative expressions (Grisi et al.,2009). Although the easiness and applicability of AHP method, it is evaluated inadequate to overcome ambiguity and fuzziness in decision making process.

Therefore, integrating intuitionistic fuzzy logic into the AHP method is a considerable way to overcome the ambiguity occuring from individual's qualitative judgment. The substantial feature of this method is to have capability to achieve uncertainty and fuzziness which is inherent in decision making problem. Due to hesitation function, more current results could be effectively obtained. However, the IF-AHP is more superior and effective than the other AHP models in the process of removing the uncertainties that emerge from the decision maker.

IF-AHP is also utilized to solve more complicated problems in which the decision maker has a number of ambiguities in appointing preferences to objects evaluated. To apply IF-AHP, the overall problem must be structured at varied hierarchical levels according to the features or characteristic of the problem being addressed (Xu and Liao, 2014). However, the concept of intuitionistic fuzzy may reinforce the extensiveness and rationalness of supplier selection process.

In recent years, IF-AHP method was widely started to apply in numerous studies to overcome the ambiguity and vagueness happening from decision makers. The most obvious difference of intuitionistic fuzzy AHP from other AHP methods is to be dealt with hesitancy concept (Xu and Liao, 2014).

6.2.1. Preliminaries

This section includes the fundamental definitions of IFS, TFN and TIFNs before expressing the steps of IF-AHP.

6.2.1.1. Intuitionistic Fuzzy Set (IFS)

Fuzzy sets introduced by Zadeh in 1965. In the classical set theory, if an item is in a cluster, the membership level is "1", whereas the non-membership level is "0". In fuzzy set theory, the membership degree of an item is between 0 and 1 (Ejegwa et al., 2014).

Fuzzy set theory was extended to IFS theory by Atanassov (1986) who integrates the degree of hesitation. Since intuitionistic fuzzy set includes the “degree of belongingness, degree of non-belongingness and the hesitation margin”, it becomes more meaningful and effective for decision makers. This theory is a more suitable method for describing the structure of human thought rather than fuzzy set theory. However, thanks to the flexibility of the IFS in dealing with ambiguity, it is a tool to make reasoning under wrongfully defined factors and doubtful knowledge (Ejegwa et al., 2014). Many authors made use of IFS theory in decision making problems in literature (Özkan and Bali, 2013).

For the following explanation of IFS, it is benefited from Efe et al. (2015):

Let X be a non-empty set. Intuitionistic fuzzy set B is defined in X as follows.

$$B=\left\{\left\langle x,\mu_B(\mathrm{x}),\mathrm{v}_B(x)\right\rangle x\in X\right\} \qquad (6.1)$$

Atanasov (1986) defines in his IFS theory the membership degree of the x element is set to B as $\mu_B(\mathrm{x})$, the degree of nonmembership as $\mathrm{v}_B(x)$ and the hesitation index as $\pi_B(x)$. In the intuitionistic fuzzy set theory, the summation of membership degree and non-membership degree is less than or equal to 1.

$$0\le\mu_A(x)+v_A(x)\le 1 \qquad (6.2)$$

The hesitation index indicates the degree of uncertainty of whether or not any x element belongs to a set.

$$\pi_A(x)=1-\mu_A(\mathrm{x})-\mathrm{v}_A(x) \qquad (6.3)$$

If $\pi_B(x)$ is small, then the information about the x element is relatively more accurate. If $\pi_B(x)$ is greater, then the information about the x element is relatively more ambiguous. When the value of $\pi_B(x)$ equals 0, the information about the x element is the certain. In this case, the intuitionistic fuzzy set becomes a fuzzy set (Efe et al., 2015).

6.2.1.2. Triangular Fuzzy Numbers (TFNs)

TFN should own the following fundamental attributes.

A TFN $\overline{B}$ may be explained a<b<c. Here, the base of the triangle is in the range [a, c] and the top point is x = b. For example, the graph of $\overline{B}$ = (1.2 / 2 / 2.4) is below (Kocatürk, 2007). The graph of $\overline{B}$ is demonstrated in Figure 6.2.

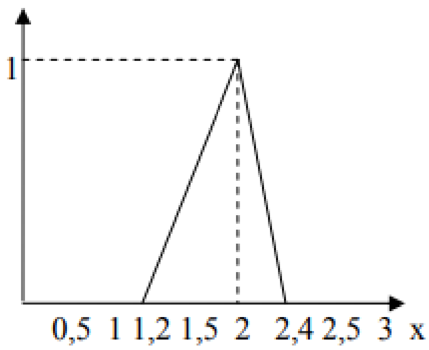

Figure 6.2 : The graph of $\overline{B} = (1.2/2/2.4)$ (Kocatürk, 2007)

$\overline{B}$ = membership function related to triangular fuzzy number can defined as follows:

$$\mu_{\overline{B}}(x) = \begin{cases} \dfrac{x-a}{b-a}, x \in [a,b] \\ \dfrac{x-b}{b-c} + 1, x[b,c] \\ 0, x \in [b,c] \end{cases} \tag{6.4}$$

6.2.1.3. Triangular Intuitionistic Fuzzy Numbers (TIFNs)

According to Shaw and Roy (2012) , the concept of TIFNs is defined as follows:

The below equations indicate the calculation of membership $\mu_B(\mathrm{x})$ and non membership $v_B(\mathrm{x})$ of TIFN B in Z.

A TIFN B is an intuitionistic fuzzy set in Z with following membership and non-membership functions.They are demonstrated in Figure 6.3.

$$\mu_B(\mathrm{x}) = \begin{cases} \frac{x-k_1}{l_1-k_1}, k_1 \le x \le l_1 \\ \frac{m_1-x}{m_1-l_1}, l_1 \le x \le m_1 \\ 0, otherwise \end{cases} \quad , \quad v_B(\mathrm{x}) = \begin{cases} \frac{l_1-x}{l_1-k_1^{'}}, k_1^{'} \le x \le l_1 \\ \frac{x-l_1}{m_1^{'}-l_1}, l_1 \le x \le m_1^{'} \\ 1, otherwise \end{cases} \tag{6.5}$$

In which $\mathrm{k}_1 < k_1^{'} < l_1 < m_1 < m_1^{'}$ and $\mu_B(\mathrm{x}), \mathrm{v}_B(x) \le 0.5$ for $\mu_B(\mathrm{x}) = \mathrm{v}_B(x) \forall \mathrm{x} \in Z$ .That TIFN can be characterised $B_{TIFN} = (\mathrm{k}_1, l_1, m_1; k_1^{'}, l_1, m_1^{'})$

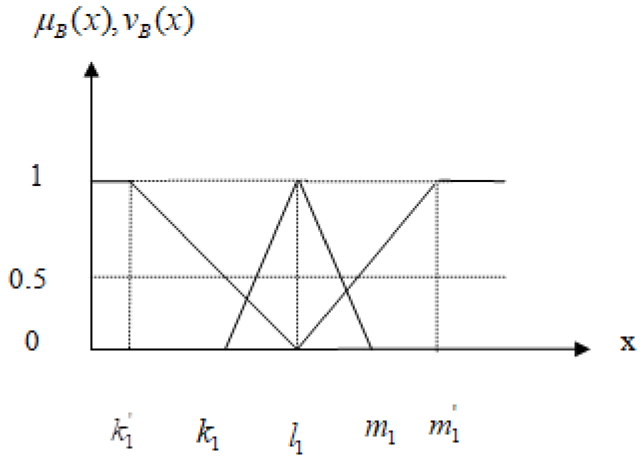

Figure 6.3: Membership and Non-membership Functions of TIFN (Shaw and Roy, 2012)

6.2.1.4. A Novel Preference Scale of Intuitionistic Fuzzy AHP

According to Abdullah and Najib (2016), a novel preference scale of IF-AHP is defined as follows:

The degree of every criterion and alternative could be explained by the AHP measure. That evaluation could be transformed into triangular intuitionistic fuzzy numbers (TIFN). This preference scale proposed by authors is based on the norm of the degree of hesitation. The transformation of the preference figure of AHP into TIFNs is described by taking the average of each AHP preference measure according to the sum of the AHP measure. The chart of transformation of consistency statements to membership degree is utilized to describe the novel preference measure of TIFNs. The necessary transactions of transformation of AHP preference number to TIFN are demonstrated in Table 6.1:

Table 6.1 : Transformation of Consistency Statement to Membership Degrees

Consistency	$\pi(x)$	$\mu''(x)$
No/very low consistency	0.8–1	0.1111–0.0
Low consistency	0.6–0.8	0.3333-0.1111
Moderate consistency	0.4-0.6	0.5555-0.3333
High consistency	0.2-0.4	0.7777-0.5555
Very high/total consistency	0-0.2	1.0000-0.7777

The equation 6.6 is utilized to calculate TIFNs:

$$\mu''(x) = \frac{x_{ij}}{m} \qquad (6.6)$$

In this equation x_{ij} denotes the measure of AHP preference number and m denotes the sum of preference scale measure.

Membership degree, non-membership degree and hesitation degree are computed by utilizing the equations 6.7, 6.8 and 6.9 respectively:

$$\mu(x) = \mu''(x)\left[1 - \mu(x)\right] \qquad (6.7)$$

$$\text{v}(x) = \left[1 - \mu''(x)\right]\left[1 - \pi(x)\right] \qquad (6.8)$$

$$\pi(x) = 1 - \mu(x) - v(x) \qquad (6.9)$$

Let x_{ij} =3 and m =9;

$$\mu''(x) = \frac{x_{ij}}{m} = \frac{3}{9} = 0.3333$$

In accordance with above chart if the value of $\mu^{n}(x)$ is 0.3333, after that the degree of hesitation is 0.6.

$$\mu(x) = \mu^{n}(x)\left[1-\mu(x)\right]$$

$$= 0.3333(1-0.6)$$
$$= 0.13,$$

$$\text{v}(x) = \left[1-\mu^{n}(x)\right]\left[1-\pi(x)\right]$$

$$= (1-0.3333)(1-0.6)$$
$$= 0.27$$

$$\pi(x) = 1-v(x)-\mu(x) \text{ and } 0 \le \pi(x) \le 1$$

$$= 1-0.27-0.13$$
$$= 0.60$$

In accordance with the computation TIFN pairwise matrix of AHP are 0.13, 0.27, 0.60 for weakly more importance scale. Other AHP numbers are similarly computed.

Table 6.2: Transformation of the AHP Preference Numbers to TIFNs

Preference on pairwise comparison	AHP preference number	Reciprocal AHP number	TIFN	Reciprocal TIFNs
Equally important (E)	1	1	(0.02, 0.18, 0.80)	(0.02, 0.18, 0.80)
Intermediate value (IV)	2	1/2	(0.06, 0.23, 0.70)	(0.23, 0.06, 0.70)
Weakly more important (WMI)	3	1/3	(0.13, 0.27, 0.60)	(0.27, 0.13, 0.60)
Intermediate value (IV)	4	1/4	(0.22, 0.28, 0.50)	(0.28, 0.22, 0.50)
Strongly more important (SMI)	5	1/5	(0.33, 0.27, 0.40)	(0.27, 0.33, 0.40)
Intermediate value (IV)	6	1/6	(0.47, 0.23, 0.30)	(0.23, 0.47, 0.30)

Very strong more important (VSMI)	7	1/7	(0.62, 0.18, 0.20)	(0.18, 0.62, 0.20)
Intermediate value (IV)	8	1/8	(0.80, 0.10, 0.10)	(0.10, 0.80, 0.10)
Extremely more important (AMI)	9	1/9	(1.0, 0, 0)	(0, 1.0, 0)

The AHP linguistic significance ratings used for pairwise comparison and the transformation of the AHP linguistic preference to TIFNs are demonstrated in Table 6.2.

In this study, intuitionistic fuzzy AHP will be used to perform pairwise comparisons of the main and sub criteria in the form of TIFN. And then this method will be used to compute the weights of the main and sub criteria.

6.2.2. The Steps of Intuitionistic Fuzzy AHP

The steps of IF-AHP method are as follows, as explained by (Abdullah and Najib , 2016)

First step is to establish hierarchical structure of MCDM problems.

For criteria and alternatives, the knowledge need to be described as fragment of MCDM problem.

Second step is to scale the binary comparative measure of the IF-AHP with the novel scale of the decision matrix of TIFNs.

DMs are requested to define grading using 'nine' AHP linguistic scale, which is from ' equally important' to 'extremely more important' regarding the considerations related to MCDM problems. The novel preference scale of AHP proposed by authors is utilized to describe the DMs' measures of each criterion and alternative. The transportation of AHP crisp number to TIFN is demonstrated in Table 6.2.

