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SUSTAINABLE SUPPLIER SELECTION PROBLEM WITH INTEGRATED QFD – ANP APPROACH IN TURKISH TEXTILE & CLOTHING INDUSTRY

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SUSTAINABLE SUPPLIER SELECTION PROBLEM WITH INTEGRATED QFD – ANP APPROACH IN TURKISH TEXTILE & CLOTHING INDUSTRY

(TÜRK TEKSTİL VE HAZIR GİYİM ENDÜSTRİSİ İÇİN KFG VE AAS İLE SÜRDÜRÜLEBİLİR TEDARİKÇİ SEÇME PROBLEMİ)

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TABLE OF CONTENTS

LIST OF SYMBOLS

AHP	: Analytical Hierarchy Process
ANN	: Artificial Neural Network
AAS	: Analitik Ağ Süreci
ANP	: Analytical Network Process
ATC	: Agreement On Textiles and Clothing
COPRAS	: Complex Proportional Assessment
CR	: Customer Requirement
CSR	: Corporate Social Responsibility
DEA	: Data Envelopment Analysis
DEMATEL	: Decision-Making Trial and Evaluation Laboratory
DM	: Decision Maker
DMU	: Decision Making Unit
ELECTRE	: Elimination Et Choix Traduisant La Realité
EMS	: Environmental Management Systems
EUP	: Eco-Design Requirements
FAD	: Fuzzy Axiomatic Design
FAHP	: Fuzzy Analytical Hierarchy Process
FANP	: Fuzzy Analytical Network Process
FIS	: Fuzzy Inference System
FPP	: Fuzzy Preference Programming
FST	: Fuzzy Set Theory
TFN	: Triangular Fuzzy Numbers
GA	: Genetic Algorithm
GATT	: General Agreement On Tariffs And Trade
GDM	: Group Decision Making
GRA	: Grey Relational Analysis
HOQ	: House of Quality
IEEE	: Institute of Electrical and Electronics Engineers
IFS	: Intuitionistic Fuzzy Set
ISM	: Interpretative Structural Modelling
KFG	: Kalite Fonksiyon Göçerimi
LEF	: Luminance Enhancement Film
MADA	: Multi-Attribute Decision Analysis
MCDM	: Multi-Criteria Decision Making
MFA	: Multi-Fibre Arrangement
MOORA	: Multi-Objective Optimisation by Ratio Analysis
NGT	: Nominal Group Technique
ODC	: Ozone Depleting Chemicals
OHSMS	: Occupational Health And Safety Management System
PCB	: Printed Circuit Board

PROMETHEE	: Preference Ranking Organization Method For Enrichment Of Evaluations
RoHS	: Restriction Of Hazardous Substances
R&D	: Research And Development
QFD	: Quality Function Deployment
SOM	: Self-Organising Map
SWARA	: Step-Wise Weight Assessment Ratio Analysis
TA	: Technical Attribute
TBL	: Triple Bottom Line
TFT-LCD	: Thin-Film-Transistor Liquid-Crystal Display
TOPSIS	: Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	: Vise Kriterijumska Optimizacija I Kompromisno Resenje
WASPAS	: Weighted Aggregated Sum Product Assessment
WEEE	: Waste Electrical Electronics Equipment
WTO	: World Trade Organisation

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Focusing environmentally green and socially conscious topics as a manufacturer has major significance in today's highly industrialised world. The governmental regulations, increasing customer awareness towards the environment and society, and the expectations from the manufacturers made companies take actions about sustainability in their in-company and external practices. Companies are not only responsible for their in-company practices but also for their vendors' operations. Supplier evaluation and selection is especially critical for manufacturing companies because of its direct relation with the competitive advantage, quality of the procurement, and its influence on the firm's operations eventually. Environmental and social sustainability have become a very hot topic in textile and clothing industry, since it is the world's second most polluting sector. Fashion industry is a labour-intensive sector, where social role of the firms towards its employees and stakeholders extremely matter. In Turkey textile and clothing industry is the second largest sector with its high contribution to the economy. This study aims to create a generic model for apparel and textile companies that search for environmentally green and socially conscious suppliers in Turkey. The proposed supplier selection model includes conventional criteria as well as environmental and social sustainability parameters since social responsibility and environmental issues emerge today. In order to get the most effective and fitting criteria for the aim, the literature has been reviewed extensively. An integrated Quality Function Deployment (QFD) and Analytical Network Process (ANP) approach is proposed for selecting the most sustainable supplier for a textile company. The proposed methodology is implemented on a real life case study of a Turkish textile company. The proposed framework, which is applicable to Turkey's textile and clothing industry can assist the fashion companies in improving the efficiency of their supplier selection processes.

ÖZET

Son yıllarda üretim endüstrisi çevresel ve sosyal sürdürülebilirlik konuları üzerine yoğunlaşmakta ve bu durum günümüzün oldukça sanayileşmiş dünyası için çok önemli bir pozitif gelişmedir. Hükümet yönetmelikleri, tüketicilerin çevresel ve toplumsal konulara karşı her geçen gün artan farkındalıkları ve üreticilerden beklentileri şirketleri şirket içi ve dışı uygulamalarında çevresel ve sosyal sürdürülebilirlik konularında aktif rol almaları gerekliliğini doğuruyor. Şirketler yalnızca şirket içi uygulamalarından değil; aynı zamanda tedarikçilerin operasyonların da sorumludurlar. Bu hususta, tedarikçi değerlendirmesi ve seçimi; rekabet avantajı ve tedarik kalitesiyle doğrudan ilişkisi ve nihayetinde firmanın operasyonlarını etkilemesi nedeniyle özellikle imalat şirketleri için kritik bir öneme sahiptir. Tekstil ve hazır giyim endüstrisi çevreye ve topluma verdiği zararlar ve kötü etkiler sebebiyle ağır eleştirilere maruz kalmaktadır. Bu nedenle çevresel ve sosyal sorumluluk konuları tekstil ve hazır giyim sektörünün en güncel konusudur. Tekstil ve hazır giyim üretim endüstrisi çevreyi en çok kirleten ikinci sektördür, aynı zamanda emek yoğun bir yapıya sahiptir; ucuz işçiliğin en yaygın olduğu meslek kollarından birisidir. Bu sebeple bu sektörün çevreye, çalışanlarına ve paydaşlarına yönelik çevresel ve sosyal rolü son derece önemlidir. Tüm dünyada olduğu gibi Türkiye'de de en önemli sektörlerden birisi olan moda sektörü, Türkiye'nin ikinci büyük ekonomik sektörüdür ve yüksek yıllık ihracat oranlarıyla ekonomiye katkısı çok fazladır. Bu çalışma, Türkiye'de çevreye duyarlı ve sosyal konularda bilinçli tedarikçi arayan tekstil ve hazır giyim firmaları için genel bir model yaratmayı amaçlamaktadır. Tedarikçi seçimi probleminde geleneksel kriterlerle birlikte çevresel ve sosyal kriterler de birlikte kullanılmadır. Çalışmanın amacı doğrultusunda, en etkin ve uygun kriterleri elde etmek için kapsamlı bir literatür taraması yapılmıştır. En uygun sürdürülebilir tedarikçiyi seçmek için Kalite Fonksiyon Göçerimi (KFG) ve Analitik Ağ Süreci (AAS) yöntemlerini içeren entegre bir model önerilmektedir. Önerilen model uygulanabilirliğini test etmek için model Türkiye'de faaliyet gösteren bir tekstil firmasında test edilmiştir.

Türkiye'nin moda endüstrisi için önerilen modelin, moda şirketlerinin tedarikçi seçim süreçlerinin verimliliğini artırmalarında yardımcı olması amaçlanmaktadır.

1. INTRODUCTION

Industry shapes our current environmental crisis and humans are involved in industry in a variety of ways. Since the beginning of the industrial revolution in the 18th century, population growth has increased dramatically, which resulted in large improvements in people's average quality of life and health (United Nations, 2015). With the increasing needs of the growing population, industries produce much more than the early years of industrialisation. As an outcome of the production, the world is dealing with a lot of environmental problems such as global warming, overflowing waste sites, increasing levels of pollution, diminishing raw materials or social problems such as human rights issues, child labour, discrimination, abuse of labour rights, etc.

Supplier is a core element of a supply chain for corporations. Firms obtain the cost and competitive advantages whereas there is a good relationship between the buyer and supplier (Marufazzaman et al., 2009). Supplier selection is an essential part of establishing a strong supply chain relationship; especially because outsourcing became a really important initiative for the profitability of the businesses. Hence, supplier selection problem has become a popular research area and there are many examples, in which majority of focuses on solving it within a conventional aspect that includes cost, quality, delivery, service and flexibility measures as the decision criteria (Dickson 1966; Weber et al., 1991). Klibi et al. (2010) emphasised that having only the conventional aspect to evaluate suppliers was not sufficient to create a sustainable competitive advantage for a company. There is also a recent focus on the environmental and social aspects in addition to conventional parameters. Winter and Lasch (2016) have studied supplier evaluation problem by using environmental and social criteria. Thus, in order to gain a sustainable competitive advantage, environmental, social and economic aspects should be all included in the supplier selection and evaluation process (Govindan et al., 2015).

Fashion industry as known as textile and clothing industry is chosen as the main focus of the study regarding to the industry. Fashion industry, which includes textile and apparel manufacturing, is one of the most important sectors in the world. Textile and clothing industry is the world second biggest economic sector and its share in the total world exports is 7% (European Commission, 2013). According to a report by the International Labour Organisation (2014), the phase out of Multi-Fibre Agreement has accelerated the outsourcing of the production from west to the east because of the speed and convenience of the production process; consequently, the competition got higher and the prices got lower in the textile and clothing industries. Until the 1980s, in these sectors the production took place relatively close to the end customer, supply bases were regional and the seasonal collections were divided to two (International Labour Organisation, 2014). Currently, the apparel brands present a new collection every week since the consumer trends change in an excessive pace in fashion industry. The competition in the fashion sector got higher and tougher with the raising demands as a result of fast changing trends, the establishment of various number of clothing brands. Today, as a consequent of the mentioned reasons, the seasonal collections exceeded to fifty-two (Gereffi and Memedovic, 2003). Outsourcing production to developing countries increased in order to lower the production costs regarding labour and raw material expenditures. Developing countries have a competitive advantage in textile and apparel manufacturing because of the cheap and skilled labour, and easy access to cheap raw materials.

Beside the economic development of the textile and clothing industry, it is the world's second most polluting sector because of the contribution to the environment (e.g. use of chemical substances in yarn and fabric production, and greenhouse gas production during manufacturing, etc.) and it is also heavily criticised about the sociological problems such as child and forced labour, and unethical work conditions (Jia et al., 2015). Because of fast changing trends and mostly outsourced clothing production, companies regularly require new sourcing and suppliers. As mentioned above, fashion industry criticised in public for social and environmental problems associated with their suppliers (e.g. apparel companies as Walmart, Benetton and Nike), and thus including environmental and social criteria in supplier evaluation and selection is especially significant in this industry (Goebel et al., 2012; Walker et al., 2012; Winter and Lasch, 2016).

Sixty-five sustainable supplier selection articles (published from 2007 to 2017 in international scientific journals available in electronic databases) with a multi-criteria decision making approach (MDCM) are carefully reviewed. Only eight of the studies (13.3%) are applied in textile and/or clothing industry. This indicates that there is a research gap in the literature in the application of sustainable supplier selection problem in textile and apparel industry since it is not widely studied. In order to fill this gap and assist the researchers and managers, who wish to integrate environmentally and socially responsible manner in supplier selection problem in the apparel sector in Turkey, a generic model for apparel and textile companies is created. The model includes conventional criteria as well as environmental and social sustainability parameters since social responsibility and environmental sustainability issues emerge today.

This study considers supplier selection problem as a multi-criteria decision making problem, and thus proposes an integrated QFD-ANP approach as the solution methodology. The proposed methodology translates the 'voice' of the stakeholders (as customer requirements) into decision criteria, and addressed the interlink between the customer requirements and the selection criteria. QFD enables selecting the most appropriate supplier in the direction of the needs of company stakeholders, whereas ANP method is formulated to address the interdependencies among the customer requirements, and to obtain the importance of CRs.

In order to test the applicability of the proposed methodology, it is implemented in a real life case study of a Turkish textile company. The proposed framework, which is applicable to Turkey's textile and clothing industry can assist the fashion companies in improving the efficiency of their supplier selection processes.

The next chapters will follow as to give more insight into the analysis. In Section 2, an extended literature review shows the earlier studies, whereas Section 3 presents the overview on textile and apparel industries, their conflicts, and the improvements. Section 4 presents Turkish textile and Apparel sector with up-to-date facts and figures and analyses them. Section 5 presents the proposed methodology and the steps of the methodology. Section 6 shows the application the proposed methodology on a real-life case study of a textile company based in Turkey. Section 7 represents the obtained results and the discussion, and finally the thesis is concluded in Section 8.

2. LITERATURE REVIEW

Sixty-five articles that published in the international journals and conferences from 2007 to 2017 are reviewed. All the reviewed articles are peer-reviewed academic journals from various publishing agencies. For the investigation of the article review electronic databases such as Elsevier’s Science Direct, Proquest, EconLit, Emerald Publishers, Springer, IEEE, and Taylor & Francis are used. The international journals and conferences belong to various majors that can be classified as in the following: 10 papers of expert systems and applied sciences journals (17.2%), 9 papers of international environment and sustainability journals (15.5%), 9 papers of international economics and management journals (15.5%), 7 papers of international industrial engineering and management journals (11.9%), 6 papers of international production research and planning journals (10.3%), 5 papers of computers and industrial engineering journals (8.6%), 4 papers of mathematics journals (6.9%), 3 papers of international supply chain management and logistics journals (5.1%), 2 papers of international textile journals (3.4%), and 1 paper of mechanical and electronics engineering journal (1.7%).

The keywords that are used in order to make the literature research include green supplier selection, sustainable supplier selection, green criteria, sustainable criteria, sustainable supplier selection in textile industry, fashion industry, and apparel industry. In the analysis the criteria, methods and the industry of the applications are emphasised.

2.1 Sustainable supplier selection problem

The competition in the business among organisations is carried from the individual level to the level of supply chain members at the market. The business relationship among the actors indicates the performance of the supply chain, and thus a distinct consideration must be taken into the strength of the relationship if the overall performance of a supply chain is being evaluated (Noemi, 2012).

According to Jones and Riley (1985), supply chain management handles the overall flow of the materials form suppliers through customers. La Londe and Masters (1994) states that two or more companies should enter into a long-term agreement to establish a supply chain network. Lambert et al. (1998) defines that the actors of the supply chain involves in the purchasing, manufacturing, sales and distribution. Chikán (1997) adds the importance of fulfilling the demand of the customers and satisfying them in the framework of supply chain management.

Above given the definitions of supply chain management from various academics, Noemi (2012) summarises that the main interest of the supply chain management is the achievement and longevity of the supply chain, and as a result, a successful supply chain helps an organisation in gaining competitive advantage among its rivals.

A supply chain consists at least two enterprises. The scope of the supply chain depends on the number of the members involved. Briefly, there are three types of supply chain that is classified accordingly the quantity of its members. They are direct supply chain, extended supply chain and ultimate supply chain.

A direct supply chain is the smallest model that consists only the organisation at the centre, the supplier and the customer in the flow (Nagy, 2008), as shown by the illustration of Mentzer (2001) in Figure 2.1.

Figure 2. 1: Direct supply chain illustrated by Mentzer (2001)

The extended supply chain consists the direct supplier's supplier and direct customer's customer, as well as the direct supplier, organisation and direct customer in the direct supply chain (Nagy, 2008). Fig. 2.2 shows the illustration of an extended supply chain model made by Mentzer (2001).

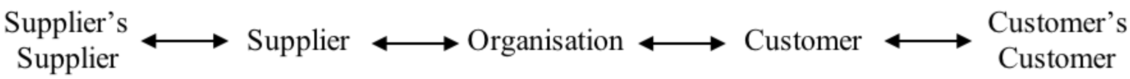

Figure 2. 2: Extended supply chain illustrated by Mentzer (2001)

The ultimate supply chain includes all the actors that participate in the flow of all goods, services, information and capital from the first supplier to the end customer (Nagy, 2008). The additional members are the logistics supplier that is in charge of delivery, distribution and the logistics activities; financial provider that is in charge of the monetary issues such as payments and credit lending; and market research companies that provides market surveys and useful information about the demands of the customers. The extended supply chain is shown in Fig. 2.3.

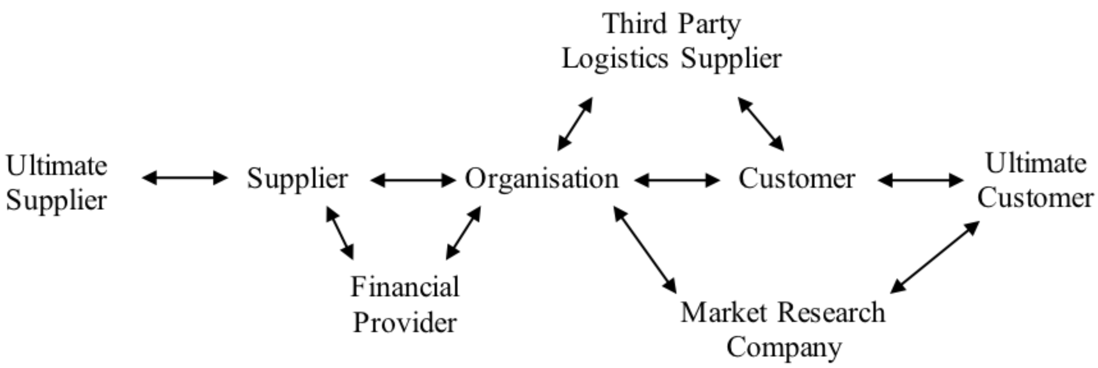

Figure 2. 3: Ultimate supply chain illustrated by Mentzer (2001)

As the actors of the supply chain is explained above, the relationship among these actors have a direct impact on the performance (Cooper et al., 1997). The strength of the supply chains are highly dependent on the relationship among its members. According to Noemi (2012), competitive advantage for an organisation in the market can be achieved through the members of a supply chain. Supplier is the core actor of a supply chain, and thus designing a well-operating supply chain network subordinates with selecting the most appropriate supplier for the organisation. Supplier performance evaluation is the most effective way to the measure the performance of the supply chain.

In the recent years, governmental regulations and awareness of the several stakeholders have urged the firms to take actions in improving environmental and social conditions of both their companies and the supply chains (Sarkis, 1998; Büyüközkan, 2012; Zimmer et al., 2016). The other reasons may have caused to this recent change can be listed as Zimmer et al. (2016) mentioned: rising competition, intensified consumption of the natural resources, desires of the various stakeholders about environmental and social sustainability, and increasing expectations of the customers.

Buyer company should not only pay attention to the lowest costs, the finest quality, the highest flexibility and the fastest delivery but also be prudent about environmentally and socially responsible purchase (Handfield et al., 2002). In this direction, this thesis aims to accomplish these goals by integrating environmental and social aspects to the supplier selection problem. This thesis generates a sustainable supplier selection problem that does not only focus organisational, cost, quality and delivery aspects but also using the environmental and social criteria in choosing the most appropriate supplier.

Supplier selection is a decision-making problem consisting several steps, such as problem definition, formulation of criteria, prioritisation of the criteria and alternatives, and selection (De Boer et al., 2001; Lima-Junior and Carpinetti, 2016). Supplier selection problem is widely studied in the literature. Dickson (1966) was the first academic that published a paper about supplier selection criteria.

Supplier selection problem consists multiple objectives and multiple alternatives. To evaluate the different alternatives, a set of decision criteria, which serves the different objectives of the problem as cost, quality, etc. is established. These multiple criteria, and multiple alternatives make the decision making process very intricate.

Supplier evaluation and selection problems involve both quantitative and qualitative parameters, therefore decision makers assume mathematical models to be quite unpractical (Baskaran et al., 2012). Thus, the practitioners mostly proposed multi-criteria decision making approaches as the solution methodology of the supplier selection problems in order to overcome the vagueness in the judgments and simplification the decision making and the selection process (Jia et al., 2015). In this regard, multi-criteria decision making methods allow decision makers to balance the criteria and to use the interdependency between them (Sarkis and Talluri, 2002; Chan and Chan, 2010; Govindan et al., 2015).

MCDM approaches such as analytical hierarchy process (AHP), analytical network process (ANP), data envelopment analysis (DEA), and fuzzy set theory (FST) may be used as single method approaches or may be integrated one with another, thus give a hybrid approach such as fuzzy analytical hierarchy process (FAHP), data envelopment analysis and analytical hierarchy process etc. From the analysis, it is seen that single methodologies are more commonly used than integrated methodologies. However, integrating methods and proposing a novel hybrid methodology in order to cover the inadequacies of single methods are also popular and provide more objective results.

In the industry-based analysis, it is found out that sustainable supplier selection problem is mostly applied the automotive industry (20%), that is followed by the electronic industry (15%), and fashion and clothing industry (11.6%). Within fashion industry, two out of sixty-five (3.3%) studies are applied in the clothing industry, three out of sixty-five studies (5%) are applied in the clothing industry, and two out of sixty-five (3.3%) studies are applied in textile and clothing industry.

2.2 Single Methodology Approach MCDM Models in Sustainable Supplier Selection

This section shows the single MCDM approaches and fuzzy integrated single MCDM models that are used as solution methodology for the sustainable supplier selection problems. Sixty-five papers are examined; thirty-four out of sixty-five papers (52.3%) used a single MCDM methodology including AHP, ANP, DEA, TOPSIS, GRA, FAD, FIS and/or their fuzzy variations. In single methodologies, the widely used approach is AHP and fuzzy AHP (18.5%). AHP is followed by TOPSIS or fuzzy TOPSIS (10%), ANP or fuzzy ANP (8.3%), GRA (6.7%), DEA (5%), FAD (3.3%), and FIS (3.3%). AHP is found practical in handling both qualitative and quantitative criteria as well as coping with uncertainty and imprecision of decision makers' judgements. However, if there are interdependencies among decision parameters, ANP is preferred since it addresses the interdependencies very well.

2.2.1 Analytical Hierarchy Process (AHP)

Twelve out of sixty-five papers (18.5%) select AHP (single or integrated with fuzzy logic). Four out of sixty-five articles (6.2%) propose single AHP approach, whereas eight out of sixty-five articles (12.3%) propose a fuzzy-based AHP approach.

Noci (1997) is the first researcher used environmental criteria and proposed an MCDM method as solution methodology for the supplier selection process. The paper aims to design a conceptual approach that identifies the selection criteria and assessing the performance of the alternatives. A numerical example is given from automotive manufacturing company.

Lu et al. (2007) propose a multi-objective decision making process for the green supply chain management to evaluate the green suppliers. The model is applied in electronics industry.

Chiou et al. (2008) propose an integrated fuzzy AHP model for selection green suppliers. The aim of the study is to determine the relative importance of multicultural setting including various actors in electronics industries in China.

Lee et al. (2009) propose a FAHP model using the traditional and green criteria. The models applied in electronics industry and Delphi method is also applied for differentiating the criteria.

Chan and Chan (2010) propose a model in the apparel supply chain by applying AHP method in order to bring a solution to the supplier selection problem. A case study is conducted in order to verify the implementation of quick response in apparel supply chains.

Grisi et al. (2010) proposes an AHP approach for sustainable supplier evaluation and fuzzy logic is applied to handle the vagueness of the qualitative human judgement.

Cifci and Buyukozkan (2011) proposes a group decision making (GDM) and fuzzy analytic hierarchy process (FAHP) as a decision framework. FAHP is selected as the methodology in order to strengthen the comprehensiveness of the evaluation process. A case study is conducted in automotive firm in Turkey in order to verify the model.

Ishizaka et al. (2012) introduce an AHPSort method based on AHP method for the supplier selection problem in order to remove the problem of high number of comparisons while using AHP Method. A case study is conducted in advertising industry to test the reliability of the model.

Mani et al. (2014) focus on socially sustainable supplier selection through social parameters by using AHP approach in the decision making. The study shows that manufacturers of electrical, automotive and cement industries were able to select suppliers based on social sustainability criteria.

Mina et al. (2014) propose a two-staged approach to select the green suppliers. In the first step, a fuzzy inference system is used. In the second step, an approach based on Delphi method is used to reduce the criteria and decide the best criteria set. Finally, FAHP is applied to rank and evaluate the suppliers. The model is applied in pharmaceutical company in Iran.