Third step is to detect the DMs' weights

Table 6.3: Linguistic Factors for the Significance of DMs

Linguistic factors	TIFN
Very important	(0.90, 0.05, 0.05)
Important	(0.75, 0.20, 0.05)
Medium	(0.50, 0.40, 0.10)
Unimportance	(0.25, 0.60, 0.15)
Very unimportance	(0.10, 0.80, 0.10)

The significance of DMs is evaluated as linguistic factors. The linguistic factors for decision makers are demonstrated in Table 6.3.

The equation 6.10 is utilized to determine the weight of a decision maker weight. It is assumed that $D=\left(\mu_k, \mathrm{v}_{k,} \pi_k\right)$ is the intuionistic fuzzy number of kth decision maker.

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\mu_k / \left(\mu_k + v_k\right)\right)\right)}{\sum_{k=1}^{t}\left(\mu_k + \pi_k\left(\mu_k / \left(\mu_k + v_k\right)\right)\right)} \tag{6.10}$$

Fourth step is to create the aggregated intuitionistic fuzzy judgment matrix based on decision maker.

Every seperate views must be integrated with the group idea to form an aggregated intuitionistic fuzzy decision matrix by implementing IFWA. It is assumed that $R^{(\mathrm{m})}=(r_{ij}^{m})_{mxn}$ intuitionistic fuzzy decision matrix of mth DM and $\lambda=\{\lambda_1,\lambda_2,...,\lambda_n\}$ denotes the whole weights of decision makers and $\sum_{m=1}^{t}\lambda=1\in[0,1]$.

$$r_{ij} = IFWA_{\lambda}(r_{ij}^{(1)}, r_{ij}^{(2)}, ..., r_{ij}^{(t)})\lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus ... \oplus \lambda_t r_{ij}^{(t)},$$

$$= \left(1-\prod_{m=1}^{t}(1-\mu_{ij}^{(m)})^{\lambda m}, \prod_{m=1}^{t}\left((v_{ij}^{(\mathrm{m})})^{\lambda_m}\right), \prod_{m=1}^{t}(1-\mu_{ij}^{(m)}) - \prod_{m=1}^{t}\left((v_{ij}^{(\mathrm{m})})^{\lambda_m}\right)\right), \tag{6.11}$$

in which

$r_{ij} = (\mu_{ij}, v_{ij}, \pi_{ij})$, $\pi_{ij} = \left(\prod_{m=1}^{t} (1-\mu_{ij}^{(m)}) - \prod_{m=1}^{t} (v_{ij}^{(m)})^{\lambda_m} \right)$, $v_{ij} = \prod_{m=1}^{t} \left((v_{ij}^{(\mathrm{m})})^{\lambda_m} \right)$

$$\pi_{ij} = \left(\prod_{m=1}^{t} (1-\mu_{ij}^{(m)}) - \prod_{m=1}^{t} (v_{ij}^{(m)})^{\lambda_m} \right).$$

Fifth step is to compute the consistency ratio of the aggregated intuitionistic fuzzy judgement matrix.

The consistency ratio could be computed by equation 6.12:

$$C.R = \frac{((\lambda_{\max} - n)/(n-1))}{R.I} \tag{6.12}$$

in which it is supposed that ($\lambda_{\max} - n$) is the mean valuation of hesitation degree ($\pi(x)$) of the criteria and n denotes the dimension of matrix in the study. The valuation of random indices (RI) is demonstrated on Table 6.4.

Table 6.4 : Random Indices of Sizes of Matrices

n	1-2	3	4	5	6	7	8	9
RI	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

CR can be accepted if it does not pass 0,10. If CR is bigger than 0.10, the judgment matrix must be evaluated as unstable. To make sure that consistency is achieved, the judgment matrix must be rearranged.

Sixth step is to compute the intuitionistic fuzzy weight of the aggregated intuitionistic fuzzy judgement matrix.

The equation 7.13 is used to calculate the entropy weights of each aggregated value of each criterion.

$$\overset{=}{w_i} = -\frac{1}{n \ln 2} \left[\mu_i \ln \mu_i + v_i \ln v_i - (1-\pi_i) \ln(1-\pi_i) - \pi_i \ln 2 \right] \tag{6.13}$$

Here if $\mu_i = 0, v_i = 0, \pi_i = 1$, then $\mu_i \ln \mu_i = 0, v_i \ln v_i = 0, (1-\pi_i) \ln(1-\pi_i) = 0$.

and if $\mu_i = 1, v_i = 0, \pi_i = 0$ then $\mu_i \ln \mu_i = 0, v_i \ln v_i = 0, (1-\pi_i)\ln(1-\pi_i) = 0$.

Final entropy weights of every criteria could be calculated by using the following equation.

$$w_i = \frac{1 - \overset{=}{w}_i}{n - \sum_{j=1}^{n} \overset{=}{w}_i} \tag{6.14}$$

where $\sum_i^n w_i = 1$

6.3. PROMETHEE method

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is a multiple decision making method developed by Jean-Pierre Brans in 1982.

After PROMETHEE I and PROMETHEE II methods were introduced in 1982, various PROMETHEE methods were introduced. A few years later, PROMETHEE III and PROMETHEE IV methods were developed by Brans and Mareschal. In 1988, the so-called GAIA method, which supports the PROMETHEE method with graphical presentations, was introduced. In 1992 and 1994, PROMETHEE V and PROMETHEE VI methods were developed (Brans and Mareschal, 2004).

There are various suitable MCDM models utilized in varied conditions in the literature (Anand and Kodali, 2008). MCDM methods used in supplier selection can rank alternatives from best to worst which are based on multiple criteria. However, PROMETHEE is accepted as a quite practical and easy method to apply outranking method. It is a method that enables to sort alternatives that are evaluated by taking contradictory criteria into consideration (Ömürbek et al., 2014).

According to Şenkayas and Hekimoğlu (2013), PROMETHEE method which considers the alternatives according to different criteria by making pairwise comparisons is conceptually and practically easier than many other decision making techniques.

However, PROMETHEE is a method based on superiority. Then, it is a method that apply a non-compensating decision rule, can express the decision maker's preferences in a very flexible way and can take qualitative criteria into consideration. The PROMETHEE technique was initially applied to the supplier selection problem by Dulmin and Mininno

(2003). The PROMETHEE method allows the researcher to select suppliers even with little knowledge (Özdemir, 2007)

The order of the alternatives is determined by utilizing PROMETHEE II in the study. The PROMETHEE method is based on pairwise comparisons according to the evaluation factors of alternatives. The main difference of PROMETHEE that seperates from other MCDM methods is that evaluating the significance weights of the evaluation factors between each other and the internal relationship of each evaluation factor. 6 different functions are used in PROMETHEE and PROMETHEE method has 7 steps.

The steps of the model are expressed by Şenkayas and Hekimoğlu (2013).

First step is to create the data matrix. The data matrix is constructed by weights and alternatives which are evaluated by criteria as shown in Table 6.5:

Table 6.5: Data Matrix

Criteria	a	b	c	w
f_1	$f_1(a)$	$f_1(\text{b})$	$f_1(\text{c})$	w_1
f_2	$f_2(\text{a})$	$f_2(\text{b})$	$f_2(\text{c})$	w_2
…	…	…	…	…
f_k	$f_k(\text{a})$	$f_k(\text{b})$	$f_k(\text{c})$	w_k

Second step is to define preference functions for criteria. The preference functions are determined to show the structure and internal relations of the identified evaluation factors. There are six types of preference functions. The preference functions are shown in Table 6.6. This operation is carried out by utilizing the following six preference functions :

Table 6.6: Preference Functions

Type	Parameter	Function
First Type (Usual)	-	$p(x) = \begin{cases} 0, \forall x \leq 0 \\ 1, \forall x > 0 \end{cases}$

Second Type (U-Shape)	m	$p(x)=\begin{cases}0, x \le m\\ 1, x > m\end{cases}$
Third Type (V-Shape)	k	$p(x)=\begin{cases}\frac{x}{k}, x \le k\\ 1, x > k\end{cases}$
Fourth Type (Level)	a,b	$p(x)=\begin{cases}0, x \le a\\ \frac{1}{2}, a < x \le a+b\\ 1, x > a+b\end{cases}$
Fifth Type (Linear)	c,d	$p(x)=\begin{cases}0, x \le c\\ \frac{x-c}{d}, c < x \le c+d\\ 1, x > c+d\end{cases}$
Sixth Type (Gaussian)	σ	$p(x)=\begin{cases}0, x \le 0\\ 1-e^{-\frac{x^2}{2\sigma^2}}, x > 0\end{cases}$

Third step is to determine the common preference functions for the pair of alternatives based on preference functions. The calculation of common preference function and for any a and b alternatives is demonstrated in equation 6.15. The schematic representation of common preference function is demonstrated in Figure 6.4.

$$P(a,b) = \begin{cases} 0 & , f(a) \le f(b) \\ p\left[f(a)-f(b)\right] & , f(a) > f(b) \end{cases} \qquad (6.15)$$

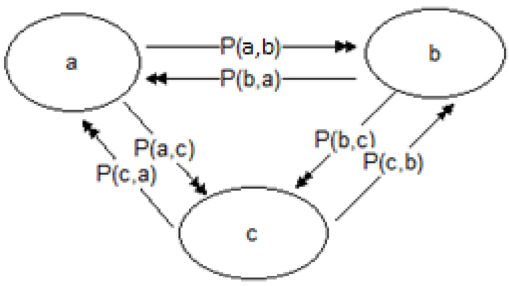

Figure 6.4: Schematic Representation of the Associate Preference Function

Fourth step is to determine preference index. The preference index for every pair of alternatives is determined. The calculation of preference index for any a and b alternatives evaluated by k criterion is done by using the equation 6.16. The

$$\pi(a,b)=\frac{\sum_{i=1}^{k}W_i * P_i(a,b)}{\sum_{i=1}^{k}W_i} \tag{6.16}$$

Fifth step is to determine positive (ϕ^+) and negative (ϕ^-) superiorities for alternatives. The positive and negative priorities for any a alternative could be computed by utilizing equation 6.17 and 6.18 respectively.

$$\phi^+(a)=\frac{1}{n-1}\sum_{i=1}^{n}\pi(a,b) \tag{6.17}$$

$$\phi^-(a)=\frac{1}{n-1}\sum_{i=1}^{n}\pi(\mathrm{b},\mathrm{a}) \tag{6.18}$$

The schematic representation of the positive and negative priorities for any alternative is demonstrated in Figure 6.5.

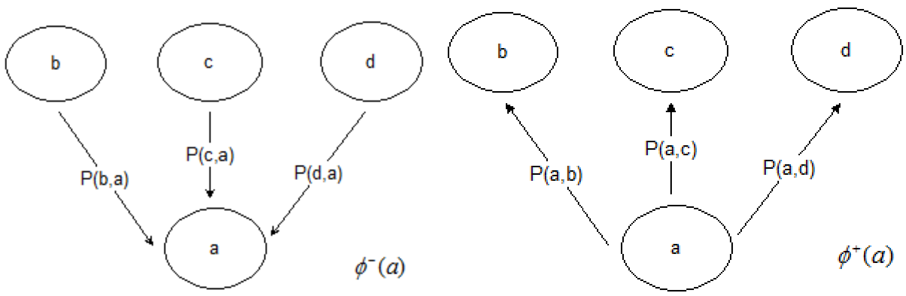

Figure 6.5: The Schematic Representation of the Positive and Negative Priorities

Sixth step is to determine relative priorities of alternatives with PROMETHEE I. The following conditions are valid for any a and b alternatives to determine relative priorities.

First condition: If one of the following conditions are valid, alternative a is preferred over alternative b.

$$\phi^+(\mathrm{a})>\phi^+(b) \quad \text{and} \quad \phi^-(\mathrm{a})<\phi^-(b) \tag{6.19}$$

$$\phi^+(\mathrm{a})>\phi^+(b) \quad \text{and} \quad \phi^-(\mathrm{a})=\phi^-(b) \tag{6.20}$$

$$\phi^{+}(\mathrm{a}) = \phi^{+}(b) \quad \text{and} \quad \phi^{-}(\mathrm{a}) < \phi^{-}(b) \tag{6.21}$$

Second condition: If the following condition is valid, alternative a and b are the same.

$$\phi^{+}(\mathrm{a}) = \phi^{+}(b) \quad \text{and} \quad \phi^{-}(\mathrm{a}) = \phi^{-}(b) \tag{6.22}$$

Third condition: If one of the following condition is valid, alternative a and b can not be compared.

$$\phi^{+}(\mathrm{a}) > \phi^{+}(b) \quad \text{and} \quad \phi^{-}(\mathrm{a}) > \phi^{-}(b) \tag{6.23}$$

$$\phi^{+}(\mathrm{a}) < \phi^{+}(b) \quad \text{and} \quad \phi^{-}(\mathrm{a}) < \phi^{-}(b) \tag{6.24}$$

Seventh step is to determine complete priorities of alternatives with PROMETHEE II. Complete priority of every alternative is calculated by equation 6.25. After calculating the complete priority values the alternatives can be ranked on the same ground.

$$\phi(a) = \phi^{+}(\mathrm{a}) - \phi^{-}(\mathrm{a}) \tag{6.25}$$

If $\phi(a) > \phi(\mathrm{b})$ alternative a is more superior (6.26)

If $\phi(a) = \phi(\mathrm{b})$ alternative a and b are the same. (6.27)

7. AN APPLICATION IN AIR FILTRATION SECTOR

An application in HEPA filter manufacturing corporation established in Ümraniye, İstanbul was carried out for the demonstration of the steps of the proposed method. The required investigations were done in the HEPA filtration manufacturing factory.

Firstly, identification of problem is carried out. After determination of alternatives and criteria, the application began with the pairwise comparison of the main criteria and sub criteria previously determined. Then, compromise evaluation among decision makers is provided to do a single ranking of suppliers and to avoid confusion. The stage of scaling of pairwise comparison of the main and subcriteria was carried out by considering compromise evaluation. Afterwards, the entropy weights of sub and main criteria are calculated. At the final step, five alternative suppliers are ranked by PROMETHEE II.

The implementation of the two methods are explained in detail as follows.

7.1. Identification of the Problem

The problem for this research is; the determination of environmental and traditional supplier selection criteria and the selection of the best environmentally conscious supplier according to determined criteria. Material examined in the study is HEPA filter media inside the HEPA filters that prevents passage of particulate matter.

7.2. Determination of Decision Maker

In this study, compromise evaluation among decision makers is ensured to do a single ranking of suppliers and to avoid complexity. However, the industrial engineers and managers of purchasing, production and quality departments are interviewed to gather necessary data for determination of supplier selection criteria and the alternatives.

7.3. Determination of Alternatives and Criteria

As understood from studies in the literature, determination of supplier criteria plays an important role in supplier selection process. Using appropriate criteria to choose suppliers can enhance the efficiency of the purchasing operation and guide executives to evaluate more broad portfolio of alternatives (Grisi et al., 2010). As companies evaluate the performance of the supplier, they have traditionally identified the criteria as price, quality, delivery and do not attach much importance to environmental criteria (Shen et al., 2013). However, as mentioned previously, selecting the supplier considering the environmental criteria will increase the yield and the success of the whole SC and which makes the company more advantageous as it meets the growing environmental customer expectation in the competitive market.

The whole of the traditional and green supplier selection criteria considering air filtration media industry were obtained from different research fields such as the literature of green supplier selection, the ideas of experts and decision makers, reference books, journals, related systems and so forth. However, purchasing, production engineering and quality departments' opinions were taken with supplier selection criteria determined for the material to be worked on in the study. Then, former researches in green supplier selection field were considered and then both traditional and environmental criteria were collected in this study.

Five main criteria were determined to choose the most environmentally conscious supplier in this study. The main criteria price, quality, delivery, flexibility and greenness. First main criterion is quality. The quality has different subjective definitions. However, the comprehensive quality definition is that the capability of a product or service of the supplier to fulfill the anticipation of the customer (Holjevac, 2008). Rejection rate of the supplier is also an indicator of the quality of the supplier. The second main one is price. The price criterion is one of the most crucial criteria. The amount of profit obtained is directly related to the price criterion. The third main criterion is delivery. Delivery criterion is used to determine the supplier's delivery performance. On time delivery and lead time are important indicators of delivery perfomance. The fourth main criterion is flexibility. The last one is greenness. Greenness criterion is utilized to assess whether suppliers' environmental performance satisfies the norms of the corporation (Yu and Hou, 2016).

Afterwards, the greenness criteria is seperated into five sub-criteria. The sub-criteria are recyclability of raw material, transportation, design for dissassembly and resuse, research and development and image. The main and sub criteria is expressed in the next sections. The structure of criteria is shown in Figure 7.1.

Five HEPA filter media suppliers were determined but suppliers' names were not disclosed due to the confidentiality and privacy policy of the companies.

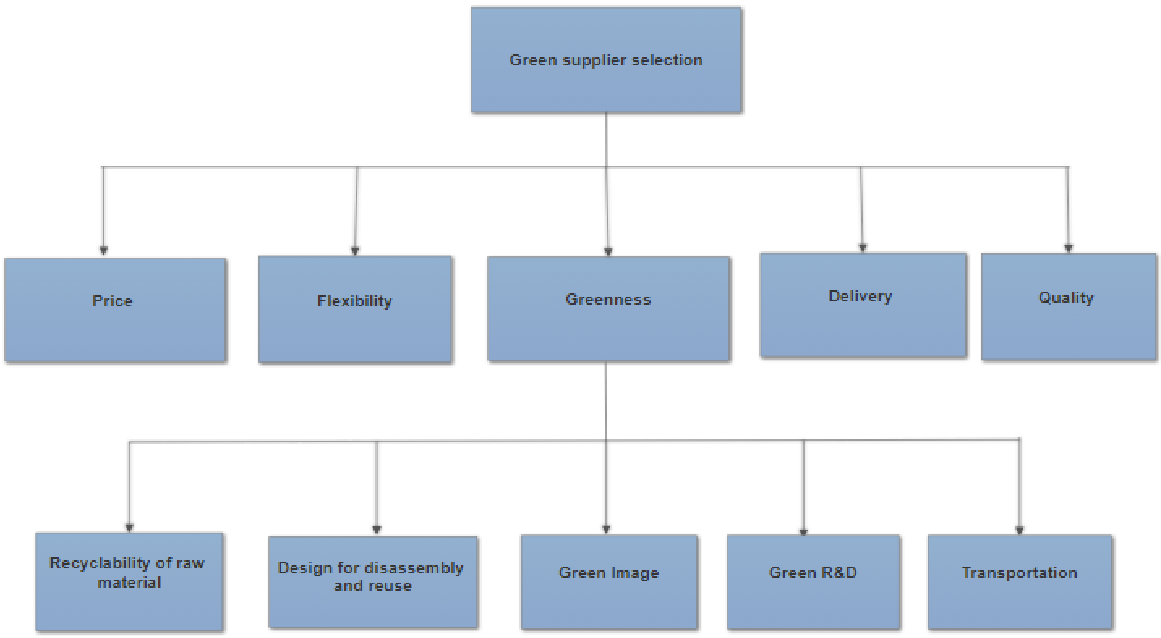

Figure 7.1 : Main and Sub Criteria in the Study

7.3.1. Main Criteria

7.3.1.1. Quality

Evaluation of quality as one of the fundamental factors in supplier selection process is quite significant (Abdolshah, 2013). However, the quality of product is a major element affecting the supplier's rivalry in the market and it has a direct great impact on firms' prestige.

(Yu and Hou, 2016 ; Kuo and Lin, 2012). There are some different definitions for quality in literature. In accordance with Holjevac there are three different definitions for quality. First one is that quality expresses the capability of a product or service to continuously fulfill or surpass the anticipations of customer. The second one is that quality means taking what the buyer paid for. The third one is that quality should not be considered as a private and independent property; instead, it should be considered as an unchangeable fragment of a service and product (Holjevac, 2008). Comprehending the concept of quality and the significance of customer pleasure are so crucial for a corporation (Alfredson and Christenson, 2014).

There are a number of ingredients that reveal the quality of the companies. Quality certificate, product rejection rate, product quality are these ingredients. It is an important quality indicator for the buyer that the supplier has a reliable image with a good quality product or service and that the supplier's required certificates and procedures are fulfilled. In accordance with a questionnaire conducted in the UK, 60% of ISO certified corporations relied on that suppliers which is certified to the ISO 9000 series operated better than those without certification. Corporations generally request that their suppliers should have a certificated quality management system. (Alfredson and Christenson, 2014)

Evaluation of quality is carried out by measuring rejected rates. The number of unsuitable parts divided by the sum of the pieces supplied is equal to the rejection rate. That ratio need to be maintained at a particular grade which is acceptable and permissible to a customer. (Alfredson and Christenson, 2014) The rejection rate also provides a clue to the quality of the product.

Rejection rate= Unsuitable Parts/Total quantity of delivered products (Alfredson and Christenson, 2014)

7.3.1.2. Price

In the previous studies, the most commonly used traditional criteria amongst authors are quality, price, delivery. The price criterion is more prominent than the quality and delivery criteria. A large number of researches that consider traditional criteria have stressed price criteria as the fundamental anxiety of the organizations (Hashemi et al., 2015). Price could both demonstrate the competitive capacity of suppliers and it is one of the fundamental factors of supplier selection (Yu and Hou, 2016).

It is clear that each firm in the supply chain often endeavours to maximize profit. Furthermore, the price of the raw materials and components has a major effect on the whole cost of the organization. Therefore, 'price' can be considered as the most crucial determinant in supplier selection and assessment. In accordance with implication of the recent studies, price is the major criterion that the industries consider (Molamohamadi et al., 2013).

However, each corporation looks for the highest probable quality with the lowest probable price (Alfredson and Christenson, 2014). Thus, it can be considered as the most significant criterion for many companies to choose suppliers.

It is generally considered to be an inverse proportion between quality and price. There is the perception that it is difficult to supply high quality products with low price. In addition, the price has an important prerequisite to gain competitive superiority in the marketplace. The clients intend to purchase qualified commodities from purchasable prices. For this reason, the corporations need to select suppliers that provide the lowest cost to protect their position on the competitive market (Dağ and Kabadayı, 2015).

However, choosing a supplier only considering the price brings with it quality problems. While entering products with low quality to the market, suppliers that offer high quality products stay out of the market because of high price (Alfredson and Christenson, 2014). In this case the relationship between the vendor and the customer is affected in the negative direction.

7.3.1.3. Delivery

On time delivery, lead time, distance of a supplier and supplier’s geographical position are the most important factors affecting the delivery criterion. It is very important that the supplier’s precision to delivery and that the ability of supplier to meet the buyer's expectations of lead time (Alfredson and Christenson, 2014). However, the distance between supplier and buyer determines the supplier’s delivery periods. These ingredients of delivery are important for a corporation in supplier selection process.

On time delivery demonstrates the delivery precision of the supplier. They actually mean the same thing. The delivery precision is equal to the orders delivered in time divided by the total delivery orders. Delivery of the correct quantity at the right time also demonstrates the supplier's delivery precision. Lead time refers to the time from order to delivery. (Alfredson and Christenson, 2014).

Delivery precision, On time delivery = Orders delivered in time/ Total delivered orders (Alfredson and Christenson, 2014).

However, on time delivery and lead time are interdependent. Provided that a supplier delivers in short time, the commodities could be distributed constantly and if a problem carry out on delivery, the buyer can be resilient owing to short-lead times. That is why on short-term deliveries, on-time delivery is not as important as short-lead time owing to the resilience parameter. But the supplier is away, on time delivery is even more important. Because it can be difficult for the buyer to be resilient because of long-lead time (Alfredson and Christenson, 2014).

7.3.1.4. Flexibility

Flexibility in production; is a system that is developed in order to be able to respond with a flexible supply in the market and has the ability to produce with a lot of variety and low cost. This system produces products that are similar in design and production characteristics to small or medium-sized parties, allowing rapid changes in product in face of market developments (Türkan, 2010). Working with a supplier that provides flexibility in production allows the firm to quickly adapt to the volatility in the market. Thanks to that, demanded quantities from supplier can be expanded to increase or decrease. This also allows the supplier to supply the product in the desired volume and capacity. However, volume flexibility enables the production area to be used more efficiently.

7.3.1.5. Greenness

The environmental productivity of an organization's supply chain could be evaluated by its own environmental endeavour and its suppliers' environmental productivity. In this regard, cooperating with suppliers on environmental topics contributes to develop the environmental productivity of this organization. For green production and relevant operations, organizations have to set their SCs green and collaborate with suppliers and partners which are environmentally conscious (Akman, 2015).

As known in recent years public awareness and sensibility on environmental events have increased because of global environmental problems such as global warming. Especially, carbon dioxide (CO_2) is a considerable green house gas that spreads owing to social and industrial actions and could induce sudden climate change. However, with the world population exceeding seven billion, if necessary precautions are not taken, those threats can not be avoided. Solid waste pollution, emission of harmful gases to human health and inadequacy of raw materials are other important environmental problems. Together with growing environmental awareness, a large number of researchers are examining the problems of supplier selection with respect to environmental aspects (Hashemi et al., 2015).

The statement declared in 2014 indicates “harmful emissions are probably reason of an increase in global mean temperature of 1.5◦C above pre-industrial levels”. However, “global CO_2 emissions have risen by more than 80% since 1990, and the data shows that 75% of CO_2 emissions for 60% of companies are from supply chain activities and 81% of these emissions are generated from the first level supplier” (Govindan and Sivakumar, 2016).