Azadnia et al. (2015) propose a rule-based weighted fuzzy approach and fuzzy AHP model. The parameters are gathered through the pre-processing of suppliers' social, environmental and economic data. The model is applied to a case study in petroleum industry.

Acar et al. (2016) address a supplier selection problem with sustainable and traditional parameters. Twenty-eight experts from the industry assisted with evaluating the decision criteria, and fuzzy AHP approach is conducted to weight the criteria and select the most appropriate supplier for the textile manufacturing company. The findings indicate that green parameters have an impact on the decision environment, however traditional criteria still have the priority in supplier selection.

2.2.2 Analytical Network Process (ANP)

Five out of sixty-five papers (7.7%) select ANP (single or integrated with fuzzy logic). Two out of sixty-five articles (3.1%) propose single ANP approach, whereas three out of sixty-five articles (4.6%) propose an integrated fuzzy ANP approach.

Hsu and Hu (2007) propose an ANP approach for the sustainable supplier selection problem. A case study in an electronics firm is given in the article. The study aims to consider the hazardous substance management guidelines in order to obey the environmental regulations while selecting the desired sustainable supplier.

Hsu and Hu (2009) propose an ANP approach applied as solution methodology for the supplier selection problem in order to address the interdependencies among decision criteria. A case study is conducted in electronic industry to verify the model.

Buyukozkan and Cifci (2011) propose an approach based on fuzzy ANP method within multi-person decision making schema under incomplete information to evaluate alternative suppliers. The model is testes in a real-life case study in white goods industry in Turkey.

Buyukozkan and Cifci (2012a) propose a novel fuzzy ANP approach for the green supplier evaluation and selection with a focus of the components and elements of green supply chain management. Fuzzy ANP is proposed to handle the vagueness of the decision makers' evaluations. The study is conducted in Turkish automotive industry for an automotive manufacturing company.

Galankashi et al. (2015) propose a fuzzy ANP approach as solution method for criteria weights and determine the most appropriate supplier. Nominal Group Technique (NGT) is deployed to extract the most critical performance measures. The study aims to integrate both traditional and green key performance indicators in the selection process.

2.2.3 Data Envelopment Analysis (DEA)

Three out of sixty-five papers (4.6%) select DEA (single or integrated with fuzzy logic). Two out of sixty-five articles (3.1%) propose single DEA approach, whereas one out of sixty-five articles (1.5%) proposes an integrated fuzzy DEA approach.

Kumar and Jain (2010) propose a comprehensive DEA for green supplier selection with carbon footprint considerations. The approach encourages the suppliers go green in order to survive the competition. They use only carbon footprint criteria as decision parameter.

Kumar et al. (2014) propose green DEA with carbon footprint monitoring for evaluating the supplier performance. The study builds on existing DEA model with weight restrictions and dual role factors. A case study conducted in a well-known auto parts manufacturer company based in India.

Azadi et al. (2015) propose a novel integrated fuzzy DEA model for the green supplier selection problem. The findings indicate that the proposed model improve the productivity, and efficiency in uncertain environment with different alpha levels. A case study is conducted in resin production company in Iran to select the appropriate supplier.

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

Six out of sixty-five articles (9.2%) select a fuzzy-based TOPSIS approach as solution methodology.

Awasthi et al. (2010) propose a fuzzy TOPSIS approach that is used for identifying the selection criteria, experts rating and assessments of experts rating. Sensitivity analysis conducted to evaluate the influence of criteria weights on the environmental performance evaluation of the suppliers. The model is applied in logistics sector and is found relatively practical since it may provide a solution under partial lack of quantitative information.

Govindan et al. (2013) propose an effective model based on triple bottom line (TBL) approach for supplier selection operations in supply chains by presenting a fuzzy TOPSIS approach to rank the alternatives and determine the supplier.

Shen et al. (2013) propose a fuzzy TOPSIS approach to aggregate the ratings and measuring the scores of the alternatives. Green criteria are used in this study to select the best green supplier and fuzzy numbers are introduced to quantify linguistic variables. Finally, a sensitivity analysis conducted to check the final decision if it is insensitive to the attributes that are used in the evaluation process. A case study is applied in automobile manufacturing company.

Ozturk and Ozcelik (2014) propose a fuzzy TOPSIS approach for the sustainable supplier problem based on TBL. Fuzzy TOPSIS approach is used for the performance ranking and selection of the most sustainable supplier for an energy company.

Cao et al. (2013) propose a novel approach to green supplier selection problem. The novel approach for making priority of the intuitionistic fuzzy judgement matrix determines the subject weights of criteria. An optimisation model is established to determine the objective weights, furthermore TOPSIS method combined with intuitionistic fuzzy set (IFS) theory helps to prioritise the candidate suppliers. The model is verified in a real-life case study in an electric automobile manufacturing company.

Jia et al. (2015) propose an integrated fuzzy TOPSIS method with sustainability criteria development based on triple bottom line (TBL) for the supplier selection problem in fashion business operations. The criteria include economic, environmental and social perspectives and the developed approach is implemented as a real case study in textile and fashion clothing company.

2.2.5 Grey Relational Analysis (GRA)

Four out of sixty-five papers (6.2%) propose GRA approach (single or integrated with fuzzy logic). One out of sixty-five papers (1.5%) propose single GRA approach, whereas three out of sixty-five papers (4.7%) propose an integrated fuzzy GRA approach.

Chen et al. (2010) propose an integrated fuzzy GRA approach to select the sustainable supplier. The study aims to avoid criteria limitations, therefore applies grey numbers for all criteria and alternatives. Fuzzy set theory is integrated with grey relational analysis (GRA) in the model and a case study is conducted in an electronics company.

Baskaran et al. (2012) propose a grey relational analysis (GRA) approach in textile supply chain. Sixty-three suppliers are evaluated with six sustainability criteria and alternatives are categorised into three categories of "good performer", "moderate performer" and "performance not up to expectation". A case study is conducted in textile and apparel industry in India. The findings of the study include the most critical criterion and the most important criterion for garment manufacturers and ancillary suppliers.

Bali et al. (2013) propose an integrated MCDM approach based on intuitionistic fuzzy set theory and grey relational analysis for green supplier evaluation. The method is selected for the solution because of the vagueness and imprecision of decision makers and subjectivity of decision criteria. A case study is conducted in the automotive industry. The findings of the application show that IFS and GRA can be used jointly for green supplier selection problem in uncertain environments.

Pang et al. (2017) propose a fuzzy grey relational analysis to evaluate and select green supplier in low-carbon supply chain. GRA approach is used to calculate the weights of criteria and membership function of normal distribution is used to compare each supplier. A case study is conducted in the steel industry. The findings include making the localisation of individual green supplier more objectively.

2.2.6 Fuzzy Axiomatic Design (FAD)

Two out of sixty-five articles (3.1%) select fuzzy axiomatic design approach as solution methodology for sustainable supplier selection problem.

Kannan et al. (2015) a FAD approach is used to select the sustainable supplier for a plastic manufacturer firm in Singapore. The approach proves to be an effective method for the analysis and selection of the most sustainable supplier.

Guo et al. (2017) propose a FAD approach to select a green supplier for a global apparel manufacturing company by developing a methodological framework based on the triple bottom line. A sensitivity analysis is also conducted to verify the effectiveness of the model.

2.2.7 Fuzzy Inference System (FIS)

Two out of sixty-five articles (3.1%) select fuzzy inference system approach as solution methodology for sustainable supplier selection problem.

Amindoust et al. (2012) propose a fuzzy inference system (FIS) approach as a solution methodology for the supplier selection problem. The decision criteria are based on three aspects of sustainability (economic, environmental and social). The criteria are weighted by linguistic evaluations of decision makers (DMs). Fuzzy logic is applied to cope with DMs subjectivity. The feasibility of the model is tested on an illustrated example in a drainage solutions company.

Amindoust and Saghafinia (2017) propose a FIS approach as ranking methodology and fuzzy set theory is applied to deal with the subjectivity of the decision makers. A case study is conducted to test the feasibility of the model in a textile manufacturing company and the findings indicate the productivity of the model for determining the most appropriate supplier.

2.3 Integrated Methodology Approach MCDM Models in Sustainable Supplier Selection

This section includes hybrid MCDM models used as solution methodology for the sustainable supplier problem. Twenty-six out of sixty-five articles (43.3%) propose an integrated or novel hybrid model as solution methodology such as integrated fuzzy AHP and TOPSIS methods, integrated ANP and GRA, or fuzzy entropy and TOPSIS, etc. Twenty-eight out of sixty-five papers (46.7%) used an integrated MCDM methodology including various MCDM methods such as GRA and AHP, FANP and PROMETHEE, DEA and AHP, DEA and ANP, AHP and VIKOR, DEMATEL and fuzzy TOPSIS, etc. There are also papers that integrated MCDM methods with different approaches such as genetic algorithm, quality function deployment, artificial neural network, linear assignment method, and nominal group technique.

Li and Zhao (2009) propose an integrated MCDM approach with AHP and GRA methods to evaluate the environmental factors for the supplier selection. AHP approach is applied to determine the weight of factors and GRA approach measures the size of correlation between the two factors. A case study is conducted in electronics company.

Tuzkaya et al. (2009) propose integrated a fuzzy ANP and fuzzy preference ranking organization method for enrichment evaluations (PROMETHEE) approach for the green supplier selection problem. Sensitivity analysis is conducted to analyse the obtained results. In the study ANP method is found as a useful tool to deal with interdependencies among the evaluation criteria, and PROMETHEE is found practical for its easiness in calculation and application. A case study is conducted in a white goods manufacturer company.

Yan (2009) proposes an integrated AHP and genetic algorithm (GA) approach. AHP method is used in order to gain dynamically adjusted weights. GA method used in order to rank the alternatives and select the green supplier. In this approach, the evaluation indicators become more evident and optimised, whereas the system can dynamically adjust over time for a better supplier evaluation indicator.

Kuo et al. (2010) propose an integrated artificial neural network (ANN), and multi-attribute decision analysis (MADA): data envelopment analysis (DEA), and analytical network process (ANP) in order to determine the green supplier performances in a digital products producer company in Taiwan. As findings of article present that ANN-MADA combination provides powerful results in the evaluation process.

Wen and Chi (2010) propose an integrated DEA and AHP approach in order to overcome the limitation of the individual approaches such as AHP and ANP methods. In this model, DEA filters to decrease the number of suppliers being assessed. Then AHP/ANP proceeds more productively on the smaller subset.

Thongchattu and Siripokapirom (2010) propose an integrated AHP and ANN approach. AHP method is applied to structure the green supplier selection problem. ANN is applied at the final stage to have a consensus on the decision making process.

Chiou et al. (2011) propose a utilised decision-making trial and evaluation laboratory (DEMATEL) approach for sustainable supplier selection in order to improve supplier's corporate social responsibility (CSR) performance. A real case study is conducted in an electronics manufacturing company in Taiwan to test the proposed model. The findings include that quality and labour's occupational safety and health management system are the most influential criteria.

Kuo and Lin (2011) propose an integrated DEA and ANP approach for consideration of interdependency between the criteria. The approach provides more flexibility on the number of decision making units (DMUs) used. A case study is conducted in the high-tech industry.

Kuo et al. (2011) propose an integrated fuzzy AHP and Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) approach. Fuzzy AHP used to weight the criteria and VIKOR is used to evaluate and rank the performance of the suppliers. A case study is conducted in a printed circuit board (PCB) manufacturing company.

Azadnia et al. (2012) propose a novel approach called FAST for the sustainable supplier selection problem. Fuzzy Analytical hierarchical process (FAHP) is used to determine the weights for the criteria set. After that phase, SOM neural network clustering technique is used to cluster the suppliers based on the scores. Finally, TOPSIS is applied to rank the clusters of suppliers in order to select the most appropriate supplier. A case study is conducted in the automotive industry in Iran.

Buyukozkan and Cifci (2012b) propose a novel integrated DEMATEL, ANP and TOPSIS approach in a fuzzy context to evaluate green supplier performance. In the study, fuzzy DEMATEL and fuzzy ANP methods are combined together in order to get a more precise analysis within the interdependent relationships of the criteria set. Finally, fuzzy TOPSIS method is used to choose the best alternative. A case study is conducted in the automotive industry.

Orji and Wei (2014) propose an integrated MCDM model for the sustainable supplier selection problem. Fuzzy logic, DEMATEL and TOPSIS methods combined to analyse the interdependencies between the criteria and select the most suitable supplier for the aim. A case study is conducted in a gear manufacturing company and findings indicate that social factors of sustainability are ranked as the most significant factors in the selection problem.

Tsui and Wen (2014) propose an integrated MCDM approach in order to select a green supplier for a TFT-LCD company in Taiwan. The proposed model integrates AHP, elimination et choix traduisant la realité (ELECTRE III) methods and linear assignment method. It consists 4 steps, which starts with assigning subjective criteria weights based on AHP. Next steps are assigning the objective criteria weights based on entropy method, evaluating the performance of the suppliers based on ELECTRE III method, and integrating ranking results of the suppliers and selecting the best alternative.

Zhao and Guo (2014) propose an integrated fuzzy set theory, fuzzy entropy and fuzzy TOPSIS approach for supplier selection. FST is used in order to transfer the linguistic data into triangular fuzzy numbers. Fuzzy entropy weighting method is used to generate weights of the criteria. Finally, fuzzy TOPSIS is conducted to rank the suppliers according to the sustainable factors and select the best performing alternative in the electric power industry in China.

Hashemi et al. (2015) propose an integrated ANP and GRA approach and economic and environmental criteria used jointly for a comprehensive green supplier selection problem. ANP is used to deal with interdependencies among criteria and GRA is modified to deal better with uncertainties in the decision process. A case study is conducted in automotive industry to test the model.

Zhang and Xu (2015) propose a novel integrated approach with hesitant fuzzy distant measures, distance-based comparison method, hesitant fuzzy QUALIFLEX outranking method and fuzzy ELECTRE. These methods are developed to select the most appropriate green supplier for an automotive manufacturing company.

Awasthi and Kannan (2016) propose an integrated fuzzy nominal group technique (NGT) and VIKOR approach. NGT is used for identifying criteria, fuzzy theory is applied for the qualitative rankings for the alternatives. Finally, VIKOR method is applied to generate the rankings for the selection programs in automotive industry in India.

Chen et al. (2016) propose an integrated fuzzy MCDM approach for green supplier selection and evaluation using both economic and environmental criteria. Fuzzy AHP is used to assign the weights of criteria and TOPSIS is used to evaluate and rank the potential alternatives in a luminance enhancement film (LEF) company.

Duman et al. (2016) propose an integrated MCDM method for a green supplier evaluation and selection problem. In the first step, a fuzzy AHP approach is applied to weight the criteria. In the second step, fuzzy TOPSIS method is used to rank the suppliers according to weighted criteria, applied in a plastic closures and dispensing systems manufacturer company. Finally, a sensitivity analysis is conducted to test the influence of weights.

Girubha et al. (2016) propose a comparison of two integrated approaches, which are interpretative structural modelling (ISM) with ANP and ELECTRE II versus ISM with ANP and VIKOR. ISM is used to identify the inter-relationship between the criteria. The output of ISM approach is used as an input for ANP approach. ANP is used to obtain the weights of the criteria. ELECTRE II and VIKOR used in the last phase separately in order to rank the alternative suppliers in an electronic switch manufacturing company in India. The findings of the study indicate that ELECTRE II method gives the single solution (Supplier 2), however VIKOR gives two solutions (Supplier 1 and 2) for the problem.

Liao et al. (2016) propose a new integrated fuzzy technique, which are namely fuzzy analytic hierarchy process, fuzzy additive ratio assessment and multi segment goal programming approach to solve the green supplier selection problem in a watch manufacturing company. The solution approach aims to evaluate the qualitative and quantitative criteria in a more efficient way. The advantage of the model is that DMs can set multiple segment aspiration levels for the problem.

Fallahpour et al. (2017) propose an integrated fuzzy preference programming (FPP) as a modification of AHP and fuzzy TOPSIS approach. In the first step of the research, a questionnaire based survey is conducted to gather the most appropriate main/sub-criteria for a sustainable supplier selection problem in an Iranian textile manufacturing company. In the second step, fuzzy preference programming, which can deal with inconsistency and uncertainty is used to weight the criteria. Finally, fuzzy TOPSIS method is used to rank the suppliers and select the most appropriate one.

Hamdan and Cheaitou (2017) propose an integrated fuzzy TOPSIS, AHP, and multi-period bi-objective and multi-objective optimisation approach. In this study, firstly fuzzy TOPSIS is used to assign two preference weights to each potential supplier according to two separate sets of criteria as traditional and green. Secondly, AHP is used to assign a global importance weight to each of the sets of criteria. Finally, the best supplier is evaluated by using multi-period bi-objective and multi-objective optimisation.

2.4 Integrated QFD and MCDM approaches in Sustainable Supplier Selection

This section presents QFD method that is integrated with one or more MCDM methods. House of Quality of QFD is used for the sustainable supplier selection method in order for the voice of stakeholders to be heard when choosing the supplier. AHP is the mostly commonly combined approach with QFD method in order to rank the stakeholder requirements, and/or alternatives. Eight articles (12.3%), which integrates QFD with MCDM methods in sustainable supplier selection topic, are found that are published between 2007 and 2017.

Ho et al. (2011) propose an integrated analytical approach by combining QFD and AHP to select the most effective supplier. QFD is used to translate the company requirements into decision criteria, whereas AHP is used to weigh the decision criteria and select accordingly the best alternative. Three HOQs are used, to find out the relationship between stakeholders, stakeholder requirements, evaluation criteria and the alternative suppliers. The proposed methodology is applied in a UK-based automobile manufacturing company.

Dai and Blackhurst (2012) propose an integrated QFD-AHP methodology that addresses sustainable supplier selection problem. QFD is used to enable the voice of stakeholders to be heard. Four HOQs are used to develop the relationships among customer requirements, company’s sustainability strategy, sustainable purchasing competitive priority, sustainable supplier selection criteria, and the candidate suppliers. AHP method is formulated to get the weights in the matrices for the first and the last HOQs of QFD. The proposed methodology is applied in a large retailer.

Abbasi et al. (2013) propose an integrated QFD, ANP and mixed-integer programming model to address the sustainable supplier selection problem and network configuration. QFD is applied in order to map the customer attributes into engineering characteristics, and ANP is applied in order to take interrelationships within QFD components into account. Triangular fuzzy numbers (TFN) are also used to deal with the uncertainty in the decision making process. Finally, a mixed-integer programming mathematical model is formulated to consider the network configuration. The proposed method is tested on a real-life case study.

Scott et al. (2013) propose an integrated QFD-AHP method in order to select the strategic suppliers with environmentally and socially responsible manner. QFD is used for different stakeholders that have a say in the company requirements, and for its ability to translate the requirements into evaluating criteria. The model consists of two HOQs of QFD. The first HOQ includes stakeholder groups and their requirements, whereas the second HOQ includes evaluating criteria. The proposed methodology is applied in the UK-based bioenergy industry.

Dey et al. (2015) propose an integrated QFD-AHP methodology that uses three house of qualities in order to demonstrate the supplier performance evaluation. The method starts with establishing a stakeholder group, and weighing the stakeholders by using AHP method. First HOQ helps developing relationship between stakeholders and stakeholder requirements. Second HOQ helps developing the relationship between stakeholder requirements and evaluating criteria. Third HOQ helps developing the relationship between evaluating criteria and candidate suppliers. The model considers both leading factors such as organisational practices, environmental and social factors; and lagging factors. The proposed methodology is applied in a UK-based manufacturing organisation.

Tavana et al. (2016) propose a novel integrated MCDM approach to assess the sustainable suppliers. ANP method is combined with quality function deployment (QFD) method in order to identify a clear hierarchical structure to weight customer requirements and decision criteria. The study is applied in a dairy company in Iran and ranking of the suppliers is made by using MOORA and WASPAS. The study addresses the lack of a systematic approach to analyse specific sustainable development elements and the need for an adequate strategy to deal with reciprocal influence between stakeholder variables and decision criteria.

Yazdani et al. (2016) propose a creative integrated SWARA, QFD and WASPAS approach for the sustainable supplier selection problem. SWARA method to rank the customer requirements, whereas QFD is formulated to translate customer requirements into the evaluation criteria. Finally, WASPAS is used to rank the alternative suppliers. The study is applied in a stainless-steel company in Iran.

Yazdani et al. (2017) propose an integrated DEMATEL, QFD, and complex proportional assessment (COPRAS) approach for the green supplier selection problem. The interrelationships between the customer requirements are addressed with DEMATEL method. QFD model is applied to establish a central relationship matrix in order to find out the degree of relationship between the decision criteria and customer requirements. Finally, COPRAS is applied to rank and select the supplier in a dairy company in Iran.

2.5 Sustainable Supplier Selection Criteria

A criteria-based analysis of the sustainable supplier selection problem literature is conducted to classify the criteria into two groups as conventional, and sustainable supplier selection criteria. Earlier publishing used conventional criteria, however the sustainable criteria began to appear in the literature by the development of new models with the changing trends related to environmental and social sustainability (Baskaran et al., 2012). The findings are given in the following.

For the conventional criteria, quality is the most widely used criterion among the examined papers. Thirty-three out of sixty-five papers (55%) used quality as a decision parameter and it is followed by cost (51.7%), flexibility/service (33.3%), technology (31.7%), delivery (30%), and organisational measures (13.3%). Quality and cost measures are found the most important conventional criteria during the supplier evaluation. Within sub-criteria groups, "rejection rate" and "quality certificates" are widely used as quality sub-criteria (15%), "transportation cost" is widely used as a cost criterion (16.7%), "information sharing" is widely used as a flexibility/service sub-criterion (15%), "capability of R&D" is widely used as a technology sub-criterion (15%), "lead time" is widely used as a delivery sub-criterion (28.3%), and "financial stability and performance" is widely used as a technology sub-criterion (18.3%).

For the environmental criteria, "environmental management systems" is the most widely used criterion among the examined papers. Twenty-five out of sixty-five papers (41.7%) used EMS as a decision parameter and it is followed by pollution (38.3%), green competencies (25%), green image (28.3%), and environmental performance (6.7%). Within sub-criteria groups, "environment-related certificates" is widely used as an EMS sub-criterion (28.3%), "energy consumption" is widely used as a pollution criterion (26.7%), and "green design" is widely used as a green competencies sub-criterion (31.7%).

For the social criteria, "workers' health and work safety" is the most widely used criterion among the examined papers. Eight out of sixty-five papers (16.7%) used "workers' health and work safety" as a decision parameter and it is followed by "CSR" (13.3%), "long working hours" (8.3%), "human rights" (6.6%), and "discrimination" (6.6%).

2.5.1 Conventional Criteria

Conventional criteria for the supplier selection problem include cost, quality, delivery, flexibility, service, technology, and organisational measures.

Cost is taken as the determinant of the final price of the product purchased and may include various costs as raw materials, operation inventory, maintenance, energy, inspection, etc. (Amindoust and Saghafinia, 2017; Fallahpour et al., 2017; Guo et al., 2017; Hamdan and Cheaitou, 2017; Pang et al., 2017; Acar et al., 2016; Awasthi and Kannan, 2016; Duman et al., 2016; Girubha et al., 2016; Yazdani et al., 2016; Azadi et al., 2015; Azadnia et al., 2015; Galankashi et al., 2015; Hashemi et al., 2015; Jia et al., 2015; Kannan et al., 2015; Kumar et al., 2014; Mina et al., 2014; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Tsui and Wen, 2014; Zhao and Guo, 2014; Govindan et al., 2013; Buyukozkan and Cifci, 2012; Chiou et al., 2011; Kuo and Lin, 2011; Chan and Chan, 2010; Grisi et al., 2010; Kuo et al., 2010; Yan 2009; Chiou et al., 2008). Cost is generally taken as a main criterion and may include several sub-criteria such as product cost, product price, transaction costs, transportation cost, freight cost, tariff and customs duty expenses, price/performance value, and compliance with sectoral price behaviour.