However, it is declared by another institute that the entire SC activities are the main reason of at least 80% of the carbon emissions. Thus, the firms have started to realize the carbon emission as one of the crucial issues in SCM (Hsu et al., 2013). Fossil fuels are one of the most crucial determinants that increase considerably carbon emissions. In particular, fossil fuels are widely used in the transportation sector. Environmentally conscious firms are trying to use sustainable energy sources instead of fossil fuels in recent years.

The firms are aiming to decrease the emissions of hazardous gases in supply chain activities and to reduce global emissions by applying carbon dealing mechanisms thanks to their green research and development activities. A large number of firms in developed territories have begun to apply low-carbon supply chain to remain live in worldwide market (Govindan and Sivakumar, 2016). The probability can carry out that the supplier may give up their operations with the purchasers in the future because of uncontrolled hazardous gases such as carbondioxide, ozone and so on (Shaw et al., 2012).

The growing sensitivity to environmental events by the public and government has also affected the companies' capability of import and export. In accordance with the environmentally-conscious countries, the producers need to comply with environmental conditions to become more advantageous in the global market. A number of developed countries forced the producers to abide by environmental standards. For example, the European Union has forced importers to comply with environmental standards, to vary their working procedures and to buy substances with less impact on the environment. Thus, with the due to environmental arrangements and the growing environmental mindfulness, the producers are bound to find out an alternative to change the harmful material provided that they desire to export their goods to the regions which are environmental concious (Lee et al., 2009).

Notwithstanding, large and medium-sized companies in all industries are searching for development and betterment in the process of procurement of raw materials, production, distribution, transportaion yield, delivery, storage and product destruction with the aim of fulfilling environmental targets and decreasing cost (Kannan et al., 2015). Hence, green research and development need to be vital part of an organization to achieve environmental objectives.

Recyclability of raw material, type of energy used by supplier in transportation, green image of the supplier, the available design of the product supplied for reusability and disassembly and the investment and commitment of the supplier to the green research and development department are important sub-criteria that give an idea of the supplier's greenness.

7.3.2. Sub Criteria

7.3.2.1. Recyclability of Raw Material

Providing raw materials from suppliers is a prevalent application for companies which are unable to meet demand due to capability or quality constraints (Govindan and Sivakumar, 2016). However, it is also a practice for producing environmentally friendly matter and moveover, the land utilized in the garbage fields could be saved (Gurel et al., 2015).

Harmful materials included in raw materials which are procured by suppliers could induce important environmental effect in SC (Kuo et al., 2010). However, hazardous gases emission such as carbon dioxide may increase during the process of extraction of raw material, re-processing and process of preparation for customers. Yet the recyclability of the raw material ensures that emission of hazardous gases and wastes being generated from processing the raw material can be prevented. Thus, the selection of the available supplier whose raw material can be recycled has gained environmental importance. However, the capability of recycling of raw materials demonstrate recycling ratio of products and it shows the supplier's sensitivity for protection of the environment (Yu and Hou, 2016).

Recycling is the transformation of waste into new materials and objects. Recycling which protects material and helps to reduce greenhouse gas emissions and it is an alternative to "traditional" waste extermination. It can obstruct potentially beneficial materials from being wasted and decrease the consumption of new raw materials, thus decreasing energy use, air pollution after firing and water pollution because of storage uptake (Url-18).

In accordance with the recent studies in the literature, pollution carried out from raw material processing contributes to air pollution seriously. And this process could be one of the serious threats to air pollution and human health in near future. However, useable raw material shortage could also carry out. Therefore, the use of recyclable raw materials is an important criterion for green supplier selection.

7.3.2.2.Transportation

Distribution and transportation processes are one of the most basic reasons of hazardous gas emissions and particulate matters in the SC (Paksoy et al., 2011). While presenting operational and economic advantages to transport materials, components and end products, there are also numerous direct environmental implications (Paquette, 2005) :

- Harmful emissions which occur from air, sea, land and rail transportation system affect the standards of air and water.
- Energy is used up in fueling freight and institutions dedicated to warehousing and logistics operations
- Transporting products and commodities in vehicles increases the size and number of vehicles. Their presence affects land utilization and residents, in addition traffic jam and noise.
- In addition, packaging is generated to ease transportation but it also produces waste (Paquette, 2005)

Transportation sector is one of the most energy-consuming sectors since it provides ninety five percent of energy from petrol. Petrol and derivatives are fossil fuel which emits hazardous gases such as carbon dioxide, hydrocarbons and nitrogen oxides (Url-19). The gases that emerge especially from fossil fuels nowadays cause serious damage to the environment. In countries with large populations, much of the air pollution is caused by toxic gases emitted from vehicles. However, causing acid rain, increasing the rate of carbon dioxide in the air and creating climate change are amongst the major environmental hazards caused by fossil fuels (Url-20). These gases are also among the main causes of global warming and ozone depletion.

Road transport is the most prevalent type of transport system and approximately seventy percent of freight transport is done by road transport (Url-21). Other types of transportation (air transportation, railway transportation) are the types of transportation that are commonly used for companies importing and exporting offshore.

The selection of vehicles that use environmentally friendly fuels will also significantly reduce environmental pollution. Companies have to prefer vehicles that use natural energy sources such as electricity and LPG systems instead of vehicles that use fossil fuels. Electric cars and planes, solar powered ships, magnetic rail and magnetic trains have to be preferred.

Environmentally conscious corporations that prefer railway transportation to road transport not only protect environment but also provide economic profitability. However, the widespread utilization of the internet can provide environmental benefits by eliminating the need for versatile distribution centers and retailers, and can lead to the occurence of different distribution activities (Polonsky, 2005).

Environmental transportation practices also help to reduce costs in logistics activities. It should be kept away from product shipments made in small batches and frequent intervals. Planning and arrangements should be made by companies for the transport of products in large batches. Utilization of noise and sound interception equipments in vehicles can prevent noise pollution (Korkankorkmaz, 2012).

However, many different vehicles are used in road transport. There are certain weight limits for domestic and international goods transport of these vehicles and they are regulated by law. Vehicles that exceed these limits are danger to both man, vehicle, property and nature.

Another measure to reduce hazardous emissions from vehicles is the utilization of filter. The exhaust contains densely carbon monoxide, nitrogen oxides, hydrocarbons and lead. The exhaust filter is the filter used to reduce exhaust emissions in the vehicles. The exhaust filter allows the particulates in the exhaust gas to be filtered and the exhaust emission to be reduced. Since these exhaust filters are frequently used over time, they are quickly filled with smut, oil and metallic parts. When the filter is contaminated, these filters need to be cleaned regularly.

However, the catalytic converter is an important filter type for vehicles that use gasoline. It greatly impedes the emission of hazardous gases into the air (url-22). Other measures that can be taken include not putting too much load on the vehicles, making the maintenance and repair of the vehicles on time and using clean fuel. Vehicles that do not pay attention to these measures consume too much fuel, and therefore more harmful gas causes emissions carry out.

7.3.2.3. Design for Disassembly and Reuse

Reuse of a product is the expansion of its life span with little or no improvement. Re-use may also be expressed as using the product for a second or more time. No novel value is added to the product (Kumar et al., 2017).

Design for disassembly is the operation to design products thus the products could be handily, cost-effectively and swiftly dismantled at the end of lifespan of product so that ingredients could be reused or recycled (Url-23). However, the design of the product, the number of assemblies of the product, the demounting capability of the product and reusability of fragments demonstrate the importance that the supplier attached to the disassembly design.

However, reusing and recycling become a much greater obligation than a great opinion with the increasing demand for the goods and the reduced storage space. By enabling product parts to be reused, corporations could reduce production costs, reduce waste and storage space and materials and improve their quality management. A company that can disassemble and reuse its own parts is not only advantageous for the future, but is more advantageous with the other green design initiatives than others who do not evaluate such changes in the industry (Url- 24).

7.3.2.4. Green Image

Under market and regulatory pressures, producers realized the importance of developing of corporation’s green image (Zhu et al., 2007). However, the corporation’s green image comes out the sensibility of the company on the environmental issues. Along increasing environmental awareness, a large number of customer prefer to purchase products of firms which take environmental issues into account.

Some topics have considerable impact on green image of the company such as attendance and support of the supplier to environmental projects, proportion of green customers and environmental education for employees, the amount of received penalties.

Taking responsibility in environmental studies affects the company's green image positively. Environmentally conscious companies often engage in projects related to waste management, energy conservation, efficiency, education, sustainable energy to protect nature.

Some sensitive companies have also developed a number of projects which aimed at students and children, to make them more conscious consumers and to promote austerity awareness. Due to these projects, carbon emissions can be reduced, austerity can be increased, and significant ideas in recycling and waste management can be reached. All these studies also strengthen the company's green image.

Environmental education of employees suggests green image of the company. Therefore each employee's perspective on environmental events is important for the company's green image. It is evident that environmental problems influence everyone in facilities without discrimating white collar or blue collar employees. Also training employees on environmental issues in facilities does not only provide that the employees feel themselves as a part of the corporation but also they try to be more frugal and more sensitive in facilities. It should be that an employee who is aware of environmental events and austerity he or she could be more sensitive in wasting and austerity such as reducing waste, energy usage, etc. (Erten, 2006). In this respect, environmental consulting firms may be asked to provide employees with informative training in environmental issues and to organize incentive activities.

However, the fact that the number of customers who are environmentally conscious is also an indicator of whether supplier is sensitive on environmental subjects or not. Green products which are manufactured by suppliers need to satisfy green customers and thanks to this satisfaction green fidelity is obtained. Green satisfaction has a considerable effect to obtain fidelity of customer (Asgharian et al.,2012).

The fewness of penalties stemming from the supplier's failure to comply with regulations and legislations and the green image of the supplier's partners in the SC also improve the purchaser's green image.

7.3.2.5. Green Research and Development

In today's business world, as the number of companies contesting on the development of environmental supply chain capabilities went up , the need of developing green suppliers became obligation. Against the dangerous environmental impact, organizations have been compelled to improve environmental topics, for instance reducing the harmful impacts of products, manufacture and logistics operation (Akman G., 2015).

The importance given by a company to the green development of research could be understood by the capital it has reserved for it. The decisions about research and development are made in a long time and it is a multi-factorial process. Many worldwide big companies utilize a considerable portion of their investments in research and development activities to become more innovative and environmentally friendly.

Table 7.1 : Green Product Samples (Özesen, 2009)

Product group	Classic product	Green product	Environmental performance
Lighting	Incandescent light bulb	Fluorescent light bulb	Less energy use
Paper	100% pure paper	50% (post-consumer)	Reducing the use of natural resources
Copy paper	Chlorinated paper	Chlorine-free paper	Decrease in toxic gas emissions

As can be seen from Table 7.1, the green developments on the product significantly increase the environmental performance of the product.

A large number of companies have made environmental improvements in their products through green research and development activities. To give examples, Vitra announces that the batteries in new wash basins save up to 80% of water and energy. The dishwasher produced by Arçelik uses only 9 liters of water and Arçelik produces refrigerators that do not use chlorofluorocarbons (CFCs) that damage the ozone layer. AEG-Electrolux has a dishwasher that consumes water and electricity according to the amount of dishwashing and energy-saving refrigerators. Nokia's new mobile phones have a system that warns the charger to be unplugged when the battery is full. McDonald's uses paper packages instead of plastic packages (Özesen, 2009).

Green improvements in products provide cost and energy savings in many areas. Dell company saves more than $ 20 million annually from supply chain and packaging improvements. Texas Instruments saves $ 8 million each year through the use of resource reduction, recycling, and reusable packaging systems in semiconductor operation. Yeşim Tekstil saves $ 1 million per year from waste water conversion. Banvit transforms 230 tons of organic waste into product per day. Tetra Pak provides 5% energy efficiency and 15% water efficiency. Garanti Bank used less PVC in its construction of the card in its Environmentally ConsciousBonus Card project. The material of this card is also produced from recycled paper (Url-7).

LG group promised to utilize 18 billion dolar in green research and development studies. The half of investment was utilized to manufacture product which consists of fewer components, is more energy efficient and can be recycled. Another half of investment is evaluated to establish plants and institutions to reduce the amount of greenhouse gases emission up to 50 million metric tons per year until 2020 (Url-25). Due to austerity in energy consumption trillions of dollars can be saved for big companies. As can be seen from examples it is evident that green research and development is a considerable criterion to protect the environment, to save energy and reduce costs.

7.4. Hierarchical Structure of the Problem

The hierarchical diagram of supplier selection problem is demonstrated in Fig.7.2. The purpose of the problem is indicated at first, afterwards knowledge about sub and main criteria and alternatives are identified on the diagram.

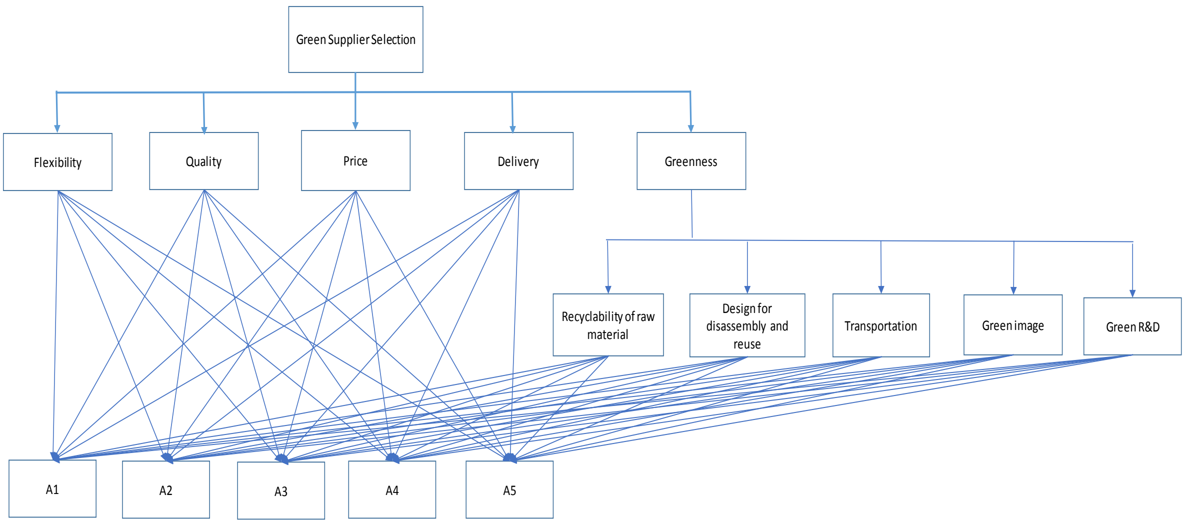

Figure 7.2: The Hierarchical Diagram for Green Supplier Selection

7.5. IF-AHP

The study starts with the pairwise comparison of main criteria in TIFNs is shown in Table 7.2, in accordance with the compromise assesment of decision makers.

Table 7.2: Pairwise Comparison of The Main Criteria in TIFNs

Main criteria	Quality	Delivery	Price	Grenness	Flexibility

Quality	(0.02,0.18, 0.80)	(0.13,0.27, 0,60)	(1.0,0,0)	(0.33,0.27, 0.40)	(0.62,0.18, 0.20)
Delivery	(0.27, 0.13 0,60)	(0.02,0.18, 0.80)	(1.0,0,0)	(0.13,0.27, 0,60)	(0.33,0.27, 0.40)
Price	(0,1.0,0)	(0,1.0,0)	(0.02,0.18, 0.80)	(0.28,0.22, 0.50)	(0.27, 0.13 0,60)
Greenness	(0.27, 0.33 0.40)	(0.27, 0.13 0,60)	(0.22,0.28, 0.50)	(0.02,0.18, 0.80)	(0.13,0.27, 0,60)
Flexibility	(0.18,0.62 0.20)	(0.27, 0.33 0.40)	(0.13,0.27, 0,60)	(0.27, 0.13 0,60)	(0.02,0.18, 0.80)

In this study, at the stage of calculation of decision maker weight, the compromise evaluation among decision makers is regarded as single decision maker's view. In this case, the weight of decision maker is regarded as 1.0.

Then, the aggregated intuitionistic fuzzy judgement matrix is constructed based on the weight of compromise evaluation. Equation (6.11) is utilized to aggregate the whole of transformation of the intuitionistic fuzzy decision matrix of the main criteria. Table 7.3 demonstrates the aggregated matrix of main criteria.

For example, aggregated matrix of greenness criteria is calculated as follows:

$$= \begin{bmatrix} 1-\prod((1-0.27)^{1.0}\times(1-0.27)^{1.0}\times(1-0.22)^{1.0}\times(1-0.02)^{1.0}\times(1-0.13)^{1.0}) \\ ,\prod((0.33)^{1.0}\times(0.13)^{1.0}\times(0.28)^{1.0}\times(0.18)^{1.0}\times(0.27)^{1.0}) \\ ,\prod((1-0.27)^{1.0}\times(1-0.22)^{1.0}\times(1-0.02)^{1.0}\times(1-0.13)^{1.0}) \\ -\prod((0.33)^{1.0}\times(0.13)^{1.0}\times(0.28)^{1.0}\times(0.18)^{1.0}\times(0.27)^{1.0}) \end{bmatrix}$$

= (0.65,0.001,0.349)

Table 7.3: Aggregated Matrix of Main Criteria in TIFNs

Main criteria	Quality	Delivery	Price	Grenness	Flexibility	Aggregated Matrix
Quality	(0.02,0.18, 0.80)	(0.13,0.27, 0,60)	(1.0,0,0)	(0.33,0.27, 0.40)	(0.62,0.18, 0.20)	(1.0,0,0)

Delivery	(0.27, 0.13 0,60)	(0.02,0.18, 0.80)	(1.0,0,0)	(0.13,0.27, 0,60)	(0.33,0.27, 0.40)	(1.0,0,0)
Price	(0,1.0,0)	(0,1.0,0)	(0.02,0.18, 0.80)	(0.28,0.22, 0.50)	(0.27, 0.13 0,60)	(0.49, 0.005,0.505)
Greenness	(0.27, 0.33 0.40)	(0.27, 0.13 0,60)	(0.22,0.28, 0.50)	(0.02,0.18, 0.80)	(0.13,0.27, 0,60)	(0.65, 0.001,0.349)
Flexibility	(0.18,0.62 0.20)	(0.27, 0.33 0.40)	(0.13,0.27, 0,60)	(0.27, 0.13 0,60)	(0.02,0.18, 0.80)	(0.63, 0.001,0.369)

Then, it is calculated that the consistency ratio of the aggregated intuitionistic fuzzy matrix of the main criteria. The computation of consistency ratio is based on formula (7.12) to examine the consistency of the pair-wise comparison of the main criteria. Computation of consistency ratio of aggregated matrix of main criteria is carried out as follows:

$$C.R = \frac{((0+0+0.505+0.349+0.369)/5)/4)}{1.12} = 0.05$$

As can be seen from this calculation, consistency test of aggregated intuitionistic fuzzy matrix for criterion is 0.05. Since this value is smaller than 0.10, the matrix is consistent.

At the stage of calculation of the intuitionistic fuzzy weight of the aggregated intuitionistic fuzzy matrix, equations (6.13) and (6.14) are utilized in order to acquire the entropy weights and final entropy weights of each main criterion.

For example, entropy weights and final entropy weights of price criterion are calculated as follows:

$$\overline{\overline{w}}_{price} = \frac{1}{5\ln 2}\left[0.49\ln 0.49 + 0.005\ln 0.005 - (1-0.505)\ln(1-0.505) - 0.505\ln 2\right],$$
$$= 0.1090$$

$$w_{price} = \frac{1-0.1090}{5-(0+0+0.1090+0.0719+0.0759)} = 0.1878$$

Table 7.4: Final Entropy Weights of Main Criteria

Criteria	Aggregated matrix	Entropy weights	Final entropy weight
Quality	(1.0,0,0)	0	0.2108

Delivery	(1.0,0,0)	0	0.2108
Price	(0.49, 0.005,0.505)	0.1090	0.1878
Greenness	(0.65, 0.001,0.349)	0.0719	0.1956
Flexibility	(0.63, 0.001,0.369)	0.0759	0.1948

The pairwise comparison of subcriteria is constructed considering compromise evaluation. It is demonstrated in TIFNs in Table 7.5.

Table 7.5: Pairwise Comparison of the Main Criteria in TIFNs

Sub criteria	Recyclability of raw mat.	Desing for disas. and reuse	Green Image	Green R&D	Transpor-tation
Recyclability of raw mat.	(0.02,0.18, 0.80)	(0.13,0.27, 0.60)	(1.0,0,0)	(0.62,0.18, 0.20)	(0.47,0.23, 0.30)
Design for disassembly and reuse	(0.27,0.13, 0.60)	(0.02,0.18, 0.80)	(1.0,0,0)	(0.33,0.27, 0.40)	(0.33,0.27, 0.40)
Green Image	(0,1.0,0)	(0,1.0,0)	(0.02,0.18, 0.80)	(0.23,0.06, 0.70)	(0.27, 0.13 0.60)
Green R&D	(0.18,0.62, 0.20)	(0.27,0.33, 0.40)	(0.06,0.23, 0.70)	(0.02,0.18, 0.80)	(0.27, 0.33 0.40)
Transportation	(0.23,0.47, 0.30)	(0.27,0.33, 0.40)	(0.13,0.27, 0.60)	(0.33,0.27, 0.40)	(0.02,0.18, 0.80)

The aggregated intuitionistic fuzzy judgement matrix is constructed based on the weight of the compromise evaluation. Equation (6.11) is also utilized to aggregate the whole of transformation of the intuitionistic fuzzy decision matrix of the sub criteria. Table 7.6 demonstrates the aggregated matrix of subcriteria.

Table 7.6: Aggregated Matrix of Sub Criteria in TIFNs

Sub criteria	Recyclabilit y of raw mat.	Desing for disas. and reuse	Green Image	Green R&D	Transpor-tation	Aggregated Matrix

Recyclability of raw mat.	(0.02,0.18, 0.80)	(0.13,0.27 , 0.60)	(1.0,0,0)	(0.62,0.18 , 0.20)	(0.47,0.23 , 0.30)	(1.0,0,0)
Design for disassembly and reuse	(0.27,0.13, 0.60)	(0.02,0.18 , 0.80)	(1.0,0,0)	(0.33,0.27 , 0.40)	(0.33,0.27 , 0.40)	(1.0,0,0)
Green Image	(0,1.0,0)	(0,1.0,0)	(0.02,0.18 , 0.80)	(0.23,0.06 , 0.70)	(0.27, 0.13 0.60)	(0.45,0.001 , 0,549)
Green R&D	(0.18,0.62, 0.20)	(0.27,0.33 , 0.40)	(0.06,0.23 , 0.70)	(0.02,0.18 , 0.80)	(0.27, 0.33 0.40)	(0.60,0.003 , 0.397)
Transportatio n	(0.23,0.47, 0.30)	(0.27,0.33 , 0.40)	(0.13,0.27 , 0.60)	(0.33,0.27 , 0.40)	(0.02,0.18 , 0.80)	(0.68,0.002 , 0,318)

Then, the consistency ratio of the aggregated intuitionistic fuzzy matrix of the sub criteria is calculated concerning Equation (6.12) . Computation of CR of aggregated matrix of sub criteria is carried out as follows:

$$C.R = \frac{((0+0+0.549+0.397+0.318)/5)/4)}{1.12} = 0.05$$

As can be seen from this calculation, the consistency test of aggregated intuitionistic fuzzy matrix for sub criterion is 0.05. Since this value is smaller than 0.10, the matrix is consistent.

At the stage of calculation of the intuitionistic fuzzy weight of the aggregated intuitionistic fuzzy matrix, equations (6.13) and (6.14) are utilized to acquire the entropy weights and final entropy weights of each sub criteria.

For example, entropy weights and final entropy weights of green image criterion are calculated as follows:

$$\overline{\overline{w}}_{greenimage} = \frac{1}{5\ln 2}\left[0.45\ln 0.45 + 0.001\ln 0.001 - (1-0.549)\ln(1-0.549) - 0.549\ln 2\right],$$
$$= 0.1118$$

$$w_{greenimage} = \frac{1-0.1118}{5-(0+0+0.1118+0.0848+0.0675)} = 0.1878$$

Then, to reach the final weights of the sub criterion, final entropy weight of greenness criteria and final entropy weight of each sub-criteria are multiplied one by one.

For example, final entropy weights of green image criterion are computed as follows:

$$\overset{=}{w}_{greenness} \times \overset{=}{w}_{greenimage} = 0.1956 \times 0.1878 = 0.0366$$

Other calculations for other sub criteria are carried out in the same manner.

The entropy weights and final entropy weights of main and sub criteria are demonstrated in Figure 7.3 and Table 7.7.