Quality criterion has been used widely as well as the cost criteria in the literature (Amindoust and Saghafinia, 2017; Fallahpour et al., 2017; Hamdan and Cheaitou, 2017; Pang et al., 2017; Yazdani et al., 2017; Girubha et al., 2016; Yazdani et al., 2016; Tavana et al., 2016; Acar et al., 2016; Azadi et al., 2015; Azadnia et al., 2015; Galankashi et al., 2015; Hashemi et al., 2015; Jia et al., 2015; Kannan et al., 2015; Mina et al., 2014; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Tsui and Wen, 2014; Govindan et al., 2013; Buyukozkan and Cifci, 2012; Chiou et al., 2011; Cifci and Buyukozkan, 2011; Kuo and Lin, 2011; Kuo et al., 2011; Chan and Chan, 2010; Kuo et al., 2010; Thangchattu and Siripokapirom, 2010; Wen and Chi, 2010; Lee et al., 2009; Li and Zhao, 2009; Yan, 2009; Chiou et al., 2008). Quality is mostly used as a main criterion and may have several sub-criteria such as rejection rate, quality assurance system, quality certificates, capability of quality management, capability of handling abnormal quality, internal audit quality, incoming quality control, and warranties and claim policies.

Delivery criterion is one of the essential main criteria to evaluate the suppliers (Amindoust and Saghafinia, 2017; Fallahpour et al., 2017; Guo et al., 2017; Girubha et al., 2016; Acar et al., 2016; Azadnia et al., 2015; Galankashi et al., 2015; Kannan et al., 2015; Tsui and Wen, 2014; Chiou et al., 2011; Cifci and Buyukozkan, 2011; Kuo and Lin, 2011; Chan and Chan, 2010; Chen et al., 2010; Grisi et al., 2010; Kuo et al., 2010; Yan, 2009; Chiou et al., 2008). Order fulfilment and on-time delivery reliability are counted among the important factors in an efficient supply chain. Delivery criterion may have several sub-criteria such as order frequency, on-time delivery, timeliness, order fulfilment rate, lead time, and stock availability.

Flexibility and service is another criterion that is widely used in conventional supplier selection problems. Flexibility and/or service measures may include compliance with changes in the volume of the production, short set-up time, service capability, and using flexible machines (Fallahpour et al., 2017; Guo et al., 2017; Pang et al., 2017; Duman et al., 2016; Acar et al., 2016; Azadi et al., 2015; Galankashi et al., 2015; Kannan et al., 2015; Orji and Wei, 2014; Tsui and Wen, 2014; Buyukozkan and Cifci, 2012; Buyukozkan and Cifci, 2011; Chiou et al., 2011; Chan and Chan, 2010; Chen et al., 2010; Kuo et al., 2010; Wen and Chi, 2010; Li and Zhao, 2009; Yan, 2009; Chiou et al., 2008). Flexibility and service criterion may have several sub-criteria such as responsiveness, rapid response, maintenance service, after sales service, service attitude, and information sharing.

Technology is also widely used criterion, which includes production facilities and capacities, as well as maintenance and support in order to meet the current and the future demands, capability level of R&D and new product design of the supplier to meet current and future demands (Guo et al., 2017; Duman et al., 2016; Girubha et al., 2016; Liao et al., 2016; Azadi et al., 2015; Azadnia et al., 2015; Hashemi et al., 2015; Kannan et al., 2015; Tsui and Wen, 2014; Öztürk and Özçelik, 2014; Govindan et al., 2013; Buyukozkan and Cifci, 2011; Chiou et al., 2011; Kuo and Lin, 2011; Kuo et al., 2011; Chan and Chan, 2010; Wen and Chi, 2010; Lee et al., 2009; Li and Zhao, 2009). Technology criterion has sub-criteria such as product performance, production agility, capability of R&D management, and capability of design.

Organisational measures as a criterion is also found significant, that may be related to organisational culture and strategical issues, financial situation of the supplier company, the distance of the supplier, the reputation and its management system (Acar et al., 2016; Duman et al., 2016; Azadi et al., 2015; Mina et al., 2014; Buyukozkan and Cifci, 2012; Buyukozkan and Cifci, 2011; Chan and Chan, 2010; Wen and Chi, 2010). It has some sub-criteria found in the literature such as distance, financial stability, industry position and rating, payment term, and internal and out-of-control management system.

2.5.2 Sustainable Criteria

“Sustainable” or as widely used in the literature “green” criteria are divided into two groups as environmental and social criteria. In the recent years, sustainable criteria started to take part in the supplier evaluation and selection problems. Incorporating sustainability layer to an organisation brings strategic benefits as centrality, visibility voluntarism (Spangenberg, 2004; Baskaran et al., 2012). The environmental, and social criteria that appeared in the sustainable supplier selection in the literature between 2007 and 2017 are given in the following in details.

2.5.2.1 Environmental Criteria

Environmental criteria appeared as environmental impact and environmental cost-related criteria. Environmental-cost related criteria is not as popular as environmental criteria itself. Cost-related criteria include cost of producing green product (Tuzkaya et al., 2009), net life cycle cost (Noci, 1997; Lee et al., 2009), cost of component disposal (Noci, 1997; Lee et al., 2009; Kannan et al., 2015), depreciation for improvement (Noci, 1997), cost of pollution effects (Grisi et al., 2010), cost of reverse logistics about green products (Tuzkaya et al., 2009), and environmental costs (Tuzkaya et al., 2009; Azadi et al., 2015; Cao et al., 2015).

Environmental management systems (EMS) as an environmental criterion is the widely used criteria in sustainable or green supplier selection (Amindoust and Saghafinia, 2017; Fallahpour et al., 2017; Guo et al., 2017; Hamdan and Cheaitou, 2017; Acar et al., 2016; Tavana et al., 2016; Azadi et al., 2015; Azadnia et al., 2015; Kannan et al., 2015; Zhang and Xu, 2015; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Bali et al., 2013; Govindan et al., 2013; Shen et al., 2013; Chiou et al., 2011; Kuo and Lin, 2011; Kuo et al., 2011; Chan and Chan, 2010; Chen et al., 2010; Grisi et al., 2010; Wen and Chi, 2010; Lee et al., 2009; Tuzkaya et al., 2009; Chiou et al., 2008). EMS can be defined as the level of environmental management system implementation and environmental protection level.

EMS is generally used as a main criterion and it has various sub-criteria such as environmental policies (Awasthi et al., 2010; Grisi et al., 2010; Kannan et al., 2015; Mina et al., 2014), environmental process planning (Lee et al., 2009; Grisi et al., 2010; Kuo and Lin, 2011; Mina et al., 2014; Kannan et al., 2015), environment-related certificates (Fallahpour et al., 2017; Pang et al., 2017; Acar et al., 2016; Girubha et al., 2016; Liao et al., 2016; Azadi et al., 2015; Cao et al., 2015; Kannan et al., 2015; Mina et al., 2014; Chan and Chan, 2010; Chen et al., 2010; Grisi et al., 2010; Kuo et al., 2010; Thangchattu and Siripokapirom, 2010; Lee et al., 2009; Tuzkaya et al., 2009; Chiou et al., 2008), eco-design requirements (EUP) (Kuo et al., 2010; Kannan et al., 2015; Acar et al., 2016), ozone depleting chemicals (ODC) (Kuo et al., 2010; Azadi et al., 2015; Acaret al., 2016), restriction of hazardous substances (RoHS) (Kuo et al., 2010; Kannan et al., 2015; Acar et al., 2016), waste electrical electronics equipment (WEEE) (Kuo et al., 2010; Acar et al., 2016), eco-labelling (Chiou et al., 2008, Thangchattu and Siripokapirom, 2010; Fallahpour et al., 2017), environmental control (Tsui and Wen, 2014), and continuous monitoring and compliance to government and local rules (Hsu and Hu, 2007; Chiou et al., 2008; Lee et al., 2009; Hsu and H,2009; Chan and Chan, 2010; Chiou et al., 2011; Hamdan and Cheaitou, 2017).

Environment performance evaluation (Chiou et al., 2008; Thongchattu and Siripokapirom, 2010; Cifci and Buyukozkan, 2011; Fallahpour et al., 2017) is another criterion, which includes 2 sub-criteria such as life cycle assessment (Thongchattu and Siripokapirom, 2010; Chen et al., 2010), and waste management (Chiou et al., 2008; Jia et al., 2015).

Green image is also another environmental criterion that has sub-criterion such as green customers (Hamdan and Cheaitou, 2017; Pang et al., 2017; Duman et al., 2016; Girubha et al., 2016; Kannan et al., 2015; Zhang and Xu, 2015; Bali et al., 2013; Shen et al., 2013; Grisi et al., 2010; Wen and Chi, 2010; Lee et al., 2009; Tuzkaya et al., 2009; Chiou et al., 2008; Noci, 1997).

Pollution control is another significant criterion in sustainable supplier selection problem and widely used in the literature. It includes various sub-criteria namely: waste water, air emissions, solid wastes, liquid wastes, gaseous wastes, noise, use of toxic substances, energy consumption, renewable energy, resource consumption, hazardous waste management, and waste disposal (Amindoust and Saghafinia, 2017; Guo et al., 2017;

Acar et al., 2016; Girubha et al., 2016; Tavana et al., 2016; Azadi et al., 2015; Azadnia et al., 2015; Galankashi et al., 2015; Hashemi et al., 2015; Jia et al., 2015; Kannan et al., 2015; Zhang and Xu, 2015; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Bali et al., 2013; Govindan et al., 2013; Shen et al., 2013; Baskaran et al., 2012; Chiou et al., 2011; Kuo et al., 2011; Lee et al., 2009; Tuzkaya et al., 2009; Yan, 2009).

"Green competencies" is an environmental criterion that is defined as control on materials used in the supplied components that reduce the impact on natural sources. It has various sub-criteria used in the earlier publishing such as R&D green products, recycle, remanufacture, reuse, reduce, reverse logistics, green packaging, green logistics, green technologies, green material selection, green purchasing, green warehousing, green design, and cleaner production (Fallahpour et al., 2017; Hamdan and Cheaitou, 2017; Guo et al., 2017; Pang et al., 2017; Acar et al., 2016; Awasthi and Kannan, 2016; Chen et al., 2016; Yazdani et al., 2016; Azadi et al., 2015; Glankashi et al., 2015; Kannan et al., 2015; Mina et al., 2014; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Zhao and Guo, 2014; Bali et al., 2013; Buyukozkan and Cifci, 2011; Buyukozkan and Cifci, 2012a; Kuo et al., 2011; Wen and Chi, 2010; Hsu and Hu, 2009; Lee et al., 2009; Tuzkaya et al., 2009; Chiou et al., 2008; Hsu and Hu, 2007; Lu et al., 2007; Noci, 1997).

2.5.2.2 Social Criteria

Social criterion regarding corporate social responsibility, employment practices and employee relations, local community influence, labour safety and worker health is also accepted as another important factor in the sustainable supplier selection process. Social criterion is used as different criteria and sub-criteria groups.

Widely used social criteria are employment practices (Govindan et al., 2013; Ozturk and Ozcelik, 2014; Tavana et al., 2016), employee rights (Azadi et al., 2015; Girubha et al., 2016; Fallahpour et al., 2017), local communities influence (Govindan et al., 2013; Girubha et al., 2016), contractual stakeholders influence (Govindan et al., 2013), worker health and work safety (Amindoust and Saghafinia, 2017; Azadi et al., 2015; Azadnia et al., 2015; Jia et al., 2015; Mani et al., 2014; Orji and Wei, 2014; Öztürk and Özçelik, 2014; Tsui and Wen, 2014; Govindan et al., 2013; Chiou et al., 2011), occupational health and safety management system (OHSMS) (Chiou et al., 2011; Azadnia et al., 2015), workers' contract, compensation and insurance (Fallapour et al., 2017), training and education at work (Ozturk and Ozcelik, 2014; Azadnia et al., 2015; Fallapour et al., 2017), poverty (Mani et al., 2014), discrimination (Baskaran et al., 2012; Mani et al., 2014; Fallahpour et al., 2017; Amindoust and Saghafinia, 2017), equality (Mani et al., 2014), standard of wages (Chiou et al., 2011; Mani et al., 2014; Fallahpour et al., 2017), long working hours (Chiou et al., 2011; Baskaran et al., 2012; Jia et al., 2015; Amindoust and Saghafinia, 2017; Fallahpour et al., 2017), unfair competition (Baskaran et al., 2012), philanthropy (Mani et al., 2014), human rights (Baskaran et al., 2012; Mani et al., 2014; Jia et al., 2015; Amindoust and Saghafinia, 2017), child and bonded labour (Mani et al., 2014; Jia et al., 2015; Amindoust and Saghafinia, 2017), and ethics (Mani et al., 2014).

Corporate social responsibility (Tavana et al., 2016; Kannan et al., 2015; Öztürk and Özçelik, 2014; Buyukozkan and Cifci, 2011; Kuo et al., 2011; Lee et al., 2009; Tuzkaya et al., 2009; Chiou et al., 2008) is also widely used by the practitioners as a social criterion and it has sub-criteria mostly related to stakeholders and community such as public disclosure of environmental records (Chiou et al., 2008; Kannan et al., 2015), staff environmental training (Zhang and Xu, 2015; Shen et al., 2013; Awasthi et al., 2010; Tuzkaya et al., 2009), relationship with stakeholders and stakeholder rights (Azadi et al., 2015; Kannan et al., 2015; Orji and Wei, 2014; Li and Zhao, 2009; Chiou et al., 2008; Noci, 1997), contribution to community (Chiou et al., 2008), management commitment (Hashemi et al., 2015; Zhang and Xu, 2015; Shen et al., 2013), and respect for policy (Azadi et al., 2015; Kannan et al., 2015; Orji and Wei, 2014)

3. TEXTILE AND APPAREL SECTOR

3.1 Textile Industry Overview

There are three materials in the textile production that are fibre, yarn and cloth respectively. The main steps in textile manufacturing includes production of fibre, converting fibre to yarn, and then converting yarn to fabric, then finishing the cloth. Textile industry is concerned with the design and production of yarn, cloth, clothing, and their distribution. There are two different types of the fibres, which are natural and synthetic (known as man-made) fibres. Natural fibres may be either plant-based (e.g. cotton, flax, etc.) or animal-based (e.g. wool, silk, etc.) while synthetic fibres are produced in the laboratory, that could include polyester, nylon, rayon, etc.

Textile mills and textile product mills are two different bodies in the textile industry. Natural and synthetic raw materials are used and turned into fibre, yarn and thread in the textile mills. Plant-based natural fibre production may include cultivating and harvesting and preparatory process. The processes start with the initial cleaning stage where the impurities of natural fibres removed and the desired texture and durability are given. After this initial stage, spinning stage follows to spin the fibres into yarn. The next steps are weaving and knitting stages, which take place in the weaving mills and knitting mills respectively, in order to turn yarns into cloth. Both mills use complex automated looms and machines. Different fibres require different preparation methods such as retting and dressing or carding and washing, however spinning and weaving are the common processes. The final stage may be finishing, which performed on the yarn or fabric. Finishing stage includes dyeing, printing, bleaching, stone washing etc. that encompasses chemical or mechanical treatments.

It could be done by the textile mill or the finishing mill depending on the facility. Beside the mentioned processes, textile production may include looping, crocheting, knotting, felting, braiding and bonding depending on the type of the fabric produced (knitted or non-woven textiles).

Textile production mills are responsible for turning the raw textiles, which is produced by the textile mills, into the finished products except apparel. The outputs of the textile production mills may include household textiles, industrial textiles and miscellaneous textiles. Household textiles are carpets, rugs, towels, curtains, sheets, cord and twine, furnishings; textiles for industrial purposes may be medical textiles, geo-textiles, agro-textiles, automotive upholstery or applications etc. while miscellaneous textiles may include flags, backpacks, tents nets, cleaning rags balloons, kites and parachutes.

Mechanisation process/industrial revolution: In the beginning of the 18th century, until the industrial revolution, the production of textile was being made with wool, which came from the large sheep-farming areas based at home or cottages. Flying shuttle (invented in 1773) is one of the key inventions, which helped the manufacturing process to speed up. Flying shuttle is the machine that allowed one weaver to use one hand and operate the loom (Williams and Farnie, 1992). The carding machine, spinning Jenny and the water frame were invented one after each other. Later, with the invention of power looms in 1784, which was powered by the steam engines, made the industrialisation happen even faster. Afterwards, cotton mills cropped up all over Great Britain thanks to the mechanised spinning and weaving processes.

3.2 Apparel Industry Overview

Clothing industry or garment industry starts with the textile industry. Clothing industry is known as fashion industry, as well. It is the total work flow that starts with the production of the garments, and includes the commerce, marketing, and sales of the products via fashion retailers and other channels. The raw materials include fabric, sewing threads, buttons, zippers, snaps, trims, etc.

Designers are responsible from designing garments for the collection that can include coat, suits, dress, hat, etc. Fabric and apparel pattern-makers are responsible for converting designers' original models of garments into separate parts in order to make them eligible for manufacturing in mass quantities. Computers are used in order to lay out the parts and draw in details to indicate the position of pleats, buttonholes, or to make adjustments for different sizes if necessary. Textile cutting machine setters, operators and tenders are responsible for preparing the pieces from which finished apparel could be made by using the patterns. Sewing machine operators add the pieces together. Finally, pressers receive a garment after it has been through these steps. Pressers are responsible for eliminating wrinkles and giving shape to finished product. Inspectors, testers, sorters, and samplers inspect finished products to ensure consistency and quality. Many of the manufacturing employees work in teams, where sewing machine operators are organised into production modules.

Along with the mechanisation of the fabric manufacturing thanks to the innovations as powered waterwheels and steam engines during industrial revolution, apparel production shifted to mass manufacturing based on assembly line method. In the 19th century sewing machines emerged streamlining clothing production. Later in the 20th century, educational institutions started to create departments about textiles, clothing and design. The industry, which is consisted mostly of manufacturing employees for the cutting and sewing functions in an assembly line, remains labour-intensive, despite advances in technology and workplace practices. Advanced machinery, use of robotics, computers and computer-controlled equipments for design, pater-making and cutting are the recent developments in the industry.

3.3 Major Events Affected Textile and Clothing Industries

The industrial revolution in the 18th and 19th century as mentioned above caused a major mechanisation and industrialisation in manufacturing. Multi-Fibre arrangement (MFA) under the jurisdiction of General Agreement on Tariffs and Trade (GATT) introduced the quota system as a measure, which allowed developed countries to regulate imports from the developing countries. MFA ruled the world textile and apparel trade between the years 1974 and 2004 (Bhagwati and Hirsch, 2001)

In the Uruguay Round of Multilateral Trade Negotiations, all the negotiations aimed at reaching a mutual agreement on the subject to be applied to the trade of all kinds of goods continued between 1986 and 1993, for 7 years among 123 countries who were the member states of General Agreement on Tariffs and Trade (GATT) (Bhagwati and Hirsch, 2001). At the end of the Uruguay Round, World Trade Organisation (WTO) was established in 1995, decided to put an end to the long life of MFA, definitively on December 31, 2004 (Raffaelli and Jenkins, 1996). It was decided to bring the textile and clothing trade under the jurisdiction of WTO. The WTO Agreement on Textiles and Clothing (ATC) provided for the gradual dismantling of the quotas that existed under MFA and aimed to bring the textiles and clothing sector under the same rules and disciplines applicable to all other industrial products (Bhagwati and Hirsch, 2001).

There are different views on how the competition in textile and clothing industry got extremely challenging and the production shifted to the east while fashion industry and design process stayed in the west. Developing countries have a natural advantage in textile and apparel production since it is labour intensive and they have low labour costs. According to Rosen (2002), the shift from the Keynesian Economic Model to the Neoliberal Economic Model in the United States in early 70s made it emerge to take the advantage of the low labour costs of the developing countries. This model was a more profitable approach for the US trade that supports the idea of opening new markets in the developing countries and expanding the low-cost and low-paid apparel manufacturing in those countries.

That was the most effective model for the financial benefit, simultaneously for the consumers producers and finally the workers. However, the professional economists ignored the role of institutions, power, culture and gender in working economies that the historians and social scientists had pointed. Boston Globe (1999) calls it a new Darwinian Struggle. It refers to the competition dominated by a small number of retailers, textile producers, and apparel manufacturers, the industry is now primarily engaged in a competition that requires reducing the price and expanding the volume of clothing sold to the consumers around the world (Boston Globe, 1999; Rosen, 2002). The high competition that the new economic model has fired, then strengthen by the phase out of the MFA.

4. TURKISH TEXTILE AND APPAREL SECTOR

The Industrial Revolution, which started in the United Kingdom in the 18th century, played a great role in the industrialisation of textile and apparel sector in numerous countries in the world including Turkey (Textile and Apparel Sector Congress, 2015). In the past, the sector was providing raw materials and products for mainly clothing and home textile, however today it also provides inputs for several other industries such as automotive, construction and medical industries (East Marmara Development Agency, 2013). When textile and apparel industries are considered together as one sector, it is one of the most important sectors of today's Turkish economy, in terms of macro-economic variables such as gross domestic product, share in manufacturing industry and industrial production, exports, net foreign exchange inflows that contributes to the economy, employment and investment. Turkish textile and apparel sector is largely export-oriented since the current capacities fairly above than the domestic demand (Ministry of Economy, 2016).

Table 4.1: Share of Textile and Apparel Industry in GDP (Direct effects, WIOD based)

	Added Value (billion TL)	Share in Global Domestic Product (%)
Textile and Apparel Industry	64,8	4,8
Textile Industry	36,4	2,7
Apparel Industry	28,4	2,1

(Source: PGLOBAL, Textile and Apparel Sector Congress Report, 2015)

As seen in table 4.1 above, the total added value created by textile and apparel industries is 64,8 billion TL in 2013. The share of textile and apparel industry in global domestic product, which is reported as 4,8%, is calculated for 2013 by using the data from The World Input-Output Database (WIOD) and Turkish Statistical Institute (TURKSTAT).

4.1 Textile Sector in Turkey

Synthetic yarns and fabrics as well as fabrics made from natural yarns such as cotton, linen, silk and wool are among the raw materials of the industry. The textile sector in Turkey is divided into three categories as home textiles, technical textiles, technical and apparel supplier industry. The industry is capital-intensive where manufacturing can be classified in four main groups as textile production, textile chemical fibre production, textile machine production, textile chemicals and dyestuff production. The production facilities mainly located in Marmara and Aegean region and the cities listed as Bursa, Denizli, İstanbul, İzmir and Uşak. İstanbul, Bursa and Denizli, in particular have developed in towel, curtain and bedlinen production while Uşak is known for its blanket production (Ministry of Economy Home Textile Sector Report, 2016).

After 1950s textile industry became especially one of the most endorsed sectors by the institutions that distribute roles in the international business sector, especially the World Bank. Especially before 1980s, Turkey was constantly emphasized to go from the import substitution accumulation model to a specialisation model in textile and clothing industry and eventually Turkey became one of the leading countries in textile and apparel sector. From 1920s to 1950s, the founding years of Turkish Republic, Turkish textile sector was dominated by the state. Until the start of the synthetic fibre production in the 1950s, textile industry was only based on cotton as raw material. Some firms representing the private sector took the first step in industrialisation with the cotton yarn production in the 1960s in Turkey. Synthetic yarn production began in the 1970s. Turkish textile sector has reached its present strong position by benefiting domestic cotton yield, fast developing synthetic sector with low labour cost, qualified labour force and strong garment industry. Turkey's geographical location, lower freight costs and shorter delivery times add an extra advantage against its strong rivalries in the Far East (Vakıfbank Textile and Apparel Sector Analysis, 1998).

4.2 Apparel Sector in Turkey

In the clothing sector, which consists of the production of garments made from knitted or woven fabrics, apparel products produced in Turkey are mostly cotton based. Raw materials and intermediate goods such as cotton, wool, yarn and fabric are sourced from the domestic market to a large extent and imports are also realised in significant amounts. Although Turkey is the 8th largest producer of cotton in the world, domestic production does not meet domestic demand (Ministry of Economy Apparel Sector Report, 2016).

Apparel sector has a labour-intensive structure in Turkey as well as in the rest of the world. Although the employment rate is high, the average wage is low since the labour supply is excessive. Apparel industry consists of the production of the garment from textile, sales and distribution of the finished garment. The production largely takes place in Istanbul, while other prominent cities in the garment production are mainly in Marmara and Aegean region, however within the framework of the incentive project it is aimed to shift the production to the east of Turkey (İş Bank Apparel Sector Report, 2017). Nearly half of the production costs of the industry consist of the fabric costs, while labour costs correspond to 25% of the production costs (Ministry of Economy Apparel Sector Report, 2016).