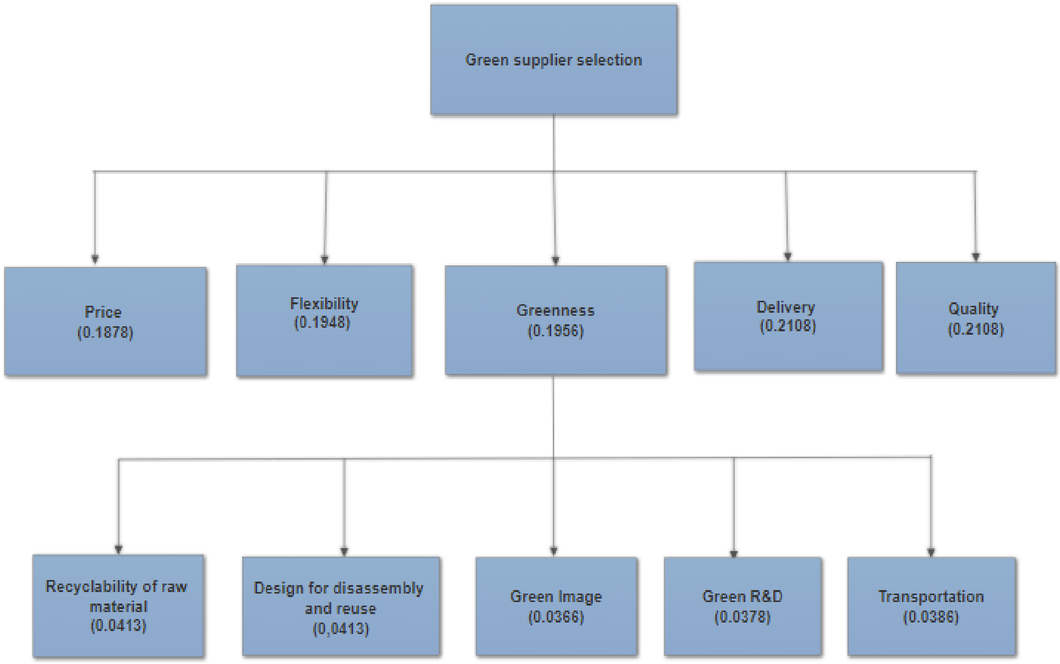

Figure 7.3: Final Entropy Weights of Each Criterion

Table 7.7: Final Entropy Weights of Main and Sub criteria

Criteria	Aggregated matrix	Entropy weights	Final entropy weight
Quality	(1.0,0,0)	0	0.2108
Delivery	(1.0,0,0)	0	0.2108
Price	(0.49, 0.005,0.505)	0.1090	0.1878
Flexibility	(0.63,0.001,0.369)	0.0759	0.1948
Recyclability of	(1.0,0,0)	0	0.0413

raw material			
Design for disassembly and reuse	(1.0,0,0)	0	0.0413
Green Image	(0.45,0.001,0,549)	0.1118	0.0366
Green R&D	(0.60,0.003, 0.397)	0.0848	0.0378
Transportation	(0.68,0.002,0.318)	0.0675	0.0386

7.6. PROMETHEE

As previously explained, PROMETHEE method starts with a data matrix as shown in Table 7.8. Data matrix for the alternatives are constructed by evaluating the criteria and the final entropy weights obtained from the IF-AHP method.

Table 7.8: Data Matrix

Alter-natives	Quality (max)	Delivery (max)	Price (max)	Flexibility (max)	Recyclability of raw mat. (max)	Desing for disas. (max)	Green Image (max)	Green R&D (max)	Trans-portation (max)
A	3	2	4	7	5	4	7	4	5
B	6	8	6	5	9	7	9	3	6
C	3	6	9	6	6	8	5	2	4
D	9	4	5	5	5	5	4	2	3
E	5	9	4	8	7	6	2	5	8
Weight	0.2108	0.2108	0.1878	0.1948	0.0413	0.0413	0.0366	0.0378	0.0386

Five alternative suppliers that produce filter media are identified for the company in which the application is carried out and it is decided that the suppliers are evaluated on the basis of nine criteria. As the alternative suppliers are considered, all criteria are evaluated by managers and experts in the range of 1 to 10 points based on past studies. When assigning between 1 and 10 for these criteria, the questions in Table 7.9 are taken into consideration.

Table 7.9 : Evaluation Factors of The Criteria For Assignment Between 1 and 10 Point

Delivery	**Transportation**
On time delivery	Fuel type
Delivery time	Filter usage in vehicles
Location of supplier	Use of sound and noise prevention equipment
Distance of supplier	Eco-friendly organic package use
Delivery in the right amount	Amount of freight moved (Large parties preferred)
Price	**Quality**
Product price	Return rate of defective product
Payment term	Compliance with product specifications
Discount rate	Quality certificate
Flexibility	**Design for disassembly and reuse**
New product flexibility	Product demountability
Volume flexibility	Appropriate design for demountable product, Mounting number
Expansion flexibility	Reusability of disassembled parts
Green image	**Recyclability of raw material**
Participation and support of the company in environmental projects	Recycling rate of raw material
Employees' training on environmental issues	Amount of harmful waste generated in recycling of raw material
Green customer ratio, Received penalty rate due to environmental incompatibility	

However, the supplier's investment and interest in protecting the environment has been taken into account when assessing the supplier's green research and development criterion. A preference function is specified for each criterion. In this stage, the functions given in Table 6.6 were used. Fifth type (linear) preference function is determined for all criteria. In determining the preference functions for the criteria, the structure of the criteria, the values they can take, and the views of managers and experts on the criteria are evaluated. Table 7.10 demonstrates the preference function parameters determined on the basis of the data and the criteria collected up to this stage of the application.

Table 7.10: Preference Functions and Parameters for Each Criterion

Criteria	Parameter	Function
Quality (max)	2,4	$p_{quality} = \begin{cases} 0, \mathrm{x} \le 2 \\ \frac{x-2}{2}, 2 < x \le 4 \\ 1, x > 4 \end{cases}$
Delivery (max)	3,5	$p_{delivery} = \begin{cases} 0, \mathrm{x} \le 3 \\ \frac{x-3}{2}, 3 < x \le 5 \\ 1, x > 5 \end{cases}$
Price (max)	2,4	$p_{price} = \begin{cases} 0, \mathrm{x} \le 2 \\ \frac{x-2}{2}, 2 < x \le 4 \\ 1, x > 4 \end{cases}$
Flexibility (max)	1,3	$p_{flexibility} = \begin{cases} 0, \mathrm{x} \le 1 \\ \frac{x-1}{2}, 1 < x \le 3 \\ 1, x > 3 \end{cases}$
Recyclability of raw material (max)	3,5	$p_{recycl.} = \begin{cases} 0, \mathrm{x} \le 3 \\ \frac{x-3}{2}, 3 < x \le 5 \\ 1, x > 5 \end{cases}$
Design for disassembly and reuse (max)	2,4	$p_{designfordis.} = \begin{cases} 0, \mathrm{x} \le 2 \\ \frac{x-2}{2}, 2 < x \le 4 \\ 1, x > 4 \end{cases}$

Green Image (max)	3,5	$p_{greenimage} = \begin{cases} 0, x \le 3 \\ \frac{x-3}{2}, 3 < x \le 5 \\ 1, x > 5 \end{cases}$
Green R&D (max)	1,3	$p_{greenR\&D} = \begin{cases} 0, x \le 1 \\ \frac{x-1}{2}, 1 < x \le 3 \\ 1, x > 3 \end{cases}$
Transportation (max)	2,4	$p_{transportation} = \begin{cases} 0, x \le 2 \\ \frac{x-2}{2}, 2 < x \le 4 \\ 1, x > 4 \end{cases}$

Afterwards, considering the preference functions determined for each criterion, common preference functions according to the equation (6.15) for alternative pairs are created and function values are calculated by these functions.

The determination of the common preference functions P1 (A, C) and the calculation of the function values for the alternatives A and C are illustrated by way of example below. Similar calculations have been made for other alternative pairs, but are not shown. Common preference function values on the basis of evaluation factors of alternatives A and C are as follows:

On the basis of quality criterion, the alternative A is equal to the alternative C :

f(A)-f(C)=0, $\Rightarrow$ P1(A,C)=0

On the basis of delivery criterion, the alternative A is worse than the alternative C :

P2(A,C)=0

On the basis of price criterion, the alternative A is worse than the alternative C :

P3(A,C)=0

On the basis of flexibility criterion, the alternative A is better than the alternative C :

f(A)-f(C)=1 but P4(A,C)=0

On the basis of recyclability of raw material criterion, the alternative A is worse than the alternative C :

P5(A,C)=0

On the basis of design for disassembly and reuse criterion, the alternative A is worse than the alternative C :

P6(A,C)=0

On the basis of green image criterion, the alternative A is better than the alternative C :

f(A)-f(C)=2, but P7(A,C)=0

On the basis of green R&D criterion, the alternative A is better than the alternative C :

f(A)-f(C)=2 $\Rightarrow$ P8(A,C)=0.5

On the basis of transportation criterion, the alternative A is worse than the alternative C:

f(A)-f(C)=1 but P9(A,C)=0

In the next step, the calculation of the preference index for the alternatives A and C is made by using equation (6.16) is shown below. Similar calculations are made for other alternative pairs. The preference indices calculated for alternative suppliers are shown in Table 7.11.

$$\pi(a,\mathrm{c}) = \frac{\sum_{i=1}^{k} W_i * P_i(a,\mathrm{c})}{\sum_{i=1}^{k} W_i} = \frac{0+0+0+0+0+0+0+0.0189+0}{1} = 0.0189$$

Table 7.11: Preference Indices for Alternative Suppliers

	A	B	C	D	E
A	-	0.0974	0.0189	0.1163	0.0366
B	0.3575	-	0.1237	0.1819	0.0366
C	0.3345	0.0939	-	0.2084	0.1878
D	0.2108	0.1054	0.2108	-	0.2108
E	0.2301	0.2137	0.1738	0.4820	-

Positive (Φ^-) and negative (Φ^-) proiorities are calculated for the alternative suppliers by equations (7.17) and (7.18). The computation of the positive and negative priorities for alternative A is shown below as an example, and the results obtained for the other alternatives are shown in Table 7.12.

$$\Phi^+(A) = \pi(\mathrm{A,B}) + \pi(A,C) + \pi(A,D) + \pi(A,E)$$
$$= 0.0974 + 0.0189 + 0.1163 + 0.0366 = 0.2692$$

$$\Phi^-(A) = \pi(\mathrm{B,A}) + \pi(C,A) + \pi(D,A) + \pi(E,A)$$
$$= 0.3575 + 0.3345 + 0.2108 + 0.2301 = 1.1329$$

Table 7.12: Positive and Negative Priorities for Alternative Suppliers

Alternatives	A	B	C	D	E
Φ^+	0.2692	0.6997	0.8246	0.7378	1.0996
Φ^-	1.1329	0.5104	0.5272	0.9886	0.4718

The complete ranking is determined by PROMETHEE II method according to the obtained data. Accordingly, complete priorities are calculated by formula (7.25), and the complete ranking is carried out according to these priorities determined by equations (7.26) and (7.27). Complete ranking is shown in Figure 7.4.

$$\phi(\mathrm{A}) = \phi^+(\mathrm{A}) - \phi^-(\mathrm{A}) = -0.8637$$

$$\phi(\mathrm{B}) = \phi^+(\mathrm{B}) - \phi^-(\mathrm{B}) = 0.1893$$

$$\phi(\mathrm{C}) = \phi^+(\mathrm{C}) - \phi^-(\mathrm{C}) = 0.2974$$

$$\phi(\mathrm{D}) = \phi^+(\mathrm{D}) - \phi^-(\mathrm{D}) = -0.2508$$

$$\phi(\mathrm{E}) = \phi^+(\mathrm{E}) - \phi^-(\mathrm{E}) = 0.6278$$

Figure 7.4: Complete Ranking of Suppliers

As a result of the complete ranking with PROMETHEE II, the best supplier is identified as supplier E. Other suppliers are listed as C-B-D-A.

8. CONCLUSION

Serious environmental problems have arisen since the industrial revolution. From the first years of the industrial revolution until the 1980s, while a large number of companies desire to keep pace with rapidly developing technology, they ignored environmental factors. Solid, liquid, gaseous wastes and shortage of raw materials released to the environment are the main environmental problems. Especially released greenhouse gases cause global warming. Along with global warming, serious global problems which threaten humankind have arisen such as the rise of sea level, the emergence of drought and desertification, the disappearance of potable water resources, climate change, and the extinction of many living species.

As these problems have begun to affect people's daily lives and health, the environmental awareness of the community has risen significantly during the recent years. However, many governments around the world have implemented environmental regulations. Especially after the nineties, due to increased public pressure and environmental regulations, many companies were forced to take environmental policies into account. Especially after the millennium, companies which have environmental sensitivity came to an advantageous position in the market. While a number of companies are reluctant to implement environmental practices for the first time, they have come to realize the importance of them after saving energy and providing a green image in the eyes of the customer.

Some researchers suggested that waste and emissions from their supply chain activities are the primary cause of global warming and other major environmental problems. Selecting the supplier, the first step in the management of the SC, is one of the most crucial steps in this process. Because the supplier's environmental attitude and perception can affect the entire supply chain process. Working with a supplier which has environmental awareness contributes to develop the company's environmental image. However, a harmful component that may occur in the raw material or semi-manufactured goods may negatively affect the whole process. The selection of supplier which has environmental sensitivity has become a very important issue in recent years. Thus, a well proposed green supplier selection model may not only assist to eliminate the operational and environmental concerns but also may raise the competitive capacity of the company.