The main advantages of Turkish clothing sector are fast delivery, proximity to target markets, technical, social and administrative know-how, experience, wide product range and design capacity. Large companies in the garment industry recently focus on domestic and overseas retailing. Turkish garment industry has a flexible production structure and has been in a position to produce fashionable products with high added value with an ability to adapt fast changing fashion trends (Ministry of Economy Apparel Sector Report, 2016).

4.3 History of Turkish Textile and Apparel Industry

4.3.1 Textile Industry

The first weaving factory was established in Istanbul Feshane in 1835. Immediately after the establishment of the Turkish Republic in 1926, Sümerbank undertook a significant role in industrialising and energising the country's economy by establishing factories in textile as well as in many other sectors. Along with the rising numbers of the textile factories, textile and apparel industry started to meet the domestic demand sufficiently and exports started in the mid-1950s. In the framework of the first (1963-1967) and the second (1968-1972) five-year development plans prepared by the State Planning Organisation, incentives for improving the textile and garment sector were put into practice. In this context, textile and apparel sector continued to play an important role in Turkish economy from the 1980s until the 2000s and has increased its share in exports (Turkey Textile Industry Employer's Union, 2014).

The country holds the advantage of an easy access to the quality raw materials such as cotton and wool and has a great potential of large and cheap labour for decades; therefore, it has been one of the most advantageous sectors of Turkey. The Treaty of Balta Liman in 1838 between the Ottoman Empire and Britain caused Ottoman Empire to lose its power on the commercial monopolies of its domains, at the same time widened Britain's rights to trade freely in the Ottoman Empire. Since back then Britain was leading the textile industry in the world, that indirectly exacerbated the competition and caused Ottoman Empire to not to complete its transition of hand looms to machine production in the industry (Vakıfbank Textile and Apparel Sector Analysis, 1998).

4.3.2 Apparel Industry

Along with the globalisation process that has accelerated since mid-1980s, it is observed that there are significant changes in the world trade volume and especially in the trade of developing countries. In the 1990s consumer trends in price, quality and fashion in the apparel sector started to change. Moreover, production in the apparel sector gained an international dimension and outsourcing in the clothing manufacturing in central and eastern European and African countries began in the 1990s. Production in general began to fracture while the local production figures began to decline.

Turkish apparel industry is an important driving force of the Turkish economy. Before 1995 especially small and medium-sized enterprises were dominant in the industry (is it still the same, make a little research and mention about today's situation). The beginning of the growth in the industry dates back to early 1970s when local demand was increasing and the development of the industry was promoted (Vakıfbank Textile and Apparel Sector Analysis, 1998). The industry, which takes the advantage of low labour cost and cheap raw materials especially cotton, grew rapidly in the 1980s and became an important part of Turkish economy. Turkish garment sector, especially 1990s, has been experiencing a great growth through the reduction of traditional marketing strategies and the fact that Hong Kong's turnaround in the monopoly and market structure of the British has shifted to Turkey, driven by price cuts to boost exports. The proximity to the main markets (USA and EU), and predominantly outsourcing in exports put Turkey to an advantageous position for exports.

4.4 Manufacturing and Employment in Textile and Apparel Sector

4.4.1 Manufacturing

According to the compound annual average growth rates calculated by using the Industrial Production Index published by TURKSTAT (January 2005 figures are indexed to 100) in Table 4.2 below, during the 10-year-period between 2006 and 2014 while the manufacturing industry grew by 3,5% per annum, the textile industry production decreased by 0,4% and the apparel industry production only increased by 0,3% per annum. Eventually, it shows that the share of the textile and apparel industry together in the manufacturing industry has decreased for this period.

Table 4.2: Textile and apparel industry growth trend (2006-2014)

	2006-2007	2008-2009	2010-2011	2012-2014	2006-2014
Manufacturing Industry	6,9	-6,5	12,5	4,5	3,5
Manufacturing of Textile Products	0,5	-12	6,3	2,8	-0,4
Manufacturing of Apparel Products	1,5	-9	5,2	1,9	0,3
GDP	5,8	-2,1	9	4,6	3,8

(Source: PGLOBAL, Textile and Apparel Sector Congress Report, 2015)

Taking into consideration the production trend in the manufacturing sector over the years published by TURKSTAT in Table 4.3a and 4.3b, it is seen that production in the textile industry is decreased by 4,5% and production in the apparel industry is increased by 3% in 2015 compared to the previous year. As a result, apparel industry is ranked as 7th and textile industry is ranked as 15th among 16 sectors in terms of increase in production in 2015 compared to the previous year.

Table 4.3a: Distribution of shares in manufacturing industry by major sectors

Sector	**2014-2013**	**2015-2014 (Jan-Nov)**
Manufacturing Industry Total	3,2	3,7
Food	4,5	1,0
Textile	**1,1**	**-4,5**
Apparel	**0,1**	**3,0**
Leather	-9,8	-10,9
Roots and Petroleum Products	-4,3	35,9

Table 4.3b: Distribution of shares in manufacturing industry by major sectors

Sector	**2014-2013**	**2015-2014 (Jan-Nov)**
Chemical Products	4,6	3,2
Pharmaceutical	14,6	24,6
Caoutchouc and Plastic	3,5	1,2
Stone and Soil Based Industries	1,8	-2,1
Metal	0,4	-0,7
Computer, Electronics and Optical Products	10,0	0,1
Electrical Devices	0,0	0,9
Machinery	2,7	-1,7
Automotive	1,8	15,9
Furniture	6,6	6,9

(Source: TURKSTAT, Textile and Apparel Sector Congress Report, 2015)

4.4.2 Employment

Operating enterprises are often small and medium sized enterprises where the number of facilities is around 35,000. The textile industry provides employment to around 450,000 people and apparel industry employs around 500,000 people in Turkey by the year 2016 (Social Security Organisation, 2016). Due to the great global competition and labour-intensive nature of both sectors, in textile and apparel industry unregistered employment rate is notably high with a value of 44% by 2017. In textile industry, the approximately 450,000 people are unregistered while in apparel industry the number is around 1,5 million people (İş Bank Apparel Sector Report, 2017). The share of textile and apparel sector's employment in total employment is approx. 5,8% over the years (2009-2013). The share of textile industry's employment is 2,4% while the share of apparel industry is 3,3% in total employment. However, the share of textile and apparel industry's employment in total industrial employment is 29,4% on average between 2009 and 2013 (TURKSTAT, Textile and Apparel Sector Congress Report, 2015).

Figure 4.1: Workforce costs in the apparel industry by countries

(Source: Social Security Organisation, shenglufashion, İş Bank Apparel Sector Report, 2017)

Average labour costs are higher in Turkey compared to the leading Asian countries in apparel exports as seen in Figure 4.1 above. The average wages in Bangladesh, where is especially the focus of investments in the sector and many international firms shifted production in the recent years, are very low. However, the rate of increase in wages in China, which is still one of the world's major apparel exporters, is faster than many other Asian countries (İş Bank Apparel Sector Report, 2017). According to Table 4.4, education sector has the highest share of female employment in total employment with 57,8% by 2013. The education sector is followed by the textile and apparel sector with 39,2%. 29% of the total registered textile sector employment and 48,5% of the total registered apparel sector employment constitute female employment (SGK, Textile and Apparel Sector Congress Report, 2015).

Table 4.4: Female employment of the sectors and its share in total employment

Sector	Total Registered Employment	Female (%)	Female Employment
Education	502.169	57,8	290.056
Textile and Apparel	918.496	39,2	359.743
Textile	441.357	29,1	128.251
Apparel	477.139	48,5	231.492
Retail Trade	1.169.771	35,3	412.958
Building and Environmental Regulation Activities	365.916	32,0	117.140

(Source: Social Security Organisation, Textile and Apparel Sector Congress Report, 2015)

4.5 Import and Exports in Textile and Apparel Industry

Between 1920 and 1950, for 30 years Turkey was exporting only fibres while importing yarn, fabric and apparel. Exports of textile products began in the 1950s while clothing exports began in 1970s. The industry in Turkey, which is supported by government incentives and benefited from cheap labour as well as low raw material costs, has developed rapidly. As a result of this development in the 80s and early 90s exports in textile industry improved greatly (Vakıfbank Textile and Apparel Sector Analysis, 1998).

The apparel sector, which is in a net exporter position, provides an average of $14-15 billion net foreign exchange each year and have 10% share in Turkey’s total exports by 2017. The exports of the garment sector recorded a limited decrease of 0.5% compared to the previous year and amounted to $15 billion. Imports, on the other hand, declined 6.3% to $2,5 billion in 2016. Imports of the sector increased by an average of 18% per year in 2002-2016 period. Nevertheless, they are still considerably lower than export figures. Foreign trade balance amounted to $12,4 billion as of 2016 (İş Bank Apparel Sector Report, 2017).

Table 4.5: The list of 6 countries in World Textile and Apparel Exports (2013, $ billion)

Sectors (Billion)	**Textile Industry**	**Apparel Industry**	**Textile and Apparel Industry**
Total World Exports	$305,89	$460,26	$766,15
China	$106,6	$177.4	$284
Italy	$13,5	$23,7	$37,2
India	$18,9	$16,8	$35,7
Germany	$14,9	$18,4	$33,3
Hong Kong	$10,7	$21,9	$32,6
Turkey	$12,2	$15,4	$27,6

(Source: World Trade Organisation, 2013; Report of the Textile and Apparel Sectoral Congress 2016)

According to WTO's 2013 data can be seen in Table 4.5, China, Italy, India, Germany, Hong Kong and Turkey are among the countries with the highest export volume in textile and apparel sector. Turkey is ranked as 5th in world textile exports and ranked as 6th in apparel exports in 2013 (Textile and Apparel Sector Congress Report, 2015, WTO). As of the year of 2016, 6.2% of world exports of knitted apparel category and 4.2% of world exports of non-woven apparel category are provided by Turkey's apparel industry as seen in Figure 4.2 (Source: TURKSTAT).

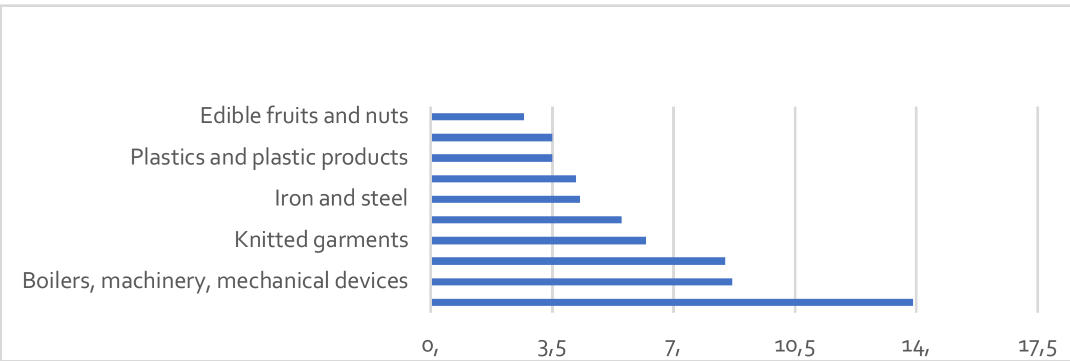

Figure 4. 2: Share of the first 10 exported articles maximum to the total exports, 2016

Approximately 70% of garments produced in Turkey are exported to the European countries as seen in the Figure 4.3 below (Source: TURKSTAT, İş Bank Apparel Sector Report, 2017). The most important competitors of Turkey in the European market are China and Bangladesh. Vietnam is increasing its market share in the United States, which is considered for Turkey as the target market for knitted wear in particular. Apart from the European countries, another important market is Iraq while Iran is also emerging as another target market in the recent years (İş Bank Apparel Sector Report, 2017).

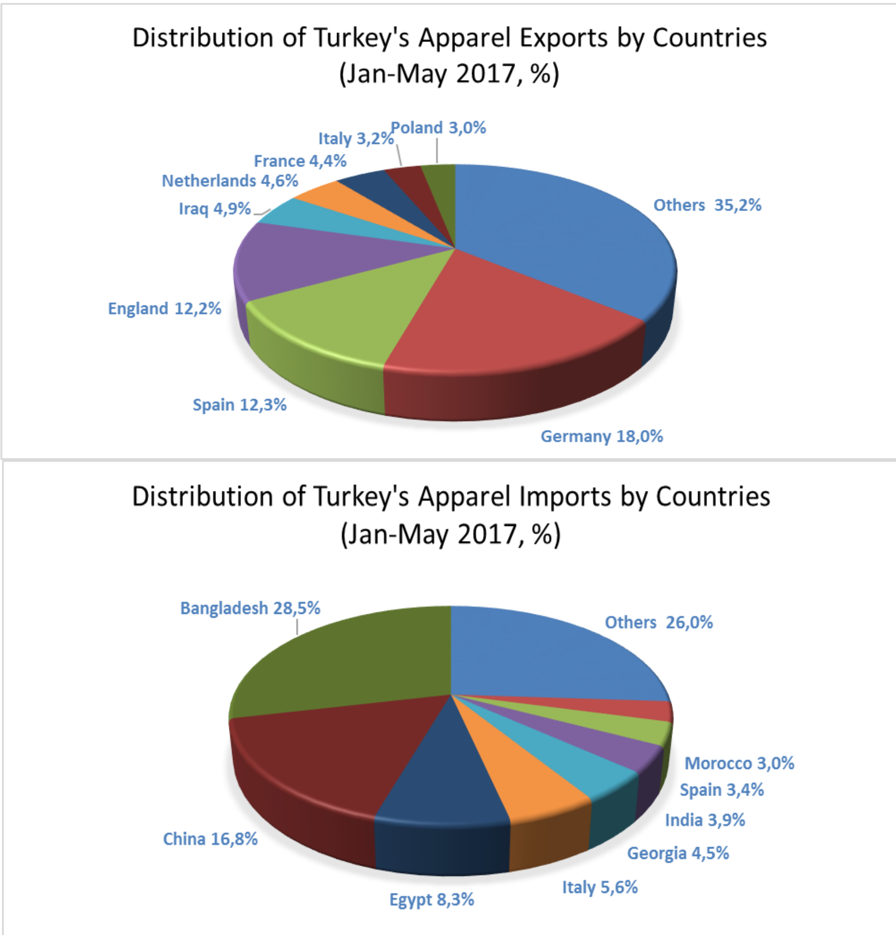

Figure 4. 3: Distribution of Turkey’s exports and imports by countries

In table 4.6, according to International Trade Centre (ITC) data, Turkey is ranked 8th in world’s apparel exports with its $15 billion exports. Moreover, considering the trend in the last 10 years, China’s share in exports has declined, while the share of Bangladesh and Vietnam has increased. Bangladesh's global apparel exports have risen considerably since 2014 (İş Bank Apparel Sector Report, 2017).

Table 4.6: Apparel exports and average growth rate of exports by countries

Country	**2007 (Billion USD)**	**2016 (Billion USD)**	**Annual Average Growth Rate (%)**
China	109	148	3,5
Bangladesh	9	33	15,3
Vietnam	7	25	14,6
Italy	22	20	1,1
Germany	15	17	1,4
Turkey	13	15	1,0

(Source: International Trade Centre (ITC) – Trade Map, İş Bank Apparel Sector Report, 2017)

Comparative sectoral exports and net exports within 2004-2013 showed in Table 4.7. Textile and apparel industries together are ranked as first in terms of both in exports and net exports (Textile and Apparel Sector Congress Report, 2015).

Table 4.7: Comparative sectoral exports and net export figures (2004-2013 total, $1000)

Sector	**Export**	**(Ranking)**	**Net (Ranking)**	**Export**
Textile and Apparel	221.511.507	(1)	123.694.949	(1)
Electro-Mechanical	162.912.459	(2)	-186.898.286	(25)
Iron-Steel	160.663.458	(3)	-71.366.750	(23)
Automotive	137.987.925	(4)	9.700.797	(5)
Mineral Products	78.309.273	(5)	-319.059.082	(26)

(Source: TURKSTAT, Textile and Apparel Sector Congress Report, 2015)

5. METHODOLOGY

5.1 Proposed Approach

The number of articles that address sustainable supplier selection problem and employ more than one method are increasing in the recent years. Moreover, there are high number of studies that considers sustainable supplier selection problem as a multi-criteria decision making problem and combine two or more MCDM methods as the solution methodology in the literature (See in the literature review, among others Chen et al., 2010; Awasthi et al., 2010; Amindoust et al., 2012; Tavana et al., 2016; Yazdani et al., 2017).

Integrating two or more methods may be perplexing because of the fact that single methods have specific features and present reliable solutions if they are adequately articulated together. This could be supported by the literature that 52.3% of the sustainable supplier selection studies (that are published in the last decade) consist fuzzy-based single MCDM approaches (Govindan et al., 2015; Tavana et al., 2016).

Supplier selection problem is a combination of both company requirements and decision criteria. The company that is in search for a supplier is the customer. The choice of the supplier should be in line with the company objectives and strategy, and thus it should satisfy the company requirements. Quality function deployment (QFD) is a method that is widely applied in order for the 'voice' of stakeholders to be heard, and to have an impact on the choice of the alternative. QFD enables translating customer requirements into technical or engineering attributes (Chan and Wu, 2002). QFD is widely applied in various industries in order to develop sustainable product design, provide the customer satisfaction, improve sustainable design process, as well as select the sustainable suppliers (Ho et al., 2011; Dai and Blackhurst, 2012; Scott et al., 2013; Tavana et al., 2016; Yazdani et al., 2016).

QFD is commonly integrated with one or more MCDM methods to determine the relative importance of the customer requirements (CRs) and/or ranking the alternatives. AHP is the most commonly used method that is combined with QFD method in weighing the CRs (Ho et al., 2011; Dai and Blackhurst, 2012; Scott et al., 2013; Dey et al., 2015). AHP builds a hierarchical structure that assumes the components are independent from each other (Buyukozkan and Berkol, 2011). AHP does not consider the potential inner and inter-dependencies among the customer requirements and technical attributes. However, ANP method, which is commonly preferred if there are inner- or inter-dependencies among the components of the network, addresses the interrelationships and feedbacks effectively. ANP enables taking subjective opinions into account, and well-integrated with other approaches (Subramanian and Ramanathan, 2012; Zimmer et al., 2014). ANP is a very responsive tool that is combined with QFD for the supplier selection problem in order to rank the customer requirements in case the interdependencies occur (Abbasi et al., 2013; Tavana et al., 2016).

In this thesis, sustainable supplier selection is handled as a multi-criteria decision making problem; and in order to provide a flexible, yet effective approach to sustainable supplier selection problem, the integration of MCDM methods, namely Quality Function Deployment (QFD), and Analytic Network Process (ANP) is proposed. The proposed methodology considers both the 'voice' of the stakeholders (as customer requirements), and interlink between the stakeholder requirements and the selection criteria. Stakeholder requirements are taken into consideration in order to select a matching supplier in the direction of the needs of company stakeholders through HOQs of QFD, whereas ANP method is formulated to address the interdependencies among the customer requirements, and to obtain the importance of them.

In the proposed methodology QFD method includes two house of qualities (HOQs) to translate the company requirements into decision criteria (HOQ-1) and decision criteria into alternative suppliers (HOQ-2). Two HOQ-model is illustrated in Fig. 5.1. ANP method is applied in order to get the importance of the customer requirement for the HOQ-1.

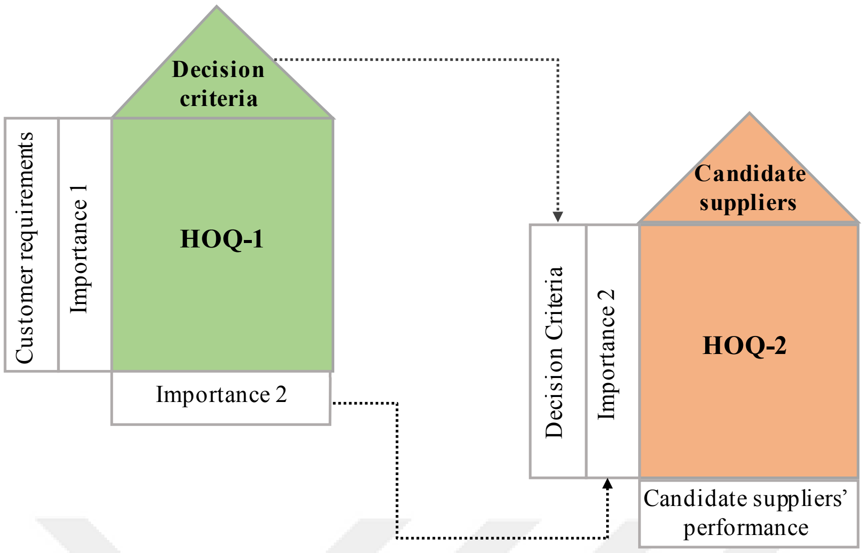

Figure 5.1: The illustration of two HoQ model (adapted from Ho et al. (2011) & Dey et al. (2015))

A five-phase integrated QFD-ANP methodology is designed to achieve these goals. Stepwise illustration of the proposed methodology and all the six phases can be seen in Figure 5.2. in the next page. The phases of the proposed methodology is explained in section 5.4. The proposed approach integrates QFD and ANP for selecting sustainable suppliers. The interdependencies among the stakeholder requirements are addressed using ANP method. The advantage of QFD method is that it considers the relationship between the stakeholder requirements and the selecting criteria since the decision criteria is weighted by translating stakeholder requirements into technical attributes (Ho et al., 2012).)

The proposed methodology is implemented in a real life case study of a Turkish textile company. The integrated QFD-ANP methodology is applied to select the most sustainable fabric supplier among the candidate suppliers for the textile company. The proposed methodology can be also adapted to a similar (apparel producers, fashion retailers, etc.) or different sectors with alike features by rearranging the necessary procedures such as customer requirements, and decision criteria. The remainder of this chapter is organised as follows: The characteristics of QFD and ANP methods are briefly mentioned in the following sections, section 5.2 and 5.3, and the computational steps of the proposed methodology is explained in section 5.4.

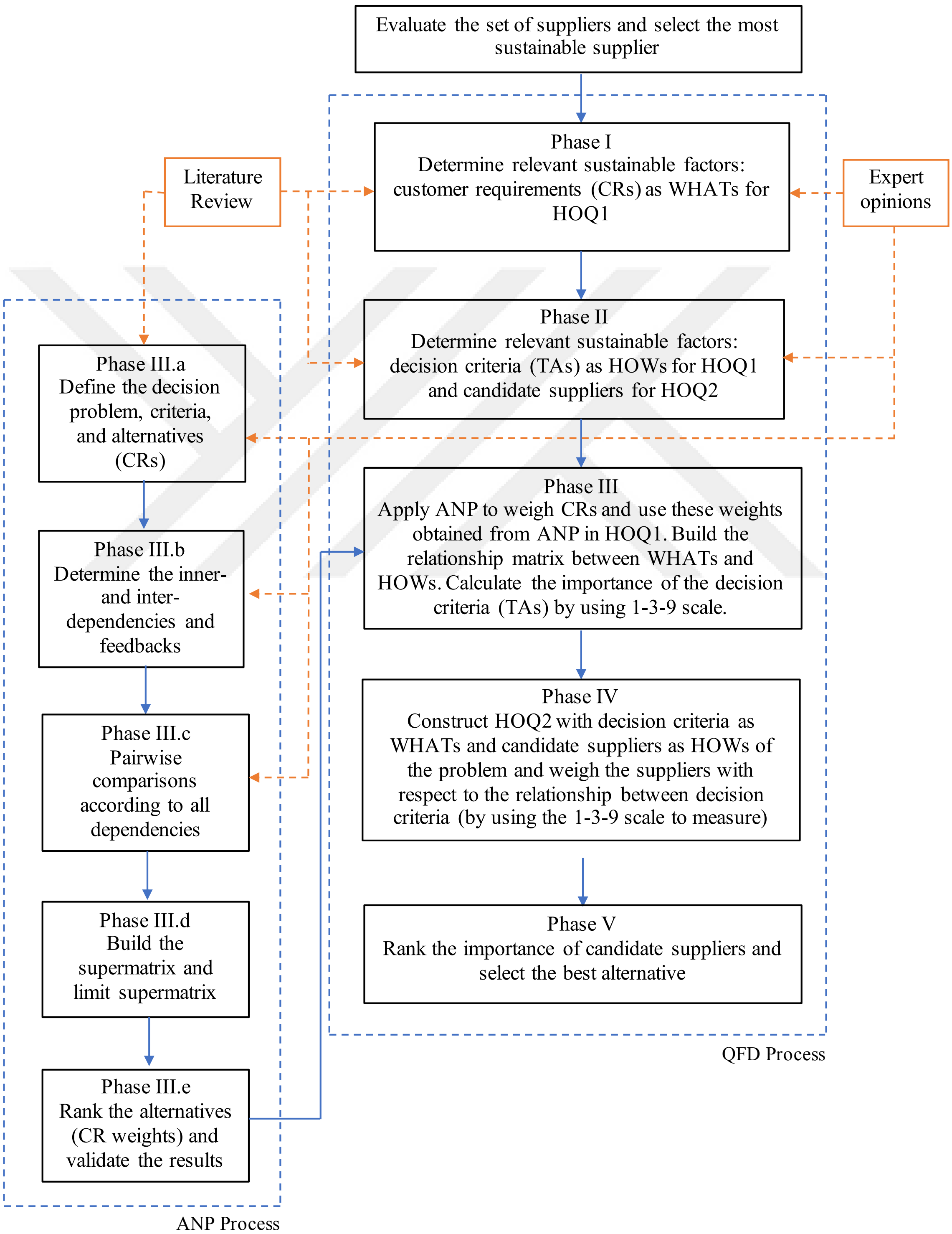

Figure 5.2: Stepwise illustration of the proposed methodology

5.2 Quality Function Deployment

Quality function deployment (QFD) is a systematic approach that is often used by the design teams for the development of new products and services that considers the expectations of the various stakeholders. QFD was developed by Yoji Akao in 1966, and demonstrated at the Mitsubishi Heavy Industries (Sullivan, 1986). The aim of QFD is to make the products and services better and responsive to the requirements of the stakeholders. It starts with identifying the needs of the stakeholders. The requirements of the stakeholders are then translated into design characteristics (Dursun and Karsak, 2013). Four phases of QFD are namely product planning, product design, process planning, and process control. Main advantages of QFD includes the customer satisfaction, shorter lead time, better flexibility, quality promotion, reduced time for marketing and knowledge preservation (Khademi-Zare et al., 2010).

House of quality (HoQ) or planning matrix is the relationship matrix where the interconnection between customer requirements and technical attributes are displayed. House of quality (Hauser and Clausing, 1988) is given in Figure 5.2, and its steps are described in the following (Akao, 1990).

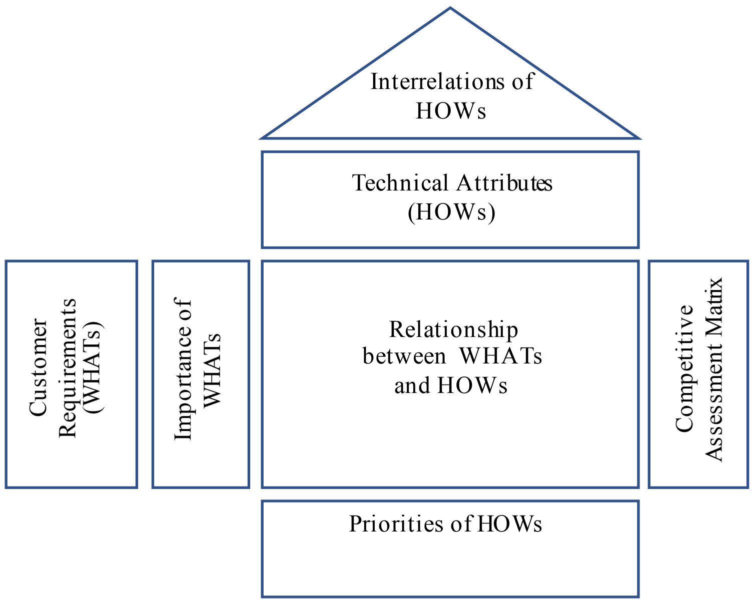

Figure 5.3: House of Quality (HOQ)

i. CRs (WHATs): Customer requirements are also known as voice of stakeholders, customer needs or customer attributes. The first step of constructing HOQ is the collection of customer requirements for the corresponding product or service. CRs guide the designers about the characteristics of the product or service to be developed.

ii. TAs (HOWs): TAs are also known as design attributes, design requirements, engineering characteristics or engineering attributes. HOW is the answer of how the customer requirements will be satisfied, and thus HOWs are closely associated with customer needs. Technical attributes have a highly important role in producing a product or service, which satisfies the needs of the customers.

iii. Importance of WHATs: This part represents the rating or weights of customer requirements (WHATs). The input gathered from the stakeholders must be weighted in order to be able to disqualify comparatively less important needs and have the chance to focus the more important ones.

iv. Relationship between WHATs and HOWs: The relationship matrix is the essential part of HOQ since it demonstrates whether TAs influence CRs, and in which level each TA affects each CR. In this part, decision makers (DMs) are asked to evaluate the relationship. The question might be as "What is the strength of the relationship between the technical attributes and the customer requirements?" A determined scale is used to measure the relationship.

v. Competitive assessment matrix: Comparative position of the company's product or service is analysed in terms of CRs by conducting a competitive analysis of the domestic product with main rival's products. The customers are asked to rank the performance of both products by using a fixed scale.

vi. Interrelations of HOWs: Interrelations of the technical attributes are indicated in the roof matrix of the house. This matrix considers how the TAs impact each other. This part is often not used.

vii. Priorities of HOWs: The importance is calculated for each technical attribute (HOW), also called TA weights. The calculation of the raw weight of TAs by using Eq. (1). The normalised weight of each TA (or the overall importance) calculated by using Eq. (2). This is counted as the last step of the HOQ.

Definition 1 (Tavana et al., 2016):

Suppose that there are *n* technical attributes (TAs) satisfying *m* customer requirements (CRs). The raw score, W_j is calculated by the total of the sum multiplied by the weights of the customer requirement, C_i with the relational strength, R_{ij}. It is given in Eq. (5.1) as follows:

$$W_j = \sum_{i=1}^{m} R_{ij} C_i , \qquad (5.1)$$

where,

W_j the importance or "raw score" of the j^{th} technical attribute (j = 1, 2,..., n);

R_{ij} the relational strength between i^{th} customer requirement, and j^{th} technical attribute (i = 1, 2,..., m; j = 1, 2,..., n);

C_i the weight of the i^{th} customer requirement (i = 1, 2,..., m).

Definition 2:

Suppose that there are *n* technical attributes (TAs) satisfying *m* customer requirements (CRs). The normalised weight, $\widetilde{w}_j$ is calculated by dividing the raw score of j^{th} technical attribute, Wj to the sum of total raw scores. It is given in Eq. (5.2) as follows:

$$\widetilde{w}_j = \frac{W_j}{\sum_{j=1}^{n} W_j} , \qquad (5.2)$$

where,

$\tilde{w}_j$ the normalised weight of the j^{th} technical attribute (j = 1, 2,..., n);

W_j the importance or "raw score" of the j^{th} technical attribute (j = 1, 2,..., n).

5.3 Analytical Network Process

Analytic Network Process is a Multi-Criteria Decision Making (MCDM) approach, which is developed by Thomas L. Saaty, and usually associated with Analytical Hierarchy Process (AHP) (Saaty, 1981; Saaty, 1996). In AHP, the problem is decomposed into a hierarchy. At the top level, the goal of the problem is placed, and the second level is where the criteria stands. If there are sub-criteria corresponding to the criteria, then they are placed in the third level. The last level represents the alternatives. However, in case there are influences or dependencies among decision levels and alternatives, AHP's necessity of the hierarchical configuration is not the optimal option (Kadoić et al., 2017). Hence, ANP allows modelling the interdependencies among decision-making elements, and gives more precise results of the global priorities of alternatives.

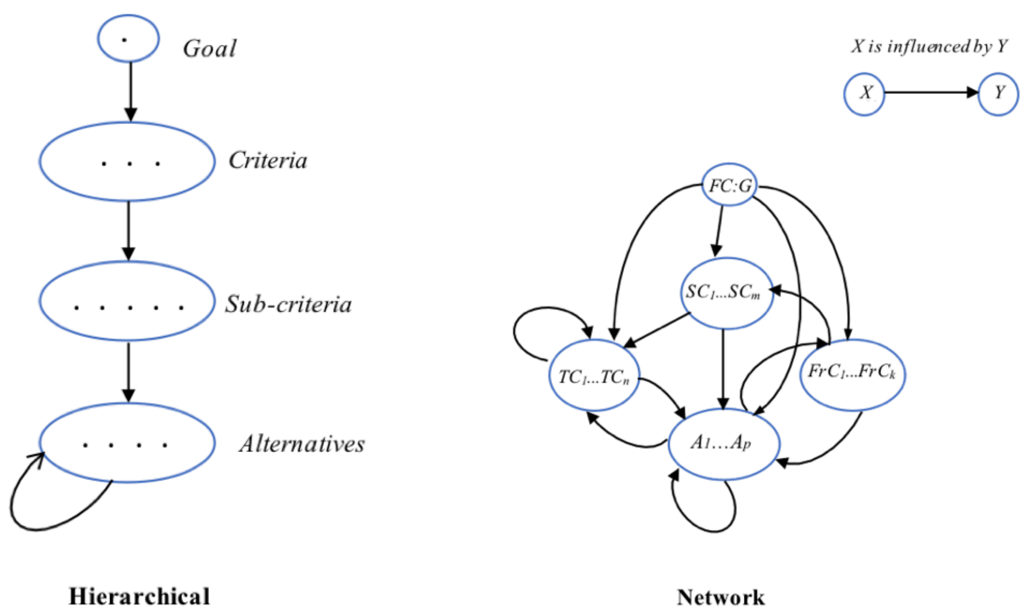

Figure 5.4: The comparison of the structure of a hierarchical and network structures

As a result, the hierarchical form in AHP becomes a network structure as seen in Figure 5.4. The common basic elements in the hierarchy and network are clusters (components), and nodes (elements). ANP can also handle the interactions both within clusters (inner dependence) and between clusters (outer dependence).

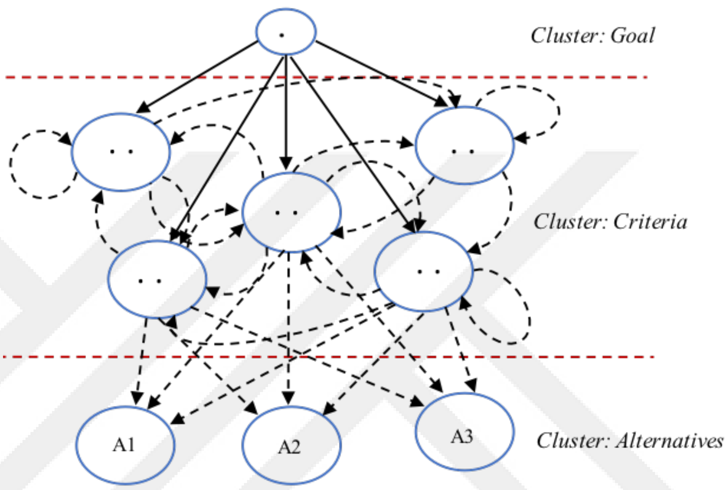

Figure 5.5: ANP structure and control hierarchy of ANP

In the hierarchical structure, 'Criteria' cluster have the elements (nodes) as shown with dots and the arrow shows direction of the influence flow. In the network structure, first cluster 'FC' represents the goal of the problem, second cluster 'SC_1 ...SC_m' represents the criteria that belongs to the second cluster, third cluster 'TC_1...TC_n' represents the criteria that belongs to the third cluster, and final cluster 'A_1...A_p' represents the alternatives cluster. In the network structure, alternatives also appear in a cluster at the same level. Control hierarchy has a critical significance for the analysis in ANP since the questions for pairwise comparisons of the sub-criteria are prepared according to the upper control criteria in the hierarchy. Figure 5.5 shows the control hierarchy of a complex problem in ANP in the following.

The weight coefficients (global priorities vector) of the criteria are obtained by interdependencies between criteria, the special network structure of ANP that considers feedbacks, and by means of getting the limit exponent of the supermatrix. Because of all these properties, ANP is superior to AHP in terms of analytical solution power (Cheng and Li, 2004).

Once the dependencies are determined through the expert opinions and the literature, effect matrix is prepared based on the dependencies. In order to build the supermatrix, pairwise comparisons are made by using the effect matrix of clusters. Pairwise comparisons is made by decision makers that determines the importance of one criterion over another based on the Saaty's 1-9 scale. A block matrix as known as super-matrix is constructed in order to assign the weights of the alternatives by using the eigenvectors obtained from the pairwise comparisons (Shyur et al., 2006). Super Decisions and Office Excel software are both practical tools solve the ANP problems.

Stepwise algorithm of ANP for the selection problem is given in the following (Saaty, 2006).

Step 1 - Define the decision problem: In this step, the aim of the decision problem, decision makers and the aims of the decision makers, criteria, sub-criteria, and the alternatives of the decision problem are defined in a detailed way.

Step 2 - Determine the dependencies: In this step, firstly, the general network of the components / clusters and elements / nodes within the clusters are determined. Secondly, the inner- and inter-dependencies are determined in order to detect the clusters and nodes of the general feedback system. If a cluster affects the node(s) of another cluster, an arrow is drawn from the cluster, which is affected, to the other cluster. This is the phase of the determination of the approach to be followed in the analysis of each cluster or each node.

Step 3 - Pairwise comparisons: In this step, the pairwise comparison are made based on Saaty's 1-9 scale (can be found in Table 5.1). Pairwise comparisons are performed as a group decision making based on consensus over a round table. The comparisons are made between the clusters and nodes that influence each other. Inconsistencies must be taken care of after all the pairwise matrices constructed. The inconsistency ratio is calculated in the following equations (see Eq. (5.3), Eq. (5.4), and Eq. (5.5))

Table 5.1: Saaty's Fundamental Scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favour one over another
5	Strong Importance	Experience and judgment strongly favour one over another
7	Very Strong Importance	Activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute Importance	Importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate Values	Used to represent compromise between the priorities listed above

After all the pairwise matrices built, the eigenvectors or the relative weights, global weight vector, and the maximum eigenvalue (λ_{max}) for each matrix is calculated. Eigenvectors and maximum eigenvalue (λ_{max}) is used to measure the consistency.

Consider X is the eigenvector of comparison matrix A, representing the relative weights of n elements in level k, (i = 1, 2,..., n). Maximum eigenvalue is calculated by using Eq. (5.3).

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AX_i)}{X_i}, \tag{5.3}$$

Compute the consistency index (CI) for each matrix of order n by using Eq. (5.4).

$$CI = \frac{\lambda_{max} - n}{n - 1}, \tag{5.4}$$

Compute the consistency ratio (CR) by using Eq. (5.5).

$$CR = \frac{CI}{RI(n)} \tag{5.5}$$

where RI(n) is known as random consistency index obtained from a large number of simulation runs and differs based upon the order of matrix, n. Table 5.2 shows the list of random index values.

Table 5.2: Random consistency index values

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

If CR value is greater than 0.10, then go to pairwise comparisons, and reduce inconsistencies. If the CR value is smaller than 0.10, then the result is consistent.

Step 4 - Construct the super-matrix: In this step, the supermatrix is constructed by the clusters and nodes, which are vertically on the left, horizontally above according to sequence numbers. In this phase, the priority values obtained from the pairwise comparisons are placed to the appropriate cells of the supermatrix. If there is no influence between the left side node and the upper side node in the supermatrix, ‘0’ is written at the intersection of the matrix. The sum of the values in the same column is equal to ‘1’. Hence, a stochastic supermatrix is obtained.

Step 5 - Build the limit supermatrix: Compute and build the limit super-matrix from which the overall score for the alternatives is restored. Global priorities of the alternatives can be found whereby limit supermatrix is computed.

Step 6 - Selecting the best alternative: Make a final decision as to choose the best alternative or (in this case) to obtain the final ranking of the alternatives.

5.4 Integrated QFD and ANP Methodology

The research objective of this study is to bring a solution to the sustainable supplier selection problem. In order to that, an integrated methodology which includes Analytical Network Process (ANP) and Quality Function Deployment (QFD) is proposed. The integrated approach contains two HOQs of QFD, namely HOQ-1 – translating stakeholder requirements into evaluating criteria, and HOQ-2 – ranking alternative suppliers with respect to the technical attributes (decision criteria). ANP, which is precisely a systematic MCDM approach if there are interdependencies between criteria, sub-criteria and/or alternatives, is used for weighing the stakeholder requirements.

The computational steps of the integrated QFD-ANP approach for sustainable supplier selection are shown as follows:

Phase 0: Define the decision problem. Set the aim of the problem precisely. Conduct a literature research about the problem to review the former studies that can be used as a guide. Determine the group of professionals (including experts from the industry and/or scholars from the academia) that will assist the study with answering questionnaires and providing data and recommendations.

Phase I – (QFD Step 1): Determine the relevant sustainable factors, which are the customer requirements. In this phase, the literature review is considered in order to get a list of stakeholder requirements from the former studies. Customer requirements are the company factors, on which the company base its choice. The experts from the company under investigation are consulted in order to obtain data and identify the specific requirements of the company. A list of customer requirements is formed with respect to the consensus of the decision-making group.

Phase II – (QFD Step 2): Determine the relevant sustainable factors, which are the decision criteria (technical attributes). Technical attributes or the decision criteria are the evaluation factors that is used to rank the candidate suppliers. Decision criteria should be in accordance with the customer requirements. In this phase, the literature review that focuses on the sustainable supplier selection criteria is conducted. An extended list of selection criteria is classified. Decision criteria for the sustainable supplier selection problem in textile and apparel industry is established with the assistance of the experts from the industry and scholars from the academia.

Phase III – (QFD Step 3): Weigh the customer requirements by using the analytical network process method. This phase consists several sub-steps that explains the phases of ANP method (see in the following). The first house of quality (HOQ-1) of QFD method is constructed by using the customer requirements (from phase 1) as WHATs, and decision criteria (from phase 2) as HOWs of the decision problem. The role of the first HOQ matrix is to evaluate the CRs, and then determine the importance of the decision criteria (TAs) with respect to the relationship between the CRs and TAs. The importance of customer requirements that is obtained from ANP method, is placed in the first column of the relationship matrix. The relationship between each customer requirement and decision criteria (TAs), which is called relational strength, is determined by the experts in consensus over a 1-3-9 scale addressing weak, medium, and strong relationship respectively as shown in Table 5.3 (Fung et al., 2002). If there is no relationship, the correspondent cell is left empty and considered as “0” means there is no relationship between the CR and TA. The importance of decision criteria (TAs) is calculated by using the Eq. (5.1), and Eq. (5.2).

Table 5.3: Numerical scale for evaluating the relational strength between WHATs and HOWs

Intensity of reciprocal influence	Definition	Explanation
1	Weak Relationship	The WHAT factor is weakly related to the HOW factor
3	Moderate Relationship	The WHAT factor is moderately related to the HOW factor
9	Strong Relationship	The WHAT factor is strongly related to the HOW factor

Phase IIIa – (ANP Step 1): Define the decision problem for ANP. Determine the goal, criteria, sub-criteria, and the decision makers. The model is established on SuperDecisions Software, and all the computations behind ANP are made by the software.

Phase IIIb – (ANP Step 2): The general network of ANP problem is established. Customer requirements are divided into criteria clusters in order to build the general network of the components. All the inner- and/or interdependence between the clusters and nodes are determined by the assistance of the literature review and the experts. Decision is made by having a consensus as a group.

Phase IIIc – (ANP Step 3): According to the inner and inter-dependencies between the clusters and nodes, pairwise comparisons surveys are established. Pairwise comparisons are made by the group of experts by using Saaty's 1-9 Scale. Inconsistencies are taken care of after all the pairwise matrices constructed. The consistency ratio is calculated in the following equations (see Eq. (5.3), Eq. (5.4), and Eq. (5.5).). The consistency ratio is checked whether it is smaller than 0.10. The supermatrix is built with respect to pairwise comparisons.

Phase IIId – (ANP Step 4): First, the weighted supermatrix, and then the limit supermatrix is constructed by using the priority values obtained by the pairwise comparisons. The limit supermatrix gives the overall score for the clusters and nodes.

The sum of the values in the same column is equal to '1'. Hence, a stochastic supermatrix is obtained.

***Phase IIIe – (ANP Step 5*):** Construct the limit supermatrix from which the overall scores for the customer requirements is restored. Global priorities of the customer requirements can be found whereby limit supermatrix is computed.

Phase IIIf – (ANP Step 6): Obtain the rankings and weights of the customer requirements. Conduct a sensitivity analysis to check the result.

Phase IV – (QFD Step 4): The second house of quality (HOQ-2) of QFD method is constructed by using the decision criteria (TAs) as WHATs, and candidate suppliers as HOWs of the problem. The role of the second HOQ matrix is to evaluate the candidate supplier, and then determine the importance of them with respect to the relationship between the TAs and candidate suppliers. The importance of decision criteria that is obtained from the first HOQ, is placed in the first column of the relationship matrix. The relationship between each decision criteria (TA) and the candidate supplier (the relational strength) is determined by the experts in consensus over a 1-3-9 scale addressing weak, medium, and strong relationship respectively as shown in Table 5.3. If there is no relationship, the correspondent cell is left empty and considered as "0". The importance of the candidate suppliers is calculated by using the Eq. (5.1), and Eq. (5.2).

Phase V – (QFD Step 5): In this phase, the alternatives are ranked and the best supplier that provides the requirements of the customer and the decision criteria is chosen.

6. CASE STUDY

In this section, the proposed methodology is applied in a real-life case study. The case study has been carried out in a Turkish textile manufacturer company, which is specialised in its field and operating actively in Istanbul area of Turkey. The company, which does not allow the use of company name in this thesis because of the company policy, will be named as XYZ Company in the following sections.

For the application of the proposed methodology, the customer requirements, and decision criteria are determined by benefiting the literature review, the opinions of the experts in XYZ Company, and the experts from the academia. The determination is made based on the group decision making on a consensus around a round table. ANP method is used for ranking the customer requirements, and QFD method is used for ranking the decision criteria (technical attributes) and evaluating the candidate suppliers by the experts in the company.

6.1 Case Company

XYZ Company is textile processer and producer company, which belongs to a Turkish Corporate Group. This Corporate Group has in total five companies that operate in various sectors including one jean producer (apparel company) and a logistics company. XYZ company was founded in 1997 by the aforementioned corporate group. XYZ Company is notably active in Turkish, and especially European market with a more than 20-year-long experience. XYZ company is a textile company, which is specialised in fabric production, processing, and supplying to its customers.

XYZ is a pioneer company, which is popular and preeminent in its field. It supplies printed and processed textiles to major and local brands in Europe.

There are major fashion retail brands such as Guess, Marks and Spencer, H&M, Esprit, Topshop, Zerres, and Inditex Group among its customers. The sector to which XYZ Company is affiliated may be referred as the intermediate sector or subsidiary industry, since the operations are quite specific and requires technical expertise. As a consequence of being involved in highly technical and specific sector, XYZ is distant from the overwhelming rivalry in textile, apparel and fashion sectors. Nevertheless, XYZ is an innovative company with a focus on its R&D department that follows the technological developments and changing trends in fashion in order to satisfy the desires of its customers ideally. XYZ launches new collection of textiles every season, follows the fashion and design fairs within Turkey and abroad regularly and participates them actively in order to keep pace with the changing demands and customer satisfaction.

Regarding the technical operations of the company: The procedures applied to the fabrics can be listed as 3D and classic foil printing onto fabric, fabric coating, rotary printing on fabric, digital transfer, and digital printing. Types of fabrics that is used for abovementioned procedures include indigo dyed fabrics, jacquards, lyocell fabrics, viscose fabrics, and the special fabrics made of high quality yarns. In addition to textile processing, XYZ also undertakes the finishing of raw fabrics that are supplied by renowned domestic fabric producers located in Gaziantep and Kahramanmaraş.