This study started with identifying the criteria which were most frequently considered in green supplier selection problem. As a result of the extensively done literature research and making use of scientific journals and experts' views, quality, delivery, price, flexibility and greenness are determined as main criteria. Recyclability of raw material, design for disassembly and reuse, green image, green research and development and transportation are determined as sub criteria of greenness.

GSS is a MCDM problem because of involving conflicting qualitative and quantitative criteria. However, MCDM problems have ambiguity and uncertainty because of human judgments and subjectivity because it is almost impossible to perceive the decision maker's linguistic evaluations by exact numbers. Thus, in recent years, intuitionistic fuzzy methods are preferred in a large number of researches to deal with the uncertainty of evaluations.

In this study, the proposed model applies IF-AHP to determine criteria weights and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) technique to carry out a final ranking of alternatives. IF-AHP is considered as an appropriate method to weight decision maker and criteria since it is easy and robust to implement in spite of the ambiguity of human judgment in the assessment period. PROMETHEE is widely regarded as a proper and practical technique to implement outranking method. However, it is based on superiority and can take qualitative criteria into consideration.

Eventually, an application was presented for validation and providing bettter understanding of the proposed method. The application was carried out in filtration industry which is never studied in the literature. The best green supplier amongst five ones which produce HEPA filtration media was determined after they were ranked. The names of suppliers were not given because of their privacy policy.

Further research could include other methods, such as IF-ANP, to overcome the ambiguity and vagueness in assessment process when there are interdependencies between criteria. However, fuzzy PROMETHEE and IF PROMETHEE can be implemented to avoid uncertainties of evaluations when constructing data matrix.

Moreover, Delphi method may be used to choose the most significant main and sub criteria. Because there can be some complexity during the determination of criteria process due to experts' disagreement. Then, at the end of study, sensitivity analysis may be used to investigate the feasibility and outcomes of the proposed technique.

APPENDIX A: LITERATURE REVIEW SUMMARY TABLE

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2009	A green supplier selection model for high-tech industry	Lee, Kang, Hsu & Hung	Quality, Finance, Organization, Technology Capability, Service, Pollution Control, Environment Management, Green Image, Green Competencies, Total Product Life Cycle Cost	Delphi Method and Fuzzy extended AHP	High- Tech Industry
2009	Research on Green Suppliers' Evaluation Based on AHP & Genetic Algorithm	Yan	Environment, Quality, Operational Capacity, Price Level, Service Level	AHP and Genetic Algorithm	Empirical Case
2009	Green supplier selection models utilizing voting hierarchy analysis process	Juang, Lin, Cao & Wang	Environment Management, Production Techniques, Design Performance	Voting Analytic Hierarchy	Computer, communication and consumer electronic sector
2009	Green Procurement in Trading Sector of Hong Kong	Heung, Wong & Lee	Profitability, Suppliers' Service Commitment, Relationship/Cooperation, Management and Organization	AHP method	Trading sector
2009	Selection of suppliers of vehicle components based on green supply chain	Li and Zhao (2009)	Quality, Technology, Service, Innovation, Management, Environment	Grey Correlational Analysis and AHP	Electronics Company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2009	Environmental performance evaluation of suppliers: A hybrid fuzzy multi-criteria decision approach	Tuzkaya, Ozgen, Ozgen & Tuzkaya	Green Process Management, Green Product, Green Image, Environment and Legislative Management, Pollution Control, Environmental Costs	Fuzzy ANP and Fuzzy PROMETHEE	White goods indusrty
2009	Supplier Performance Evaluation for Green Supply Chain Management	Grisi, Guerra & Naviglio	Price, Quality of Delivery, Quality, Environmental Competences, EMS, Green Image, Current Environmental Impact,	Fuzzy AHP	Empirical Case
2010	Integration of artificial neural network and MADA methods for green supplier selection	Kuo, Wang & Tien	Quality, Cost, Delivery, Service, Environment, Corporate Social Responsibility	ANN,ANP, Delphi and DEA method	Electronic company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2010	A portfolio-based analysis for green supplier management using the analytical network process	Sarkis, Zhu & Dou	Strategic Performance Measures, Organizational Factors, Environmental Factors	ANP and Portfolio Analysis	Empirical Case
2010	An Extended QUALIFLEX Method Under Probability Hesitant Fuzzy Environment for Selecting Green Suppliers	Li and Wang	Pollution Production, Pollution Control, Resource Consumption, Eco-design, EMS, Green Image, Commitment of GSCM from Managers, Use of Environmentally Friendly Technology, Use of Environmentally Friendly Materials, Staff Environmental Training	QUALIFLEX method	Automobile Industry
2010	Green Supplier Selection Framework Based on Multi-Criteria Decision-Analysis Approach	Watrobski & Salabun	Cost, Product Quality, Quality, Delivery/Logistics, Financials of Manufacturing and Product,Risk factors, Service, Profile, Green Innovation, Environment Production, Environment Management, Pollution control, Hazardous Substance Management, Green Image, Social Responsibility, Green product, Green Materials	QUALIFLEX method	Cable Bundles Company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2010	Green supplier selection consensus by neural network	Thongchattu & Siripokapirom	Company Reliability, Material Quality, Material Price, Environmental, ISO 14000	AHP and ANN	Empirical Case
2010	Evaluation of Green Suppliers Considering Decision Criteria Dependencies	Büyüközkan & Feyzioğlu	Product Cost, Product Quality Service Performance, Environmental Performance	Choquet integral method	White goods indusrty
2010	A fuzzy multi criteria approach for evaluating environmental performance of suppliers	Awasthi, Chauhan & Goyal	Benefit category, Cost category	Fuzzy TOPSIS and Fuzzy set theory	Logistic
2010	Developing Green Supplier Selection Procedure: A DEA Approach	Wen & Chi	Environmental, Traditional, Partnership Aspects	AHP/ANP and DEA	Empirical Case
2011	Iron and Steel Companies Green Suppliers' Selection Model Based on Vague Sets Group DM method	Yang & Ying-Tuo	Quality of Products, Environmental Friendship, Price, Development Capabilities of Suppliers	Vague Sets Group Decision-making Method	Iron and Steel Companies

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2011	Supplier selection using analytic network process and data envelopment analysis	Kuo and Lin	Organisation Structure and Manufacturing Capability, Supplier's Implementation Capability, Quality System, Environmental Issues	DEA and ANP method	High- Tech Industry
2011	Using multi-objective genetic algorithm for partner selection in green supply chain problems	Yeh & Chuang	Production Cost, Transportation Cost, Production Time, Green Principles, Average Product Quality, Transportation Time, Air Pollution	MOGA method	Electronics Industry
2011	Evaluating the Green Suppliers of the Printed Circuit Board Factories Based on the Fuzzy AHP and VIKOR	Kuo, Shia, Chen, Ho	Quality, Tecnology Capacity, Contamination Control, Environment, Management, Green Competition	Fuzzy AHP and VIKOR	Printed circuit board industry
2011	Supplier Selection Analysis under the Green Supply Chain	Ma & Liu	Product Quality, Price, Cost, Financial Position, Productive Power, Standard of Service, Manage and Culture, Environmental Protection, Geographic Location	AHP and DEA	Empirical Case

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2011	Green supplier selection generic framework: a multi-attribute utility theory approach	Shaik & Abdulkader	Environmental Efficiency, Environmental & Quality Management Systems, Green Design, Green Image, Green Competencies, Green Product Life Cycle Cost, Management Competencies, Technical Capability	Multi-attribute utility theory approach	Empirical Case
2012	A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy AHP and fuzzy TOPSIS to evaluate green suppliers	Büyüközkan & Çifçi	Quality, Cost, Time, Flexibility	Fuzzy DEMATEL, Fuzzy AHP and Fuzzy TOPSIS	Automobile industry
2012	Developing the Green Supplier Selection Procedure Based on Analytical Hierarchy Process and Outranking Methods	Tsui & Wen	Green Management System, Supplier's Green Image, Green Product Management, Financial Issues, Quality, Service, Technology Issues, Organizational Culture and Strategy	AHP, PROMETHEE I and PROMETHEE II	Optoelectronics industry
2012	Establishing green supplier appraisement platform using grey concepts	Sahu, Datta & Mahapatra	Enterprise Ability, Service Level, Cooperation Degree, Environmental Factors	Grey-TOPSIS and COPRAS-G	Automobile Sector

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2012	An integrated fuzzy multi-criteria group decision-making approach for green supplier evaluation	Büyüközkan	Product Cost, Product Quality Service Performance, Environmental Performance	Fuzzy AHP, Fuzzy axiomatix design and Fuzzy TOPSIS	Automobile industry
2012	Evaluating firm's green supply chain management in linguistic preferences	Tseng & Chiu	Environmental and Non-environmental GSCM Criteria	GRA method	Original equipment manufacturing sector
2012	Supplier selection using fuzzy AHP and fuzzy MOLP for developing low carbon supply chain	Shaw, Shankar, Yadav & Thakur	Cost, Quality, Lead time, Green House Gas (GHS) Emission and Demand	Fuzzy AHP and Fuzzy MOLP	Garment manufacturing company
2012	Green Supplier Assessment in Environmentally Responsive Supply Chains through Analytical Network Process	Agarwal & Vijayvargy	Operational Life Cycle, Environmental Friendly Practices, Overall Performance Evaluation, Process Management	Portfolio Analysis and ANP	Automobile Industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2012	Research on the Optimization of Green Suppliers Based on AHP and GRA	Peng	Enterprise Ability, Service Level, Cooperation Degree, Environmental Factors	AHP and GRA	Refrigator manufacturing industry
2012	Evaluation of the green supply chain management practices: a fuzzy ANP approach	Büyüközkan & Çifçi	Organisational Performance Dimension, Green Logistics Dimension, Green Organisational Activities Dimension	Fuzzy ANP method	Automobile Industry
2013	A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences	Shen, Olfat, Govindan, Khohaverdi & Diabat	Pollution Production,Resource Consumption, Eco-design, Green Image, EMS, Commitment of GSCM from Managers, Use of Environmentally Friendly Technology, Use of Environmentally Friendly Materials, Staff Environmental Training	Fuzzy TOPSIS method	Automobile Manufacturing Company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2013	Integrated fuzzy multi criteria decision making method and multi objective programming approach for supplier selection and order allocation in a green supply chain	Kannan, Khodaverdi, Olfat, Jafarian & Diabat	Cost, Quality,Delivery Reliability,Technology Capability, Environmental Metrics	AHP method and Fuzzy TOPSIS	Automobile Manufacturing Company
2013	Green supplier selection based on IFS and GRA	Bali, Köse & Gümüş	Service Quality, Green Image, Use of Green Materials,Pollution/Waste Control In Production, Green Product, Distribution, Reverse Logistics, Green Design or R&D	IFS and GRA method	Automobile corporation
2013	A MCDM Method for Green Supplier Selection in Multi Period Based on Uncertainty	Bali and Güreşen	Green Image, Technological Infrastructure, Pollution and Waste Level, Service Quality, Cost, Green Design and R&D	DIFWA and IFS method	Battery manufacturing industry
2013	Greener supplier selection: state of the art and some empirical evidence	Genovese, Koh, Bruno & Esposito	Cost, Delivery Punctuality, Flexibility, Quality, Innovation Level	The questionnaire and AHP model	Empirical case

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2013	Evaluating Green Performance of Suppliers via Analytic Network Process and TOPSIS	Akman and Pışkın	Pollution Control,EMS, Green Products, Environmental Collaboration, Environmental Competency	ANP and TOPSIS	Automobile Industry
2014	Selecting Green suppliers based on GSCM practices: Using Fuzzy TOPSIS applied to a Brazilian electronics company	Kannan, Jabbour & Jabbour	Seventeen Anonymous Criteria	Fuzzy TOPSIS	Electronics Company
2014	Green supplier selection and evaluation using DEA-type composite indicators	Dobos & Vörösmarty	Traditional Dimension, Environmental Dimension	DEA method and Composite indicator method	Empirical Case

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2014	Green supplier selection in edible oil production by a hybrid model using delphi method and green data envelopment analysis (GDEA)	Banaeian, Nielsen, Mobli & Omid	Financial, Delivery & Service, Qualitative, EMS	Delphi Method and Green DEA	Edible oil sector
2014	Evaluating a green supplier selection problem using a hybrid MODM algorithm	Bakeshlou, Khamseh, Asl, Sadeghi & Abbaszadeh	Environmental, Technology, Service, Quality,Cost	Fuzzy ANP, Fuzzy DEMATEL and Fuzzy MOLP	Empirical Case
2014	A new approach to green supplier selection based on fuzzy multi-criteria decision making method and linear physical programming	Ashlaghi	Environmental, Service, Quality, Cost	Fuzzy DEMATEL and Fuzzy ANP	Empirical Case