The XYZ Company has a company policy, which is not to compromise on quality, to satisfy the desires of the leading fashion brands, and to be able to get the competitive advantage among its potential rivals in its field. Having all the required ISO quality certifications, the company is also sensitive about the environment. Moreover, XYZ holds worldwide recognised environment-related certificate, Oeko-Tex and the organic textile certificate, Global Organic Textile (GOT) documents, and regular inspections related to these certifications are being held. XYZ also considers workers' health and work safety, and has completed the necessary regulations and certifications. Thus, XYZ hires a fulltime specialist, who is in charge of work safety. XYZ, as a principle, is against the child labour, and does not employ workers under the age of 18.

Since XYZ Company is specialised in fabric processing, it needs to collaborate with various suppliers for all the required fabrics, printing utensils, and painting materials. The company usually takes the advantage of the international and national fairs to meet the potential suppliers. Subsequently, XYZ conducts a further research about the potential suppliers. However, XYZ does not use a distinct method to evaluate and select its suppliers, The selection is done based on the experience and references. In this case study, selecting the sustainable fabric suppliers for XYZ Company is taken into consideration. There are five different fabric suppliers, which will be evaluated by using the integrated ANP and QFD methodology. Supplier 1 and Supplier 5 are Italian companies, based in Italy, and the Supplier 2 is a Romanian fabric producer, based in Romania. Supplier 3 and Supplier 4 are Turkish producers, based in Turkey.

6.2 Application Steps of Proposed Methodology

The application steps of the proposed methodology for sustainable supplier selection problem for the case company of this thesis, XYZ Company is given in the following.

Phase 0: The definition of the decision problem, the goal of the problem and decision makers are explained in the following. The proposed methodology, which is explained in Section 5.1 is applied.

i. Decision Problem: The decision problem of this case study is finding a sustainable fabric supplier for the case company, XYZ. There are several candidate suppliers, and the most sustainable supplier among the alternatives must be determined and selected.

ii. Goal of the problem: The goal is to select the most sustainable alternative, which provides both the various requirements of XYZ Company and decision criteria or technical attributes (TAs) effectively.

iii. Decision makers: The group of professionals that contribute the study with their expertise are determined. They are in total three experts, who are two experts from the industry and a scholar from the academia; one of the experts works in XYZ Company, and responsible for the overseas fabric purchasing and planning specialist; the other expert is from the apparel sector with experience in the fashion supply chain, quality and production departments as a director.

Phase I – (QFD Step 1): This phase is the first step of QFD. The customer requirements, which is the company requirements in our case, are determined. The experts from the company are consulted in order to get the customer requirements. The list of the customer requirements and their explanations are given in Table 6.1 in the following.

Table 6.1: The list of the customer requirements and their explanation

Aspect	**Customer Requirement**	**Explanation**
Cost	Affordable Price	The cheapest price for the product purchased without compromising the quality
	No Cost in Customs Duty	Low cost or no cost in the customs duty if the product purchased is transported from abroad
Quality	High Quality	The finest quality of the product purchased in terms of raw materials, durability, safety etc.
	Quality Certificates	Certified quality documentation that the supplier should provide regarding the quality
Delivery	Delivery Speed	The shortest delivery time of the product purchased after ordering
	On-Time Delivery Rate	Delivery of the products purchased on time as per the agreement between the parties
Flexibility	High Flexibility	The highest flexibility of the supplier regarding the changing conditions
	Rapid Response	The fastest response and adaptation to the changing conditions
Sustainability	Environmental Commitment	The highest awareness and commitment about the environmental sustainability
	Environmental Certificates	Certified environmental sustainability documentation that the supplier should provide
	Ethical and Fair Treatment to its Employees	Supplier is sensitive about ethical and fair treatment to its employees regarding the employee rights, labour health and work safety, assisting employees with continuous education, and controlling underage or forced labour, etc.

Phase II – (QFD Step 2): The evaluation factors, which is the decision criteria (technical attributes) in our case, are determined. Decision criteria (TAs) are in accordance with the customer requirements. The literature is reviewed in order to classify the conventional and sustainable criteria that is used in the sustainable supplier selection studies between 2007 and 2017. A hundred and thirty selection criteria is found in the literature (see all selection criteria and regarding references in Appendix A). The decision makers are consulted in order to determine the decision criteria and indicators with a consensus. The list of the decision criteria (TAs) and their explanations are given in the following tables, Table 6.2.a – 6.2d.

Table 6.2a: The list of the decision criteria and their explanation

Decision Criteria	Definition & Indicator
Business Aspect	
Product price	Purchasing price of unit of product or material that supplier provides. The indicator of this criterion is the lowest product price without compromising the quality.
Logistics cost	Logistics costs include handling and packaging costs, transportation costs and the tariffs and customs duty expenses. Transportation may be done by rail, road, sea or air (road/rail transportation, shipping or air cargo). Tariff and customs duty expenses occur upon the agreement between the parties. In some cases, supplier may take the responsibility of the expenses, thus the buyer is not obliged to pay any customs duty. Customs duty expenses are out of question if the buyer purchases the goods from a domestic supplier. The indicator of this criterion is the lowest cost of logistics.
On-time delivery	Delivery of the goods and services on time as per agreement between the supplier and customer. The indicator of this criterion is the ratio of following delivery schedule for each supplier.
Lead time	Time between placing a “materials order” and receiving materials. The indicator of this criterion is the lead time per the unit of an order for each supplier.

Table 6.2b: The list of the decision criteria and their explanation

Decision Criteria	Definition & Indicator
Business Aspect	
Inventory performance	The process of productively overseeing the constant flow of units of products ordered, stocked and sold in order to satisfy demand without excess expenditure. Inventory performance of a supplier can be measured with the inventory turnover ratio of the suppliers. Inventory turnover ratio is the indicator of the inventory held by the supplier in contrast with the sales.
Convenience of logistics process	The service level of the logistics indicates the ease of the process that may differ from one supplier to another depending on the agreement between both parties. For instance, if the supplier provides entire transportation service and customs duty related expenses/affairs itself, it enables a certain convenience for the buyer.
Flexibility of the supplier	Flexibility means the compliance with product volume changes, responsiveness to the changes, service capability number of tasks performable by a worker, using flexible machines, the demand that can be profitably sustained.
Industry position and reputation	The position in industry (including production leadership and reputation among the peers) along with financial position and credit rating of the supplier. It can be measured with the portion in the market of each candidate supplier.
Payment term	Terms under which buyer will pay the supplier for purchases, calculation of the due date based upon the date of the purchasing activity. Since extended payment terms increase company's working capital and reduces the need for corporate loans, the longest payment term is taken as the best option.
Quality Aspect	
Reject rate	Rejection occurs when defective parts detected because of the quality problems. It can be measured with the number of total rejected parts per total numbers of products delivered from the supplier.

Table 6.2c: The list of the decision criteria and their explanation

Decision Criteria	Definition & Indicator
Quality Aspect	
Quality certificates	Having quality certificates provides a formal recognition as well as assurance of the product and service that a supplier provides. Quality certifications (e.g. ISO 9000 family) bring a value to the organisation and also helps the supplier gain the buyers retention, trust and loyalty.
Warranties and claim policy	Existence of warranties and claim policies are provided by the supplier or agreements between the customer and the supplier for the faulty products.
Capability of R&D	The capability level of the research and development department in the company, can be measured with how much proportion of R&D accounted for sales revenue.
Environmental Aspect	
Compliance with environmental policies, and governmental rules	Compliance level of the supplier with the environmental policies, governmental and local rules and regulations.
Environment-related certificates	Holding environment-related certificates such as ISO 14000, ISO 14001 etc. An extended list of environmental and organic-product certificates can be found in Appendix B.
Use of toxic/restricted substances	Control or avoid the usage of toxic chemicals in processes as cultivation, and production process, etc. Being transparent about sharing information regarding the use of restricted substances.
Recycle/Reuse/Remanufacturing	Ability to treat the used products or their accessories, to reprocess the materials, and to replace the required new materials when producing new products. Remanufacture and reuse of products after service life. Ability to obtain the used products and their related accessories.
Green packaging	Recyclable and/or environment friendly material for packing, minimal packing in order to avoid unnecessary consumption
Green purchasing	Purchase of environment-friendly raw materials.

Table 6.2d: The list of the decision criteria and their explanation

Decision Criteria	Definition & Indicator
Social Aspect	
Occupational Health and Safety Management System (OHSMS)	There are two influencing factors can be listed for this criterion, which are the level of implementation of OHSMS.
Employee rights	The rights of employees regarding their decision of whether to associate or not to associate with any group. It assess any activity of supplier interfere towards obstructing or preventing the employee activities.
Continuous training and education	This criterion influenced by three factors that can be listed as the average hours of training per year per manager (ATM), average hours of training per year per personnel (ATP), and the number of created job opportunity (NJO). The facility should provide the continuous training and education for the employees.
Equality	All the workers are treated equally and given the same opportunities regardless their age, race, sexuality, and gender. This also include equality in recruitment, promotion, payment, and working conditions.
Standard of wages	Compliance with the standards set but the governmental legislations. It is the standard of wages against man hours spent.
Child and forced labour	Control the underage/child or forced employment in business operation. Legal minimum age for being employed should be taken into consideration in the hiring process.

Phase III – (QFD Step 3): Customer requirements (CRs) are weighted by using the analytical network process method. The first HOQ is constructed using CRs as WHATs and TAs as HOWs of the problem after the weights of CRs are obtained from ANP method. The steps of ANP method is explained in the following *Phase IIIa* until *IIIf*. *Phase III* continues after the implementation of ANP steps.

Phase IIIa – (ANP Step 1): The definition of the ANP problem, the goal, criteria, sub-criteria, decision makers are explained in the following.

i. Decision problem: The decision problem of the ANP phase is to rate the sub-criteria (CRs) and obtain the weights of customer requirements in order to use them in HOQ-1.

ii. Goal of the problem: The goal is to evaluate the customer requirements for sustainable supplier selection and obtain the importance of each customer requirement.

iii. Decision makers: Decision makers for the pairwise comparisons are two experts from XYZ Company.

iv. Criteria and sub-criteria: Customer requirements are divided to criteria and sub-criteria components in order to build the network model. Five main criteria of the problem are cost, quality, delivery, flexibility, and sustainability, whereas eleven sub-criteria of the problem are affordable price, no cost in customs duty; high quality, quality certificates; delivery speed, on-time delivery rate; high flexibility, rapid response; environmental commitment, environmental certificates, and ethical and fair treatment to its employees, respectively (see in Table 6.1 in Phase I).

Phase IIIb – (ANP Step 2): Given the relevant criteria and sub-criteria, the general network of ANP problem is established. All the inner and inter-dependencies between the clusters and nodes are determined by the assistance of decision makers and the literature review. Feedbacks, inner- and inter-dependencies are represented by the arrows among the clusters. The direction of arrow signifies dependence. The network model with all dependencies and feedbacks can be seen in Fig. 6.1. The outer dependencies can be briefly explained as: Quality is influenced by cost and sustainability clusters, this is an example to the feedback since cost and sustainability clusters both are also influenced by quality, as well. All the clusters have inner-dependencies as seen from the loop arrow. Flexibility and delivery clusters have also feedback that means they both influence each other.

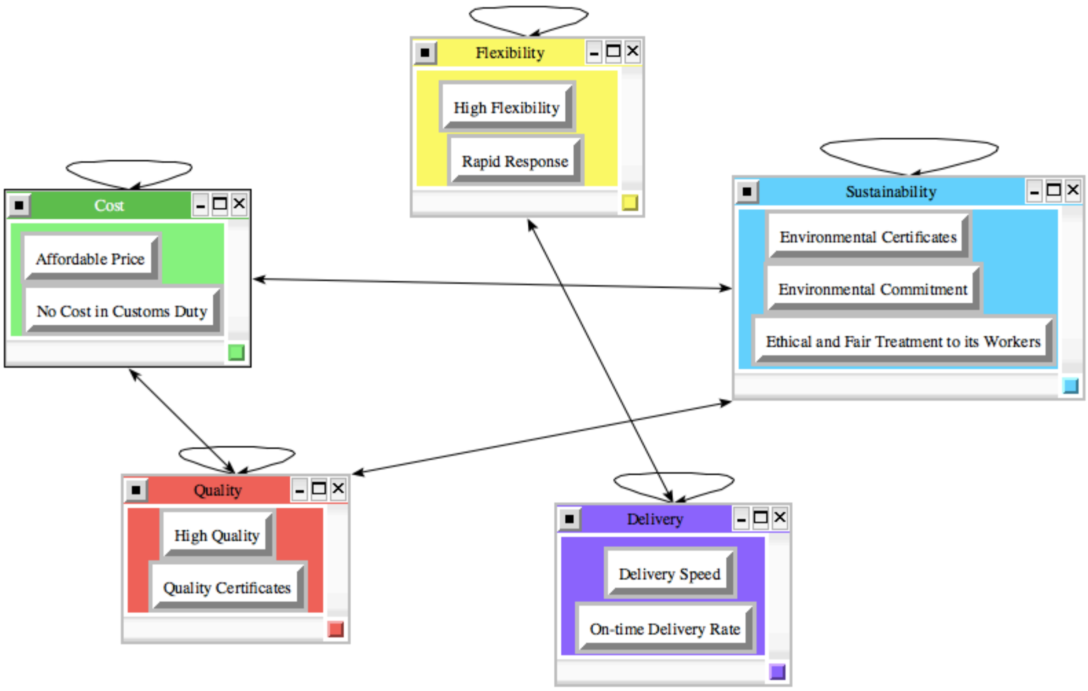

Figure 6.1: The network of ANP model of the decision problem

Phase IIIc – (ANP Step 3): In this step, pairwise comparisons between clusters and nodes are set. To construct the comparison matrices, clusters and their nodes are compared with respect to a control criterion. Inner- and inter-dependencies are taken care of in order to perform all pairwise comparisons. Saaty's 1-9 fundamental scale is used for the evaluation (see Table 5.1). The weights that are obtained pairwise comparison matrices , are used to build the unweighted, weighted and limit supermatrices. The consistency ratio is checked for each pairwise comparison. All the comparison matrices by decision makers are given in the following tables (see from Table 6.3 until 6.12).

As an example, Table 6.3 shows the pairwise comparison matrix for the clusters with respect to "cost" criterion. Three criteria (cost, quality, and sustainability) that influence "cost" criterion are compared based on "cost" criterion. The experts are requested to answer which aspect is more significant under cost criterion (see the sample questionnaire for pairwise comparison of the clusters with respect to cost criterion in Appendix C). Quality appears superior to the other two alternatives with respect to "cost" criterion.

Table 6.3: Pairwise comparison matrix of the clusters with respect to cost criterion

Factors	Cost	Quality	Sustainability	Weights
Cost	1	1/6	1/3	0.100
Quality	6	1	2	0.600
Sustainability	3	1/2	1	0.300

Table 6.4: Pairwise comparison matrix of the clusters with respect to delivery criterion

Factors	Delivery	Flexibility	Weights
Delivery	1	1/6	0.889
Flexibility	6	1	0.111

Table 6.5: Pairwise comparison matrix of the clusters with respect to flexibility criterion

Factors	Delivery	Flexibility	Weights
Delivery	1	1/2	0.333
Flexibility	2	1	0.667

Table 6.6: Pairwise comparison matrix of the clusters with respect to quality criterion

Factors	Cost	Quality	Sustainability	Weights
Cost	1	1/3	1/2	0.163
Quality	3	1	2	0.540
Sustainability	2	1/2	1	0.297

Table 6.7: Pairwise comparison matrix of the clusters with respect to sustainability criterion

Factors	Cost	Quality	Sustainability	Weights
Cost	1	1/2	1/4	0.136
Quality	2	1	1/3	0.238
Sustainability	4	3	1	0.625

Table 6.8: Pairwise comparison matrix of the nodes with respect to affordable price

Factors	High quality	Quality certificates	Weights
High quality	1	1/3	0.250
Quality certificates	3	1	0.750

Table 6.9: Pairwise comparison matrix of the nodes with respect to affordable price

Factors	Env. certificates	Env. commitment	Ethical and fair treatment	Weights
Env. certificates	1	1/3	1/2	0.163
Env. commitment	3	1	2	0.540
Ethical and fair treatment	2	1/2	1	0.297

Table 6.10: Pairwise comparison matrix of the nodes with respect to high quality

Factors	Env. certificates	Env. commitment	Ethical and fair treatment	Weights
Env. certificates	1	1/4	1/4	0.111
Env. commitment	4	1	1	0.444
Ethical and fair treatment	4	1	1	0.444

Table 6.11: Pairwise comparison matrix of the nodes with respect to delivery speed

Factors	High flexibility	Rapid response	Weights
High flexibility	1	1/3	0.250
Rapid response	3	1	0.750

Table 6.12: Pairwise comparison matrix of the nodes with respect to on-time delivery

Factors	High flexibility	Rapid response	Weights
High flexibility	1	1/2	0.333
Rapid response	2	1	0.667

Phase IIId – (ANP Step 4 & 5): In this study, in order to find the priorities of the customer requirements, pairwise comparisons are conducted by experts from XYZ Company.

Cluster priorities matrix show the influence power of one cluster on other clusters as given in the following table, Table 6.13. For instance, the "quality" cluster influences the "cost" cluster by (0.6000). As another example, the cluster of "sustainability" influences itself by (0.6250) because of the inner dependence of that cluster. If there is no influence, then the value in the cell is 0.0000.

Table 6.13: Cluster priorities matrix

Cluster labels	Cost	Delivery	Flexibility	Quality	Sustainability
Cost	0.1000	0.0000	0.0000	0.1634	0.1365
Delivery	0.0000	0.8889	0.3333	0.0000	0.0000
Flexibility	0.0000	0.1111	0.6667	0.0000	0.0000
Quality	0.6000	0.0000	0.0000	0.5396	0.2385
Sustainability	0.3000	0.0000	0.0000	0.2970	0.6250

Weighted and limit supermatrices are built according to these pairwise comparison matrices. Super Decisions Software (webpage: http://www.superdecisions.com/) supports all the mathematical calculations of ANP method. Super Decisions Software computed the weighted supermatrix, which can be seen in Table 6.14, and limit supermatrix, which can be seen in Table 6.15. The synthesised results and the priorities of the customer requirements are provided.

Table 6.14: Weighted supermatrix of the customer requirements

	Cost		Delivery		Flexibility		Quality		Sustainability		
	Affordable price	**No cost in customs**	**Delivery speed**	**On-time delivery**	**High flexibility**	**Rapid response**	**High quality**	**Quality certificates**	**Env. certificates**	**Env. commitment**	**Ethical & Fair Treatment**
Affordable price	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1634	0.0000	0.1365	0.0000	0.3640
No cost in customs	0.1000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Delivery speed	0.0000	0.0000	0.0000	0.8889	0.0000	0.3333	0.0000	0.0000	0.0000	0.0000	0.0000
On-time delivery	0.0000	0.0000	0.8889	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
High flexibility	0.0000	0.0000	0.0278	0.0371	0.0000	0.6667	0.0000	0.0000	0.0000	0.0000	0.0000
Rapid response	0.0000	0.0000	0.0833	0.0741	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
High quality	0.1500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2385	0.2762	0.6360
Quality certificates	0.4500	0.0000	0.0000	0.0000	0.0000	0.0000	0.5396	0.0000	0.0000	0.0000	0.0000
Env. certificates	0.0491	0.0000	0.0000	0.0000	0.0000	0.0330	1.0000	0.0000	0.0000	0.7238	0.0000
Env. commitment	0.1619	0.0000	0.0000	0.0000	0.0000	0.0000	0.1320	0.0000	0.6251	0.0000	0.0000
Ethical & Fair Treatment	0.0891	0.0000	0.0000	0.0000	0.0000	0.0000	0.1320	0.0000	0.0000	0.0000	0.0000

Table 6.15: Limit supermatrix of the customer requirements

	Cost		Delivery		Flexibility		Quality		Sustainability		
	Affordable price	**No cost in customs**	**Delivery speed**	**On-time delivery**	**High flexibility**	**Rapid response**	**High quality**	**Quality certificates**	**Env. certificates**	**Env. commitment**	**Ethical & Fair Treatment**
Affordable price	0.0851	0.0000	0.0000	0.0000	0.0000	0.0000	0.0851	0.0851	0.0851	0.0851	0.0851
No cost in customs	0.0086	0.0000	0.0000	0.0000	0.0000	0.0000	0.0086	0.0086	0.0086	0.0086	0.0086
Delivery speed	0.0000	0.0000	0.3335	0.3335	0.3335	0.3335	0.0000	0.0000	0.0000	0.0000	0.0000
On-time delivery	0.0000	0.0000	0.2964	0.2964	0.2964	0.2964	0.0000	0.0000	0.0000	0.0000	0.0000
High flexibility	0.0000	0.0000	0.1602	0.1602	0.1602	0.1602	0.0000	0.0000	0.0000	0.0000	0.0000
Rapid response	0.0000	0.0000	0.2100	0.2100	0.2100	0.2100	0.0000	0.0000	0.0000	0.0000	0.0000
High quality	0.1774	0.0000	0.0000	0.0000	0.0000	0.0000	0.1774	0.1774	0.1774	0.1774	0.1774
Quality certificates	0.1352	0.0000	0.0000	0.0000	0.0000	0.0000	0.1352	0.1352	0.1352	0.1352	0.1352
Env. certificates	0.3220	0.0000	0.0000	0.0000	0.0000	0.0330	0.3220	0.3220	0.3220	0.3220	0.3220
Env. commitment	0.2405	0.0000	0.0000	0.0000	0.0000	0.0000	0.2405	0.2405	0.2405	0.2405	0.2405
Ethical & Fair Treatment	0.0313	0.0000	0.0000	0.0000	0.0000	0.0000	0.0313	0.0313	0.0313	0.0313	0.0313

The weighted supermatrix has zero values when there is no influence. For instance, "high flexibility" does not influence "no cost in customs duty" node. However, it influences "delivery speed" (0.0278), "on-time delivery" (0.0371), and "rapid response" (0.667) nodes. After the weighted matrix is constructed and obtained, the limit matrix is constructed by raising the weighted supermatrix to powers by multiplying it by itself. When every column finally gets the same value, it means that the limit matrix has been reached.

Phase IIIf – (ANP Step 6): In the final step of ANP, the overall priorities of the customer requirements that is obtained from the limit supermatrix is given in Table 6.15. The results are given in Table 6.16, which shows that the most important customer requirement for the company is "affordable price" (90.8%), which is followed by the second best alternative, "high quality" (56.8%). The third best alternative is "rapid response" (56.7%) that is followed by "delivery speed" (52.9%), "on-time delivery rate" (47.1%), and "environmental certificates" (45.2%) respectively. These results are presented to XYZ company after computation is done. The experts from XYZ Company approved that the results provided by ANP method are consistent with their preferences.

Table 6.16: Priorities of customer requirements (CRs)

Name	Normals	Limiting
Affordable price	0.9084	0.0510
No cost in customs duty	0.0916	0.0051
Delivery speed	0.5294	0.1334
On-time delivery rate	0.4706	0.1186
High flexibility	0.4328	0.0641
Rapid response	0.5672	0.0840
High quality	0.5677	0.1064
Quality certificates	0.4325	0.0811
Environmental certificates	0.4523	0.1932
Environmental commitment	0.4051	0.1443
Ethical & Fair Treatment	0.0526	0.0188

Phase III (cont'd.)– (QFD Step 3): The priorities of the customer requirements (CRs) are obtained from *Phase IIIf* (see in Table 6.16). The first house of quality, HOQ-1 is built by using CRs as WHATs and TAs as HOWs of the problem as seen in Table 6.17a and 6.17b. Decision makers asked to evaluate the relational strength of each CR with each TA over a 1-3-9 scale. The magnitude of the relational strength is written at crossing-points between CR and TA items. If there is no relationship then the cell is left empty which means as relational strength is "0". The importance of decision criteria (TAs), raw weights and relative weights (Rw) are calculated by using the Eq. (5.1) and Eq. (5.2).

Relative weights of all decision criteria are obtained regarding the relationships and the weights of the customer requirements. From the results, it can be concluded that the most important decision criteria for sustainable supplier selection is "product price", with an importance degree of 0.074. The second most important decision criteria is "green purchasing" (0.073), which is followed by "inventory performance" (0.070), "convenience of logistics" (0.069), and "green packaging" (0.062). Overall ranking results are provided in the "Rw" row in Table 6.17a and 6.17b.

Phase IV – (QFD Step 4): The second house of quality, HOQ-2 is constructed by using the decision criteria (TA) weights from HOQ-1. The decision criteria are placed as WHATS, and candidate suppliers; Supplier 1, Supplier 2, Supplier 3, Supplier 4, and Supplier 5 as HOWs of the problem. Supplier are evaluated with respect to the relationships between decision criteria and decision criteria weights. The relationships are determined by the experts with consensus over a 1-3-9 scale. The importance of the candidate suppliers is calculated by using Eq. (5.1), and Eq. (5.2). The HOQ-2 is given in 6.18 in the following. The results show that the best alternative is the Supplier 4 with an importance degree of 0.259.

Phase V – (QFD Step 5): In the last phase, the results show that "Supplier 4" has relatively the highest importance. The best supplier that provides the requirements of the customer and the decision criteria is "Supplier 4".

Table 6.17a: The first house of quality (HOQ-1)

	CR	W	Product price	Logistics cost	On-time delivery	Lead time	Inventory performance	Convenience of logistics	Flexibility	Industry position & reputation	Payment term	Reject rate	Quality certificates	Warranties & claim policy	Capability of R&D	Compliance with environmental
	CR	***W***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Affordable price	**1**	*90.84*	9	9			1	3		1	3		1		1	1
No cost in customs duty	**2**	*9.16*	9	9				9						1		
Delivery speed	**3**	*52.94*		3	9	9	9	3	3						1	
On-time delivery rate	**4**	*47.06*			9	9	3	9	3						1	
High flexibility	**5**	*43.28*			3	3	9	3	9		3				1	
Rapid response	**6**	*56.72*				3	9	9	9						1	
High quality	**7**	*56.77*	9							1		9	9	9	9	1
Quality certificates	**8**	*43.25*										3	9	3	3	
Environmental certificates	**9**	*45.23*	3							3			1			9
Environmental commitment	**10**	*40.51*	3	1						3			1		3	9
Ethical & Fair Treatment	**11**	*5.26*	9							9						
		Rw	*0.074*	*0.048*	*0.045*	*0.052*	*0.070*	*0.069*	*0.052*	*0.014*	*0.018*	*0.028*	*0.043*	*0.028*	*0.046*	*0.040*
		Raw score	*1715.5*	*1099.3*	*1029,8*	*1200*	*1608.5*	*1577.6*	*1200*	*330.6*	*402.4*	*640.7*	*985.9*	*649.8*	*1053.1*	*919.3*

Table 6.17b: The first house of quality (HOQ-1)

	CR	*W*	Environment-related certificates	Use of toxic substances	Recycle/Reuse/Remanufacture	Green packaging	Green purchasing	OHSMS	Employee rights	Continuous training & education	Equality	Standard of wages	Child & forced labour
			15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Affordable price	**1**	*90.84*	1		3	9	9	1	1	3	3	9	9
No cost in customs duty	**2**	*9.16*											
Delivery speed	**3**	*52.94*											
On-time delivery rate	**4**	*47.06*											
High flexibility	**5**	*43.28*											
Rapid response	**6**	*56.72*											
High quality	**7**	*56.77*	1	1		1	1						
Quality certificates	**8**	*43.25*	1	1		1	1						
Environmental certificates	**9**	*45.23*	9	9	3	3	9			1			
Environmental commitment	**10**	*40.51*	9	9	9	9	9			3			
Ethical & Fair Treatment	**11**	*5.26*		3				9	9	9	9	9	9
		Rw	*0.042*	*0.039*	*0.034*	*0.062*	*0.073*	*0.006*	*0.006*	*0.021*	*0.014*	*0.038*	*0.038*
		Raw score	*962.5*	*887.5*	*772.8*	*1417.9*	*1689.2*	*138.2*	*138.2*	*486.6*	*319.9*	*864.9*	*864.9*

Table 6.18: The second house of quality (HOQ-2)

	TA	*W*	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
	TA	***W***	**1**	**2**	**3**	**4**	**5**
Product price	**1**	*0.074*	3	3	9	3	1
Logistics cost	**2**	*0.048*	1	3	9	9	1
On-time delivery	**3**	*0.045*	1	1	9	9	3
Lead time	**4**	*0.052*	1	3	9	9	3
Inventory performance	**5**	*0.070*	1		9	9	3
Convenience of logistics	**6**	*0.069*	1	3	9	9	
Flexibility	**7**	*0.052*	3	9	1		3
Industry position & reputation	**8**	*0.014*	9	3		1	3
Payment term	**9**	*0.018*	9	3		1	9
Reject rate	**10**	*0.028*	9		1	3	1
Quality certificates	**11**	*0.043*	9	3		9	3
Warranties & claim policy	**12**	*0.028*	3		9	9	3
Capability of R&D	**13**	*0.046*	*9*	*9*		*3*	*3*
Compliance with environmental policies	**14**	*0.040*	9	9		1	3
Environment-related certificates	**15**	*0.042*	9	3		9	1
Use of toxic substances	**16**	*0.039*	9	9	3	9	9
Recycle/ Reuse / Remanufacture	**17**	*0.034*	9	9		3	1
Green packaging	**18**	*0.062*	3	3		9	1
Green purchasing	**19**	*0.073*	3	3		9	1
OHSMS	**20**	*0.006*	9	3		9	3
Employee rights	**21**	*0.006*	9	9		1	3
Continuous training & education	**22**	*0.021*	9	9		1	3
Equality	**23**	*0.014*	9	9		1	3
Standard of wages	**24**	*0.038*	9	9	1	3	3
Child & forced labour	**25**	*0.038*	9	9	9	9	9
		Rw	*0.229*	*0.206*	*0.186*	*0.259*	*0121*
		Raw score	*4.99*	*4.50*	*4.05*	*5.65*	*2.64*

7. OBTAINED RESULTS AND DISCUSSION

7.1 Results for Weights of the Decision Criteria

Several decision criteria are mentioned in the literature review, twenty-five decision criteria are determined to fit the best with the Turkish textile and apparel sector and XYZ Company. The ranking of the selected decision criteria, which is obtained from HOQ-1 of QFD method, is given in Table 7.1. "Product price" has the highest importance.

Table 7.1: Weights of the selected decision criteria

Decision criteria	Relative weights (%)
Product price	7.4%
Logistics cost	4.8%
On-time delivery	4.5%
Lead time	5.2%
Inventory performance	7.0%
Convenience of logistics	6.9%
Flexibility	5.2%
Industry position & reputation	1.4%
Payment term	1.8%
Reject rate	2.8%
Quality certificates	4.3%
Warranties & claim policy	2.8%
Capability of R&D	4.6%
Compliance with environmental policies	4.0%
Environment-related certificates	4.2%
Use of toxic substances	3.9%
Recycle/Reuse/Remanufacture	3.4%
Green packaging	6.2%
Green purchasing	7.3%
OHSMS	0.6%
Employee rights	0.6%
Continuous training & education	2.1%
Equality	1.4%
Standard of wages	3.8%
Child & forced labour	3.8 %

7.2 Results for Weights of the Candidate Suppliers

The importance and ranking of the candidate suppliers are obtained from HOQ-2 of QFD method. Five candidate suppliers are evaluated with the customer requirements and the decision criteria in consecutive steps. Candidate suppliers are Supplier 1 (Italian), Supplier 2 (Romanian), Supplier 3 (Turkish), Supplier 4 (Turkish), Supplier 5 (Italian). According to the cost parameter, Supplier 3 and Supplier 4 provide the most affordable fabric. Supplier 5 provides the most expensive fabric. According to the quality parameter, Supplier 1 and Supplier 4 provides the highest quality fabric, whereas quality level of the fabric, which Supplier 2, Supplier 3, and Supplier 5 provides, are rather low. According to delivery parameter, delivery performance of Supplier 3and Supplier 4 are the highest, whereas delivery performance of Supplier 1 and Supplier 2 are the lowest. According the environmental and social parameters, Supplier 3 proves the lowest performance. Supplier 1 and Supplier 4 have the best environmental performance, and Supplier 1 and Supplier 2 have the best social performance.

Hence, the most sustainable supplier, Supplier 4 (25.9%), which has the highest importance in overall evaluations of HOQ-2, is the best alternative for XYZ Company with respect to their company requirements and decision criteria. According to the result of the integrated QFD-ANP approach, "Supplier 4" should be selected. Overall rankings are provided in the following table, Table 7.2.

Table 7.2: Overall rankings and importance of the alternative suppliers

Alternatives	Relative weight (%)
Supplier 1	22.9%
Supplier 2	20.6%
Supplier 3	18.6%
Supplier 4	25.9%
Supplier 5	12.1%

7.3 Discussion

XYZ Company is active in Turkish and European textile and apparel market for more than twenty years. At the same time, the fact that XYZ Company gives priority and major importance to the issues as quality, environmental sustainability and ethical work corresponds with the subject of this thesis. XYZ, instead of conducting an established methodology for the selection of its suppliers, uses more subjective instruments. Examples of these are references, experiences, and commitment. Due to the lack of a fixed methodology for the supplier selection, it could make the incorrect choice of supplier that can lead to an unsustainable system. Moreover, it may cause financial and opportunity losses. To avoid opportunity costs caused by efficiency losses and foregone earnings resulted from the choice of less appropriate suppliers, the proposed methodology that this thesis explains should be implemented (Abbasi et al., 2013; Scott et al., 2013; Tavana et al., 2017).

There were many advantages when collaborating with XYZ Company, as the case study of this thesis. Despite this, there were also some disadvantages that should also be mentioned. XYZ currently prefers to use conventional methods to evaluate and select its suppliers and implementing this thesis' outlined integrated method might prove complicated or time consuming for the company. Further, it may simply not be practical for them, which would discourage its use by the company and its composing teams. Additionally, XYZ prefers collaborating with multiple, and a wide range of suppliers in supplying both fabrics, and printing utensils, and thus sometimes selecting only the best supplier might not be the favourable solution for the company. All the aforementioned reasons might endanger the use of the proposed integrated methodology in the long term.

The proposed method is flexible to use in another company with similar features. However, some necessary modifications are recommended according to the industry that the company belongs. Since the number of options are high, and the scale consists many magnitudes, it becomes very challenging for the decision makers to make rather objective judgements. The limitations of the study are the subjectivity and vagueness of the human judgements, and the interpretation of the data. In order to handle them, fuzzy triangular numbers can be integrated to QFD and ANP evaluations, and the choice of experts can be made accurately as for the topic of expertise for the further research and studies.

8. CONCLUSION AND PERSPECTIVES

This thesis proposed an integrated methodology for the selection of sustainable suppliers in the textile and apparel industry in Turkey. The proposed methodology integrates quality function deployment (QFD) and analytical network process (ANP) methods in order to evaluate the candidate suppliers by combining the conventional (cost, and quality, etc.) and sustainable (social and environmental) criteria together. Selected suppliers or business partners should satisfy the companies that incorporates with them. Thus, company requirements or the “voice” of the company should be heard during the evaluation process. QFD method is often used to translate the customer requirements into technical attributes or decision criteria. ANP method is a multi-criteria decision making methodology, which is famous for its responsiveness to the dependencies between the elements of the problem. In this thesis, firstly, the importance of company requirements are calculated by using ANP method because of the inner- and inter-dependencies between company requirements, and then a “two house of quality (HOQ) model” of QFD method is used for the selection of sustainable suppliers. The first HOQ translated the company requirements into decision criteria, and then the second HOQ translated decision criteria into candidate suppliers by finding out the relational strengths between each items.

The proposed model has aimed to create a generic study for Turkish textile and apparel industry. To the best of the author’s knowledge, there is not a single study addressing sustainable supplier selection in Turkish textile and apparel industry. The study has carried out a detailed research about the sustainable supplier selection studies that have an MCDM approach in the literature.

This thesis brings an extensive systematic analysis about the "supplier selection criteria" by classifying all the criteria that is found in the literature between the years 2007 and 2012; and determines twenty-five criteria that is fitting to Turkey's apparel and textile sectors by the help of the experts that contributed to this study.

Supplier is a core element of a supply chain for corporations. Today, the competition among organisations is carried out from the individual level to the supply chain level at the market. The business relationship among the actors indicates the performance of the supply chain, and thus a distinct consideration must be taken for the strength of the relationship if the overall performance of a supply chain is being evaluated. Hence, supplier selection is an essential part of establishing a strong supply chain relationship; especially because outsourcing became a really important initiative for the profitability of the businesses.

Fashion industry as known as textile and clothing industry is chosen as the main focus of the study regarding to the industry. Textile and clothing industry is the world second biggest economic sector. It is the second largest sector with its high contribution to the economy in Turkey, as well. Today, fashion sector is under heavy criticisms because of its environmental and social practices. Textile and clothing industries are the world's second most polluting sector. The use of chemical substances in yarn and fabric production, the greenhouse gas production during manufacturing, and the consumption of natural resources are the examples regarding the environmental problems. The critics regarding the social problems are because of the child and forced labour, unethical and unfair work conditions that the textile and apparel sectors are responsible for.

Because of fast changing trends and mostly outsourced clothing production in fashion, fashion brands regularly require new sourcing and suppliers. An organisation is not only responsible for its in-company practices but also its suppliers' and business partners' practices. Thus, including environmental and social criteria in supplier evaluation and selection is especially significant.

For finding the suitable criteria for Turkish textile and apparel industries, a deep analysis about these sectors in Turkey has been carried out (see in Section 4) and the literature has been reviewed extensively. Sixty-five sustainable supplier selection articles (published between 2007 and 2017 in international scientific journals available in electronic databases) with a multi-criteria decision making approach (MDCM) are carefully analysed.

The proposed model has been implemented in a real life case study in a Turkish textile company based in Istanbul. The company under analysis is a leading fabric processing and manufacturing company that mostly sells its products to reputable fashion brands in the European market. The most sustainable supplier is selected among five candidate suppliers according to the company requirements and the decision criteria, which have been determined by the decision makers from the sector and the academia.

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APPENDICES

Appendix A. Supplier selection criteria obtained from the literatüre

All the conventional and sustainable criteria and sub-criteria, which is obtained from the literature review, are listed in the following table. The articles that used related criterion or sub-criterion are shown in the “references” column chronologically.

Table A.1: Supplier selection criteria obtained from the literature

Traditional Criteria				
Name	**Main Criteria**	**Sub-Criteria**	**References**	**# of ref. cited**
Cost/Price Measures	x		Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Guo et al. (2017); Hamdan and Cheaitou (2017); Pang et al. (2017); Acar et al. (2016); Awasthi and Kannan (2016); Duman et al. (2016); Girubha et al. (2016); Yazdani et al. (2016); Azadi et al. (2015); Azadnia et al. (2015); Galankashi et al. (2015); Hashemi et al. (2015); Jia et al. (2015); Kannan et al. (2015); Kumar et al. (2014); Mina et al. (2014); Orji and Wei (2014); Öztürk and Özçelik (2014); Tsui and Wen (2014); Zhao and Guo (2014); Govindan et al. (2013); Buyukozkan and Cifci (2012); Chiou et al. (2011); Kuo and Lin (2011); Chan and Chan (2010); Grisi et al. (2010); Kuo et al. (2010); Yan (2009); Chiou et al. (2008)	31
Product cost		x	Fallahpour et al. (2017); Guo et al. (2017); Zhao and Guo (2014)	3
Transaction costs		x	Girubha et al. (2016); Yan (2009)	2
Product / Material Price		x	Yazdani et al. (2017); Girubha et al. (2016); Liao et al. (2016); Kannan et al. (2015); Chan and Chan (2010); Grisi et al. (2010); Thangchattu and Siripokapirom (2010); Yan (2009)	8
Transportation /Freight cost		x	Fallahpour et al. (2017); Guo et al. (2017); Pang et al. (2017); Acar et al. (2016); Azadi et al. (2015); Kannan et al. (2015); Cifci and Buyukozkan (2011); Chan and Chan (2010); Grisi et al. (2010); Kuo et al. (2010)	10
Tariff and customs duty expenses		x	Cifci and Buyukozkan (2011); Grisi et al. (2010)	2
Price/Performance value		x	Acar et al. (2016); Kannan et al. (2015); Kuo et al. (2010)	3
Compliance with sectoral price behaviour		x	Acar et al. (2016); Kuo et al. (2010)	2

Organisational Measures	x		Acar et al. (2016); Duman et al. (2016); Azadi et al. (2015); Mina et al. (2014); Buyukozkan and Cifci (2012); Buyukozkan and Cifci (2011); Chan and Chan (2010); Wen and Chi (2010)	8
Distance (km)		x	Galankashi et al. (2015); Kumar et at. (2014); Chan and Chan (2010); Li and Zhao (2009)	4
Financial stability/performance		x	Pang et al. (2017); Girubha et al. (2016); Tavana et al. (2016); Azadi et al. (2015); Kumar et al. (2014); Mina et al. (2014); Tsui and Wen (2014); Buyukozkan and Cifci (2011); Kuo and Lin (2011); Chan and Chan (2010); Wen and Chi (2010)	11
Industry position and rating		x	Pang et al. (2017); Duman et al. (2016); Girubha et al. (2016); Galankashi et al. (2015); Mina et al. (2014); Kumar et al. (2014); Chan and Chan (2010); Li and Zhao (2009)	8
Payment term		x	Hamdan and Cheaitou (2017); Girubha et al. (2016)	2
Shelf life		x	Kumar et at. (2014)	1
Internal and out-of-control management system		x	Tsui and Wen (2014); Chiou et al. (2008)	2
Delivery Measures	x		Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Guo et al. (2017); Girubha et al. (2016); Acar et al. (2016); Azadnia et al. (2015); Galankashi et al. (2015); Kannan et al. (2015); Tsui and Wen (2014); Chiou et al. (2011); Cifci and Buyukozkan (2011); Kuo and Lin (2011); Chan and Chan (2010); Chen et al. (2010); Grisi et al. (2010); Kuo et al. (2010); Yan (2009); Chiou et al. (2008)	18
Order frequency		x	Acar et al. (2016); Kuo et al. (2010)	2
On-time delivery / timeliness		x	Fallahpour et al. (2017);Azadi et al. (2015); Jia et al. (2015); Kannan et al. (2015); Orji and Wei (2014); Öztürk and Özçelik (2014); Zhao and Guo (2014); Govindan et al. (2013); Buyukozkan and Cifci (2012); Chen et al. (2010); Grisi et al. (2010); Li and Zhao (2009); Yan (2009)	13
Order fulfilment rate		x	Guo et al. (2017); Acar et al. (2016); Kannan et al. (2015); Kuo et al. (2010)	4
Lead/delivery time		x	Fallahpour et al. (2017); Guo et al. (2017); Hamdan and Cheaitou (2017); Yazdani et al. (2017); Liao et al. (2016); Tavana et al. (2016); Yazdani et al. (2016); Acar et al. (2016); Kannan et al. (2015); Kumar et al. (2014); Öztürk and Özçelik (2014); Cifci and Buyukozkan (2011); Kuo and Lin (2011); Chan and Chan (2010); Kuo et al. (2010); Thangchattu and Siripokapiram (2010); Yan (2009)	17
Stock Management/Availability	x	x	Amindoust and Saghafinia (2017); Hamdan and Cheaitou (2017); Acar et al. (2016); Kannan et al. (2015); Chan and Chan (2010)	5
Flexibility/Service Measures	x		Fallahpour et al. (2017); Guo et al. (2017); Pang et al. (2017); Duman et al. (2016); Acar et al. (2016); Azadi et al. (2015); Galankashi et al. (2015); Kannan et al. (2015); Orji and Wei (2014); Tsui and Wen (2014); Buyukozkan and Cifci (2012); Buyukozkan and Cifci (2011); Chiou et al. (2011); Chan and Chan (2010); Chen et al. (2010); Kuo et al. (2010); Wen and Chi (2010); Li and Zhao (2009); Yan (2009); Chiou et al. (2008)	20
Response to specific requests of the company		x	Kannan et al. (2015); Grisi et al. (2010); Chiou et al. (2011)	3

Rapid response capability		x	Fallahpour et al. (2017); Girubha et al. (2016); Acar et al. (2016); Kuo et al. (2010); Yan (2009); Noci (1997)	6
Maintenance service		x	Mina et al. (2014); Li and Zhao (2009)	2
After sales service		x	Fallahpour et al. (2017); Girubha et al. (2016); Mina et al. (2014); Yan (2009)	4
Service attitude/quality		x	Kannan et al. (2015); Bali et al. (2013); Buyukozkan and Cifci (2011); Yan (2009)	4
Information sharing		x	Pang et al. (2017); Acar et al. (2016); Azadi et al. (2015); Kannan et al. (2015); Orji and Wei (2014); Tsui and Wen (2014); Chiou et al. (2011); Chan and Chan (2010); Yan (2009)	9
Quality Measures	x		Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Hamdan and Cheaitou (2017); Pang et al. (2017); Yazdani et al. (2017); Girubha et al. (2016); Yazdani et al. (2016); Tavana et al. (2016); Acar et al. (2016); Azadi et al. (2015); Azadnia et al. (2015); Galankashi et al. (2015); Hashemi et al. (2015); Jia et al.(2015); Kannan et al. (2015); Mina et al. (2014); Orji and Wei (2014); Öztürk and Özçelik (2014); Tsui and Wen (2014); Govindan et al. (2013); Buyukozkan and Cifci (2012); Chiou et al. (2011); Cifci and Buyukozkan (2011); Kuo and Lin (2011); Kuo et al. (2011); Chan and Chan (2010); Kuo et al. (2010); Thangchattu and Siripokapirom (2010); Wen and Chi (2010); Lee et al. (2009); Li and Zhao (2009); Yan (2009); Chiou et al. (2008)	33
Rejection rate		x	Fallahpour et al. (2017); Girubha et al. (2016); Jia et al. (2015); Kannan et al. (2015); Cifci and Buyukozkan (2011); Grisi et al. (2010); Kuo et al. (2010); Thangchattu and Siripokapirom (2010); Li and Zhao (2009)	9
Quality assurance system / Quality certificates		x	Liao et al. (2016); Acar et al. (2016); Kannan et al. (2015); Kuo and Lin (2011); Kuo et al. (2011); Chan and Chan (2010); Kuo et al. (2010); Lee et al. (2009); Li and Zhao (2009)	9
Capability of quality management		x	Acar et al. (2016); Chan and Chan (2010); Kuo et al. (2010); Lee et al. (2009)	4
Capability of handling abnormal quality		x	Fallahpour et al. (2017); Kannan et al. (2015); Kuo et al. (2011); Lee et al. (2009)	4
Internal audit quality		x	Fallahpour et al. (2017); Kannan et al. (2015); Grisi et al. (2010); Thangchattu and Siripokapirom (2010)	4
Incoming quality control		x	Mina et al. (2014); Kuo et al. (2011); Hsu and Hu (2009); Hsu and Hu (2007)	4
Warranties, claim policies and compensation		x	Pang et al. (2017); Kannan et al. (2015); Chan and Chan (2010); Kuo et al. (2010); Li and Zhao (2009)	5
Loyalty	x		Azadnia et al. (2015)	1
Time	x		Awasthi and Kannan (2016)	1
Labour	x		Awasthi and Kannan (2016); Govindan et al. (2013)	2
Technical/Technology Capability	x		Guo et al. (2017); Duman et al. (2016); Girubha et al. (2016); Liao et al. (2016); Azadi et al. (2015); Azadnia et al. (2015); Hashemi et al. (2015); Kannan et al. (2015); Tsui and Wen (2014); Öztürk and Özçelik (2014); Govindan et al. (2013); Buyukozkan and Cifci (2011); Chiou et al. (2011); Kuo and Lin (2011); Kuo et al. (2011); Chan and Chan (2010); Wen and Chi (2010); Lee et al. (2009); Li and Zhao (2009)	19