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2014	A grey-based Carbon Management Model for Green Supplier Selection	Hashemi, Karimi, Aghakhani & Kalantar	Planning, Implementation, Management	Improved GRA	Empirical case
Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2014	Evaluation of the Parameters of the Green Supplier Selection Decision in Textile Industry	Acar, Önden & Gürel	Classical and Environmental Dimensions	Fuzzy AHP	Textile industry
2014	An integrated MCDM approach to green supplier selection	Yazdani	Production & Manufacturing, Design Characteristics, General Characteristics, End -of-life Management Characteristics	Fuzzy TOPSIS and Fuzzy AHP	Automobile Industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2014	Selecting Green Supplier of Thermal Power Equipment by Using a Hybrid MCDM Method for Sustainability	Zhao and Guo	Equipment Quotation, Delivery Accuracy Rate, Equipment Operational Costs, Equipment Efficiency, Environmental Consciousness	Fuzzy Entropy and TOPSIS	Electric Power Industry
2014	A Hybrid Multiple Criteria Group Decision-Making Approach for Green Supplier Selection in the TFT-LCD Industry	Tsui and Wen	Environmental Factor, Enterprise Operating, Strategic Technologyand Development	AHP, Entropy Method and ELECTRE-III	TFT-LCD Industry
2014	A New Fuzzy TOPSIS-TODIM Hybrid Method for Green Supplier Selection Using Fuzzy Time Function	Khamseh & Mahmoodi	Annual Growth In Green Products, Cost of Revenue, Industry leadership:Green Market Share, Customer Retention/Percentage of Growth With Existing Customers, Customer Acquisition:The Number of New Green Customers/Total Revenue to New Green Customers, Life Cycle Assessment	Fuzzy TOPSIS and TODIM	Tier Company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2015	A Methodology for Green Supplier Selection in Food Industries	Banaeian, Mobli, Nielsen & Omid	Conventional dimension and Green dimension	AHP, Fuzzy GRA and TOPSIS	Edible oil company
2015	Green supplier selection using an AHP-Entropy-TOPSIS framework	Freeman & Chen	Cost, Green Competency, Quality, Delivery Schedule, EMP	AHP-Entropy based TOPSIS	Electronic machinery manufacturer
2015	Fuzzy Axiomatic Design approach based green supplier selection: a case study from Singapore	Kannan, Govindan & Rajendran	Quality,Price,Capability of Supplier/Delivery,Service,Environment Protection/ Environment Management,Management System, Corporate Social Responsibility,Pollution Control,Green Product,Green Image, Green Innovation, Environmental Performance, Hazardous Substance Management	Fuzzy Axiomatic Design method	Plastic Material Manufacturing
2015	Discussing and evaluating green supply chain suppliers: a case study of the printed circuit board industry in China	Guo & Tsai	Green Production, Green Manufacturing Environment, Green Management, Green Transportation and Recycling	DEMATEL method	Printed circuit board industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2015	Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods	Akman	Green Design, Pollution Prevention,Green Image,Green Capability, EMS	Fuzzy C-means, AHP and VIKOR	Automobile Industry
2015	An integrated green supplier selection approach with analytical network process and improved Grey relational analysis	Hashemi, Karimi & Tavana	Economic and Environmental Dimensions	ANP and improved GRA	Automobile industry
2015	Prioritizing Green Supplier Selection Criteria using Fuzzy Analytical Network Process	Galankashi, Chegeni, Soleimanynanadegany, Memari, Anjomshoae, Helmi & Dargi	Price, Quality, Reputation, Service and delivery, Distance, Use of Green Materials, Air Emission Level, Waste Level, Energy Efficiency, Green Design Capability	Fuzzy ANP and Nominal Group Technique	Electronic industry
2015	Optimization Decision of Supplier Selection in Green Procurement under the Mode of Low Carbon Economy	Hu, Rao, Zheng & Huang	Commercial and Environmental Criteria	LT-TOPSIS,2-tuple averaging(TWA) and 2-tuple ordered weighted averaging(TOWA) operator	Empirical Case

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2015	Ranking green electronic supplier in auto industry using fuzzy Delphi	Saeidi, Ghasemi, Fakhari & Mokhtari	Electronic GSC and GSC Criteria	Fuzzy Delphi, Fuzzy AHP and VIKOR	Automobile Industry
2015	Criteria definition and approaches in green supplier selection – a case study for raw material and packaging of food industry	Banaeian, Mobli, Nielsen & Omid	Financial, Delivery & Service, Qualitative, EMS	Fuzzy GRA, Delphi, AHP and Linear Programming	Edible oil production company
2015	A Generic Simulation Model for Green Supplier Selection	Boosothonsatit, Kara & Ibbotson	Cost Minimization, Lead Time Minimization, Environmental Impact Minimization	Generic simulation model	Boat manufacturer

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2015	Integration of MCDM Methods for Green Supplier Selection	Chaghooshi, Pahlevani & Zarchi	Pollution Control, Green Product, Delivery, Quality, Cost	AHP and VIKOR	Empirical Case
2015	Integration of fuzzy ANP and fuzzy TOPSIS for evaluating carbon performance of suppliers	Kuo, Hsu & Chen	Organizational Management Dimension, Process management Dimension, Procurement Management Dimension, R&D Management Dimension	Fuzzy TOPSIS and MOLP	Electronic Company
2016	Green supplier selection and order allocation in a low-carbon paper industry: integrated multi-criteria heterogeneous decision-making and multi-objective linear programming approaches	Govindan & Sivakumar	Cost, Quality, Delivery,Recycle Capability, GHG Emissions Criteria	Fuzzy TOPSIS and MOLP method	Paper Industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	Evaluation and selection of suppliers considering green perspectives	Sahu, Datta & Mahapatra	Management Competencies, Green Image, Design for Environment, EMS, Environmental Competencies	Fuzzy-TOPSIS and fuzzy-based multi-level multi-criteria decision-making method	Empirical Case
2016	Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry	Banaeian, Mobli, Fahimnia, Nielsen & Omid	Service Level, Quality, Price, EMS	Fuzzy TOPSIS, Fuzzy VIKOR and Fuzzy GRA	Edible vegetable oils manufacturer
2016	An integrated model for green partner selection and supply chain construction	Wu and Barnes	Cost, Pollution Control, Resource Consumption, Quality	ANP and MOP	Electrical appliance and equipment manufacturing industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	An interval valued hesitant fuzzy ranking method based on group decision analysis for green supplier selection	Darabi & Heydari	Cost, Quality,Delivery, Technology Capability,Environmental Competency	Interval- Valued Hesitant Fuzzy Ranking Method	Automobile Manufacturing Company
2016	New hybrid COPRAS-G MADM Model for improving and selecting suppliers in green supply chain management	Liou, Tamošaitienė, Zavadskas & Tzeng	Organisational management , Operational Management, Product Design, Compliance with Regulations	COPRAS-G and DEMATEL based ANP	Electronics Company
2016	An approach for green supplier selection in the automobile manufacturing industry	Yu & Hou	Product, Supplier, Cooperation and Development Potential, Green performance	MMAHP and AHP	Automobile manufacturing sector

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	Key factors affecting green procurement in real estate development: a China study	Shen, Zhang & Zhang	Green Features in Production Stage, Green Features in Construction stage, Green features in Operation Stage	The one-way analysis of variance(ANOVA)	Real estate sector
2016	A Fuzzy MCDM Approach for Green Supplier Selection from the Economic and Environmental Aspects	Chen, Chou, Luu & Yu	Economic and Environmental Criteria	Fuzzy TOPSIS and Fuzzy AHP	Luminance enhancement film(LEF) industry
2016	An intuitionsitic fuzzy judgement matrix and TOPSIS integrated multi-criteria decision making method for green supplier selection	Cao, Wu & Liang	Environmental Costs, Remanufacturing Activity, Energy Consumption, Reverse Logistics Program, Hazardous Waste Management, Environmental Certification	IFS and TOPSIS	Electric automobile company

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	Developing a Green Supplier Selection Model by Using the DANP with VIKOR	Kuo, Hsu & Li	Environmental and Management Dimensions	DEMATEL, ANP and VIKOR	Electronics Company
2016	The Establishment of a Green Supplier Selection and Guidance Mechanism with the ANP and IPA	Chung, Chao & Lou	Operation, Ability, Green Dimensions	ANP and IPA	Bicycle Manufacturer
2016	An integrated model for green supplier selection under fuzzy environment: application of data envelopment analysis and genetic programming approach	Fallahpour, Olugu, Musa, Khezrimotlagh & Wong	Traditional and Environmental Criteria	DEA-GP and KAM models	Garment Manufacturer

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	An Approach to Solve Multi-criteria Supplier Selection While Considering Environmental Aspects Using Differential Evolution	Jauhar, Pant & Deep	Management Criteria, Environmental Criteria	DEA method	Automobile industry
2016	Green Government Procurement: Decision- Making with Rough Set, TOPSIS, and VIKOR Methodologies	Sarkis & Bai	Environmental Economic and Social Dimensions	TOPSIS and VIKOR	Empirical Case
2016	A Hybrid Multi-Criteria Decision Making Approach for Green Supplier Selection	Duman, Vo & Kongar	Cost and Benefit Criteria	Fuzzy TOPSIS and fuzzy AHP	Cosmetic industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2016	New integration of MCDM methods and QFD in the selection of green suppliers	Yazdani, Zolfani & Zavadskas	Quality Adoption, Price, Energy Consumption, Delivery Speed, Green Design, Re-use, Re-cycle Rates, Production Planning	SWARA, QFD and WASPAS	Stainless steel industry
2016	Integrated Fuzzy AHP, ARAS-F and MSGP methods for green supplierr evaluation and selection	Liao, Fu & Wu	Purchase Cost, Quality Service, Technology Capability, Environment Skill, Delivery Performance	Fuzzy AHP, ARAS-F and MSGP method	Watch manufacturing company
2016	Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets	Ghorabaee, Zavadskas, Amiri & Esmaeili	Environmental Pollution and Production, Resource Consumption, Ecological Design, EMS, Commitment Managers to GSCM, Use of Green Technology, Use of Green Materials	Extended WASPAS and IT2FS sets	Empirical Case
2016	Green Supplier Evaluation by Using an Integrated Fuzzy AHP-VIKOR Approach	HakimiAsl, Amalnick, Zorriassatine & HakimiAsl	Price/Cost, Quality, Delivery, Financial performance, Production Flexibility, Innovation Capability, Organizational Culture, EMS, Green Procurement, Pollution	Fuzzy ANP and VIKOR	Electric Power Industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2017	Suppliers' green performance evaluation using fuzzy extended ELECTRE approach	Kumar, Singh & Vaish	Quality, Service, Cost, Flexibility, Green Practice, Environmental Management and pollution control	Fuzzy extended ELECTRE	Automobile industry
2017	Supplier selection and order allocation with green criteria:An MCDM and multi-objective optimization approach	Hamdan and Cheaitou	General and Traditional Criteria	Fuzzy TOPSIS and AHP	Facilities management company
2017	An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment	Qin, Liu & Pedrycz	Green Product Innovation,Green Image,Use of Environmental Technology,Resource Consumption, Green Competencies,Environment Management, Quality Management, Total Product Life Cycle Cost, Pollution Production, Staff Environmental Training	Extended TODIM multi-criteria group decision making method and Internal Type-2 Fuzzy TOPSIS	Automobile manufacturing sector

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2017	Integrated QFD-MCDM framework for green supplier selection	Yazdani, Chatterjee Zavadskas & Zolfani	Environmental and Customer Requirement Criteria	DEMATEL, QFD and COPRAS method	Dairy industry
2017	Towards fuzzy preference relationship based on decision making approach to access the performance of suppliers in environmental conscious manufacturing domain	Sinha & Anand	Environmental Costs, Green Image, Design for Environment, EMS, Environmental Competencies	Multi preference fuzzy relationship based methodology	Two Empirical Cases
2017	Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS	Gupta and Barua	Collaborations, Environmental Investments and Economic Benefits, Resource Availability and Green Competencies, Environmental Management Initiatives, Research and Design Initiatives, Green Purchasing Capabilities, Regulatory Obligations, Pressures and Market Demand	Best-worst method and Fuzzy TOPSIS	Automobile industry

Year	Title of Paper	Author(s)	Dimension(s)/ Main criteria/Aspect(s)	Method(s)/Technique(s)	Sector
2017	Application of novel PROMETHEE-based method for construction of a group compromise ranking to prioritization of green suppliers in food supply chain	Govindan, Kadzinski and Sivakumar	Cost, Quality, Delivery, Environmental Impacts, Technology Capability	Simos procedure and PROMETHEE method	Indian Food Industry

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