Product performance/competitiveness		x	Zhao and Guo (2014); Li and Zhao (2009); Yan (2009)	3
Production agility		x	Kuo et al. (2011); Li and Zhao (2009)	2
Capability of R&D management		x	Fallahpour et al. (2017); Pang et al. (2017); Kannan et al. (2015); Tsui and Wen (2014); Chen et al. (2010); Hsu and Hu (2009); Lee et al. (2009); Li and Zhao (2009); Hsu and Hu (2007)	9
Proportion of engineers and technicians		x	Li and Zhao (2009)	1
Capability of design		x	Kuo et al. (2010); Lee et al. (2009);	2
Green Criteria				
Name	**Main Criteria**	**Sub-Criteria**	**References**	
Cost-related criteria				
Cost of producing green product		x	Tuzkaya et al. (2009)	1
Net life-cycle cost	x		Lee et al. (2009); Noci (1997)	2
Cost of the supplier component		x	Noci (1997)	1
Cost of component disposal		x	Lee et al. (2009); Kannan et al. (2015); Noci (1997)	3
Depreciation for improvement		x	Noci (1997)	1
Cost of pollution effects		x	Grisi et al. (2010)	1
Cost of reverse logistics about green products		x	Tuzkaya et al. (2009)	1
Environmental costs	x		Azadi et al. (2015); Cao et al. (2015); Tuzkaya et al. (2009)	3
Environmental Criteria				
Environmental Management System (EMS)	x	x	Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Guo et al. (2017); Hamdan and Cheaitou (2017); Acar et al. (2016); Tavana et al. (2016); Azadi et al. (2015); Azadnia et al. (2015); Kannan et al. (2015); Zhang and Xu (2015); Orji and Wei (2014); Öztürk and Özçelik (2014); Bali et al. (2013); Govindan et al. (2013); Shen et al. (2013); Chiou et al. (2011); Kuo and Lin (2011); Kuo et al. (2011); Chan and Chan (2010); Chen et al. (2010); Grisi et al. (2010); Wen and Chi (2010); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008)	25
Environmental policies		x	Kannan et al. (2015); Mina et al. (2014); Awasthi et al. (2010); Grisi et al. (2010)	4
Environmental/green process planning		x	Kannan et al. (2015); Mina et al. (2014); Grisi et al. (2010); Kuo and Lin (2011); Lee et al. (2009)	5
Environment-related certificates (ISO 14001, ISO 14000, oeko tex etc.)		x	Fallahpour et al. (2017); Pang et al. (2017); Acar et al. (2016); Girubha et al. (2016); Liao et al. (2016); Azadi et al. (2015); Cao et al. (2015); Kannan et al. (2015); Mina et al. (2014); Chan and Chan (2010); Chen et al. (2010); Grisi et al. (2010); Kuo et al. (2010); Thangchattu and Siripokapirom (2010); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008)	17

Eco-Design requirements (EUP)		x	Acar et al. (2016); Kannan et al. (2015); Kuo et al. (2010)	3
Ozone depleting chemicals (ODC)		x	Acar et al. (2016); Azadi et al. (2015); Kuo et al. (2010)	3
Restriction of hazardous substances (RoHS)		x	Acar et al. (2016); Kannan et al. (2015); Kuo et al. (2010)	3
Waste electrical electronic equipment (WEEE)		x	Acar et al. (2016); Kuo et al. (2010)	2
Eco-Labelling		x	Fallahpour et al. (2017);Thangchattu and Siripokapirom (2010); Chiou et al. (2008)	3
Internal control process		x	Kuo et al. (2011); Lee et al. (2009); Tuzkaya et al. (2009)	3
Environmental control		x	Tsui and Wen (2014)	1
Continuous monitoring and compliance to government & local rules/regulations		x	Hamdan and Cheaitou (2017); Chiou et al. (2011); Chan and Chan (2010); Hsu and Hu (2009); Lee et al. (2009); Chiou et al. (2008); Hsu and Hu (2007)	7
Environmental performance (evaluation)	x	x	Fallahpour et al. (2017);Cifci and Buyukozkan (2011); Thangchattu and Siripokapirom (2010); Chiou et al. (2008)	4
Life cycle assessment		x	Chen et al. (2010); Thangchattu and Siripokapirom (2010)	2
Waste management		x	Jia et al. (2015); Chiou et al. (2008)	2
Green Image	x		Hamdan and Cheaitou (2017); Pang et al. (2017); Duman et al. (2016); Girubha et al. (2016); Kannan et al. (2015); Zhang and Xu (2015); Bali et al. (2013); Shen et al. (2013); Grisi et al. (2010); Wen and Chi (2010); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008); Noci (1997)	14
Ratio of green customer to total customers		x	Kannan et al. (2015); Grisi et al. (2010); Lee et al. (2009); Noci (1997)	4
Customer fidelisation		x	Grisi et al. (2010)	1
(Corporate) Social responsibility	x	x	Tavana et al. (2016); Kannan et al. (2015); Öztürk and Özçelik (2014); Buyukozkan and Cifci (2011); Kuo et al. (2011); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008)	8
Public disclosure of environmental record		x	Kannan et al. (2015); Chiou et al. (2008)	2
Staff environmental training		x	Zhang and Xu (2015); Shen et al. (2013); Awasthi et al. (2010); Tuzkaya et al. (2009)	4
Relationship with stakeholders / Rights of stakeholders		x	Azadi et al. (2015); Kannan et al. (2015); Orji and Wei (2014); Li and Zhao (2009); Chiou et al. (2008); Noci, (1997)	6
Contributions to community		x	Chiou et al. (2008)	1
Management commitment		x	Hashemi et al. (2015); Zhang and Xu (2015); Shen et al. (2013)	3
Respect for the policy		x	Azadi et al. (2015); Kannan et al. (2015); Orji and Wei (2014)	3

Pollution (Production/Control)	x	x	Amindoust and Saghafinia (2017); Guo et al. (2017); Acar et al. (2016); Girubha et al. (2016); Tavana et al. (2016); Azadi et al. (2015); Azadnia et al. (2015); Galankashi et al. (2015); Hashemi et al. (2015); Jia et al. (2015); Kannan et al. (2015); Zhang and Xu (2015); Orji and Wei (2014); Öztürk and Özçelik (2014); Bali et al. (2013); Govindan et al. (2013); Shen et al. (2013); Baskaran et al. (2012); Chiou et al. (2011); Kuo et al. (2011); Lee et al. (2009); Tuzkaya et al. (2009); Yan (2009)	23
Waste water		x	Fallahpour et al. (2017);Awasthi and Kannan (2016); Azadi et al. (2015); Jia et al. (2015); Kannan et al. (2015); Chiou et al. (2011); Lee et al. (2009); Tuzkaya et al. (2009); Noci (1997)	9
Green house/air emissions		x	Amindoust and Saghafinia (2017); Fallahpour et al. (2017);Guo et al. (2017); Awasthi and Kannan (2016); Azadnia et al. 2015; Galankashi et al. (2015); Kannan et al. (2015); Mina et al. (2014); Chiou et al. (2011); Grisi et al. (2010); Kumar and Jain (2010); Lee et al. (2009); Tuzkaya et al. (2009); Noci (1997)	14
Solid wastes		x	Acar et al. (2016); Chiou et al. (2011); Kuo et al. (2011); Grisi et al. (2010); Lee et al. (2009); Tuzkaya et al. (2009); Lu et al. (2007); Noci (1997)	8
Liquid waste		x	Lu et al. (2007)	1
Gaseous waste		x	Chiou et al. (2008)	1
Noise		x	Awasthi and Kannan (2016)	1
Use of toxic/restricted substances		x	Acar et al. (2016); Jia et al. (2015); Tuzkaya et al. (2009); Chiou et al. (2008)	4
Energy consumption		x	Pang et al. (2017); Yazdani et al. (2017); Acar et al. (2016); Awasthi and Kannan, (2016); Tavana et al. (2016); Yazdani et al. (2016); Azadi et al. (2015); Cao et al. (2015); Galankashi et al. (2015); Jia et al. (2015); Kuo et al. (2011); Grisi et al. (2010); Lee et al. (2009); Tuzkaya et al. (2009); Lu et al. (2007); Noci (1997)	16
Renewable energy		x	Azadi et al. (2015)	1
Resource consumption		x	Guo et al. (2017); Yazdani et al. (2017); Awasthi and Kannan (2016); Girubha et al. (2016); Azadi et al. (2015); Hashemi et al. (2015); Zhang and Xu (2015); Öztürk and Özçelik (2014); Govindan et al. (2013); Shen et al. (2013); Chiou et al. (2011)	11
Hazardous waste/ substance management		x	Fallahpour et al. (2017);Awasthi and Kannan (2016); Cao et al (2015); Jia et al. (2015); Kannan et al. (2015); Chiou et al. (2011); Kuo et al. (2011); Hsu and Hu (2009); Tuzkaya et al. (2009); Hsu and Hu (2007)	9
Waste disposal		x	Kannan et al. (2015); Buyukozkan and Cifci (2012); Tuzkaya et al. (2009); Yan (2009)	4
Green product/competencies	x		Fallahpour et al. (2017); Guo et al. (2017); Acar et al. (2016); Azadi et al. (2015); Kannan et al. (2015); Orji and Wei (2014); Öztürk and Özçelik (2014); Zhao and Guo (2014); Bali et al. (2013); Buyukozkan and Cifci (2011); Kuo et al. (2011); Wen and Chi (2010); Lee et al. (2009); Chiou et al. (2008); Noci (1997)	15
(Internal) Green production plan		x	Chen et al. (2010); Tuzkaya et al. (2009)	2

R&D Green products		x	Guo et al. (2017); Azadi et al. (2015); Kannan et al. (2015); Chen et al. (2010); Tuzkaya et al. (2009)	5
Recycle		x	Fallahpour et al. (2017); Yazdani et al. (2017); Acar et al. (2016); Yazdani et al. (2016); Azadi et al. (2015); Kannan et al. (2015); Buyukozkan and Cifci (2012); Lee et al. (2009); Tuzkaya et al. (2009)	9
Reverse logistics		x	Awasthi and Kannan (2016); Tavana et al. (2016); Cao et al. (2015); Bali et al. (2013); Buyukozkan and Cifci (2012); Tuzkaya et al. (2009); Chiou et al. (2008)	7
Remanufacturing/Reuse activities		x	Fallahpour et al. (2017); Yazdani et al. (2017); Acar et al. (2016); Yazdani et al. (2016); Cao et al. (2015); Kannan et al. (2015); Buyukozkan and Cifci (2012); Tuzkaya et al. (2009); Chiou et al. (2008)	9
Reduce		x	Buyukozkan and Cifci (2012)	1
Green packaging		x	Fallahpour et al. (2017); Acar et al. (2016); Awasthi and Kannan (2016); Kannan et al. (2015); Mina et al. (2014); Bali et al. (2013); Buyukozkan and Cifci (2012); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008)	10
Green logistics		x	Fallahpour et al. (2017);Awasthi and Kannan (2016); Buyukozkan and Cifci (2012); Kuo et al. (2011)	4
Green/environmental technologies		x	Fallahpour et al. (2017); Pang et al. (2017); Liao et al. (2016); Chen et al. (2016); Kannan et al. (2015); Zhang and Xu (2015); Bali et al. (2013); Awasthi et al. (2010); Tuzkaya et al. (2009); Noci (1997)	10
(Green) material selection/use		x	Fallahpour et al. (2017); Acar et al. (2016); Galankashi et al. (2015); Zhang and Xu (2015); Mina et al. (2014); Bali et al. (2013); Shen et al. (2013); Kuo et al. (2011); Awasthi et al. (2010); Hsu and Hu (2009); Lee et al. (2009); Tuzkaya et al. (2009); Chiou et al. (2008); Hsu and Hu (2007); Lu et al. (2007); Noci (1997)	16
Green purchasing/procurement	x	x	Awasthi and Kannan (2016); Kuo and Lin, (2011); Chen et al. (2010); Hsu and Hu, (2009); Hsu and Hu (2007)	5
Second tier supplier environmental evaluation		x	Tuzkaya et al. (2009); Chiou et al. (2008)	2
Green warehousing		x	Fallahpour et al. (2017); Awasthi and Kannan (2016)	2
Green/Eco design		x	Fallahpour et al. (2017);Hamdan and Cheaitou (2017); Yazdani et al. (2017); Awasthi and Kannan (2016); Yazdani et al. (2016); Azadi et al. (2015); Galankashi et al. (2015); Kannan et al. (2015); Zhang and Xu (2015); Orji and Wei (2014); Öztürk and Özçelik (2014); Bali et al. (2013); Govindan et al. (2013); Shen et al. (2013); Chen et al. (2010); Hsu and Hu (2009); Tuzkaya et al. (2009); Chiou et al. (2008); Hsu and Hu (2007)	19
Cleaner production		x	Kannan et al. (2015); Chen et al. (2010); Chiou et al. (2008)	3
Social Criteria				
Employment Practices		x	Tavana et al. (2016); Öztürk and Özçelik (2014); Govindan et al. (2013)	3
Employee rights		x	Fallahpour et al. (2017); Girubha et al. (2016); Azadi et al. (2015)	3
Local communities influence		x	Girubha et al. (2016); Govindan et al. (2013)	2

Contractual stakeholders influence		x	Govindan et al. (2013)	1
Worker Health and Work Safety	x		Amindoust and Saghafinia (2017); Azadi et al. (2015); Azadnia et al. (2015); Jia et al. (2015); Mani et al. (2014); Orji and Wei (2014); Öztürk and Özçelik (2014); Tsui and Wen (2014); Govindan et al. (2013); Chiou et al. (2011)	10
Occupational health and safety management system (OHSMS)		x	Azadnia et al. (2015); Chiou et al. (2011)	2
Workers' contract, compensation and insurance		x	Fallahpour et al. (2017)	1
Training education and community development		x	Fallahpour et al. (2017); Azadnia et al. (2015); Öztürk and Özçelik (2014)	3
Social Equities	x		Amindoust and Saghafinia (2017); Mani et al. (2014)	2
Poverty		x	Mani et al. (2014)	1
Discrimination	x	x	Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Mani et al. (2014); Baskaran et al. (2012)	4
Equality		x	Mani et al. (2014)	1
Wages	x		Fallahpour et al. (2017); Mani et al. (2014); Chiou et al. (2011)	3
Education	x		Mani et al. (2014)	1
Long Working Hours	x		Amindoust and Saghafinia (2017); Fallahpour et al. (2017); Jia et al. (2015); Baskaran et al. (2012); Chiou et al. (2011)	5
Society/unfair competition	x		Baskaran et al. (2012)	1
Philanthropy	x		Mani et al. (2014)	1
Human Rights	x		Amindoust and Saghafinia (2017); Jia et al. (2015); Mani et al. (2014); Baskaran et al. (2012)	4
Child and Bonded Labour	x		Amindoust and Saghafinia (2017); Jia et al. (2015); Mani et al. (2014)	3
Housing	x		Mani et al. (2014)	1
Ethics	x		Mani et al. (2014)	1

Appendix B. Standards and Associations for Environmental Management Systems

There are numerous international organisations that provides standards and certificates for the environmental management and protection. In this section, these organisations and associations are going to be mentioned briefly in order to clarify the sub-criterion called "environmental certificates" as explaining the existing certification programmes and organisations that provide environmental management and protection services.

European Union (EU), United Nations (UN), International Organisation for Standardisation (ISO), American Society for Testing and Materials (ASTM) and Global Organic Textile (GOT) can be counted as the organisations.

United Nations Environment Programme (UNEP)

UNEP is founded in 1972. Its aim to determine global, regional and national environmental conditions and trends. It develops national and international environmental instruments and strengthens institutions for the wise management of the environment.

ISO 14000 Family of Environmental Management Standards

International organisation for standardisation has developed many standards for helping organisations to take action to manage environmental issues. ISO 14000 is a family of environmental management standards. For sampling and test methods related to specific environmental challenges, ISO has developed a wide range of standards regarding air, water, and soil quality, noise and radiation levels and also transportation of dangerous goods. The standards that ISO developed, also serve as the technical basis for environmental regulations in many countries. ISO technical committee ISO/TC 207, environmental management, is responsible for developing and maintaining the ISO 14000 family of standards. The aims include of several members of ISO 14000 family are given in the Table 1.1.

Table B.1: ISO 14000 family standards and their scopes

ISO 14001:2004	It guides the organisations to manage better the impact of their activities on the environment and to prove environmental management.
ISO 14004:2004	It complements ISO 14001 by presenting additional guidance and useful explanations.
ISO 14005:2010	It includes the use of environmental performance evaluation.
ISO 14006:2011	It is responsible for the environment management systems, distinctly guidelines for incorporating eco-design.
ISO 14020:2000	It is a series of standards including approaches about environmental labels and declarations, eco-labels, self-declared environmental claims, and environmental information about products and services.
ISO 14031:2013	It guides the organisations on how to evaluate their environmental performance and to select suitable performance indicators. Then the performance is evaluated according to the criteria set by management and reported as internal and external environmental performance.
ISO 14040:2006	It presents guidelines on the principles of life cycle assessment and give information to reduce the overall environmental impacts of products or services.
ISO 14044:2006	It is responsible for the life cycle assessment, and shows the requirements and guidelines
ISO 14045:2012	It is responsible for eco-efficiency assessment of product systems, distinctly principles, requirements and guidelines.
ISO 14051:2011	It is responsible for material flow cost accounting and its general framework
ISO 14063	It is related to environmental communication guidelines and examples, and responsible for showing important links to external stakeholders.
ISO 14063:2006	It is responsible for the environmental communication and shows the guidelines and examples.

ISO 14064-1-2-3:2006	The series are related to international greenhouse gas accounting and verification standards. They present requirements and support organisations and proponents to reduce GHG emission levels.
ISO 14065	It specifies requirements to accredit organisational bodies that commit GHG validation or verification using ISO 14064 or other relevant standards.
ISO 14065:2013	It introduces the requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition.
ISO 14066:2011	It gives the competence requirements for GHG validation teams and verification teams.
ISO/TS 14033:2012	It is responsible for the environmental management, distinctly quantitative environmental information, guidelines and examples.
ISO/TR 14047:2012	It is responsible for the life cycle assessment, distinctly illustrative examples on how to apply ISO 14044 to impact assessment situations.
ISO/TR 14049:2012	It is responsible for the life cycle assessment, and presents illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis.
ISO/TS 14067:2013	It is responsible for the greenhouse gas counting, carbon footprint of products, requirement and guidelines about these issues for quantification and communication
ISO/TS 14071:2014	It is responsible for life cycle assessment, distinctly about critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006.

American Society for Testing and Materials (ASTM) Environment Standards

ASTM technical committees mostly focuses on standards about environmental safety in order to increase air and water sanitation levels, and obtaining eco-friendly homes and office buildings; improving the waste management and recycling programmes; enhancing environmental assessment processes. The list of environmental standards developed by ASTM is given below.

- Atmospheric Analysis Standards
- Environmental Assessment Standards and Risk Management Standards
- Environmental Toxicology Standards
- Waste Management Standards
- Water Testing Standards

Global Organic Textile Standard (GOTS)

The GOTS international working group has four member organisations: OTA (USA), IVN (Germany), Soil Association (UK) and JOCA (Japan). These four member organisations work closely with other international stakeholder organisations for their expertise in organic farming and environmentally and socially responsible textile processing.

GOTS is a textile processing standard for organic fibres and considers all parts of the textile supply chain including ecological and social criteria. The certification standard considers the entire process from harvesting through environmentally sensitive manufacturing. There are two label-grade choices.

Table B.2: Label explanations

Label-Grade 1	It is also referred as "organic". If a textile product has the GOTS label-grade 1 certification, it must have a minimum of 95% certified organic fibres.
Label-Grade 2	It is also referred as "made with X% organic". If a textile product has GOTS label-grade 2 certification, it must contain greater than 70% certified organic fibres (also valid: less than 30% non-organic fibres). Non-organic fibre must have a maximum 10% synthetic fibres.

NATURTEXTIL BEST

Internationale Verband der Naturtextilwirtschaft (IVN) has members from all levels of textile production. It has two-step quality seal "NATURTEXTIL" that addresses all levels of textile production and includes social standards. The aim of IVN is to increase the awareness of eco-friendly textiles among consumers, press and retail trade. It defines and implements specific criteria to set ecological and social accountability in production processes and also high-quality standards in the finished product. Products labelled with 'NATURTEXTIL BEST' must be produced using 100% certified organic fibres and restricted fibre processing methods (bleaching, chlorination, mercerization, etc.). The use of hazardous dyes, auxiliaries and substances (e.g. formaldehyde, heavy metals and many more) are forbidden, and accessories (buttons, pockets, etc.) must be made using high-quality natural raw materials.

The EU Eco-Management and Audit Scheme (EMAS)

EMAS is a premium management instrument developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance. EMAS has developed a wide range of standards regarding air, chemicals, environmental assessment, environmental implementation review, green public procurement, land protection, marine, nature and biodiversity, noise, soil, sustainable development, waste management, and water.

Eco-labelling and certification of textiles and clothing

The eco-label certifications prove that the products and services follows the international regulations and environmental standards, and the fact that their reduced environmental impacts along the life cycles. Today there are 460 eco-labels worldwide and 109 of them are related to textile products. Eco-labels are issued either by government or private enterprises. Some government-based eco-labels are EU Ecolabel, Blue Angel (Germany), Eco Mark (Japan), White Swan (Nordic Countries) and Green Label

(Singapore). Some private labels are Eco-tex and Oeko-Tex (textile and clothing) (Germany).

EU Ecolabel: The Environment Directorate General of the European Commission (DG Environment) was established in 1973 to protect and improve Europe's environment for present and future generations. The main aim of the commission is to suggest policies and legislation for protecting natural habitats, cleaner air and water, waste management, toxic chemicals and guide businesses for sustainability. The commission's decision for the textile product groups were accepted in late 2014. The aim of it is to source materials using more sustainable agriculture forms, to use resources and energy more efficiently, to enhance processes in the less polluting way, to control the use of hazardous substances, and to design and specify high-quality and durable products.

Eco-Tex (Oeko-Tex) standards: An eco-label specific to textiles was founded in 1993 by the Austrian Textile Research Institute, called Oeko-Tex label. Oeko-Tex certificate is the most widely recognised textile environmental standard in the world. It has different standards developed can be namely counted: *OEKO-TEX® Standard 100* is specialised in textile raw materials, intermediate and end products at all stages of production. The laboratory tests currently contain around 100 test parameters based on international test standards and other recognised testing procedures such as colour-fastness and a skin-friendly pH-value. *Sustainable Textile Production (STeP)* is the new OEKO-TEX® certification system. STeP certification is possible for all processing stages from fibre production, spinning, weaving and knitting to finishing facilities and clothing manufacturers. The last one in this family is *OEKO-TEX® Standard 100 plus* label. With this label, manufacturers certify to their end users that their products have been optimized for human ecology and also their production conditions are environmentally friendly.

There are many more eco-labels in Europe and in the world. The most important ones are listed in the following paragraph: The Blue Angel Label (Germany), eco-INSTITUT (Germany), Ecoproof, Green Shape, NF Environnement Label (France), The Skal Label (Holland), Netherland - Stichtung Millieukeur (Holland), The Nordic Ecolabel – Nordic Swan (Sweden, Norway, Finland, Iceland and Denmark), the KRAV Label (Sweden), bluesign® standard (Switzerland), Coop Naturaline (Switzerland), IMO certified (Switzerland), Global Recycled Standard, Japan EcoMark (Japan), Singapore Green Label Scheme (Singapore), BMP certified cotton (Australia), Good Environmental Choice (Australia), India Eco-Mark (India), Thai Green Label (Thailand), and China Environmental Labelling (China).

Appendix C. Pairwise Comparison sample questionnaire

Table C.1: Sample questions for the pairwise comparison wrt cost criterion

Comparisons with respect to "Cost" in clusters																		
1. Indicate your preference of "Cost" over "Quality" with respect to "Cost" criterion																		
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
2. Indicate your preference of "Cost" over "Sustainability" with respect to "Cost"																		
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Sustainability
3. Indicate your preference of "Quality" over "Sustainability" with respect to "Cost"																		
Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Sustainability

BIOGRAPHICAL SKETCH

Merve BACIN was born in Ordu on April 29, 1989. In 2007, she graduated from Ordu Anatolian High School. She was granted a full scholarship to attend Istanbul Kültür University where she studied her bachelor's in Industrial Engineering exclusively in English. During her bachelor studies, she studied International Business in Hochschule Bremen within the framework of Erasmus Programme for one year. After completing her bachelor's degree, she worked for a total of six months in Online Marketing at a German start-up company based in Berlin. She was enrolled as a graduate student in Industrial Engineering in Galatasaray University in 2015. She has been carrying out a deep analysis through her master thesis about a more sustainable and responsible fashion industry by changing the way it thinks of supply chain to a more non-conventional model. Her research interests include sustainability, supply chain sustainability, life cycle assessment, multi-criteria decision making and sustainable product design.