A HYBRID APPROACH FOR SUPPLIER SELECTION: A CASE STUDY FOR PETROLEUM MARKET

(TEDARİKÇİ SEÇİMİ İÇİN MELEZ BİR YAKLAŞIM: PETROL PİYASASINDA BİR UYGULAMA)

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Elif UÇAR, M.S.

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prepared by **Elif UÇAR** in partial fulfillment of the requirements for the degree of **Master of Science in Industrial Engineering** at the **Galatasaray University** is approved by the

Examining Committee:

Prof. Dr. H. Ziya ULUKAN (Supervisor)
Department of Industrial Engineering
Galatasaray University ----------

Assist. Prof. Dr. Emre ALPTEKİN
Department of Industrial Engineering
Galatasaray University ----------

Prof. Dr. Cengiz KAHRAMAN
Department of Industrial Engineering
İstanbul Technical University ----------

Date: ----------

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LIST OF SYMBOLS

AHP : Analytic Hierarchy Process
ANP : Analytic Network Process
CFA : Confirmatory Factor Analysis
DEA : Data Envelopment Analysis
DEMATEL : Decision Making Trial and Evaluation Laboratory
EFA : Exploratory Factor Analysis
ELECTRE : ELimination and Choice Expressing the REality
EPDK : Enerji Piyasası Denetleme Kurumu
FAHP : Fuzzy Analytic Hierarchy Process
FILP : Fuzzy Integer Linear Programming
GA : Genetic Algorithms
GP : Goal Programming
GSCM : Green Supply Chain Management
ILP : Integer Linear Programming
IP : Integer Programming
ISM : Interpretive Structural Modeling
IVHF : Interval-Valued Hesitant Fuzzy
LP : Linear Programming
LPG : Liquefied Petroleum Gas
MADM : Multi-Attribute Decision Making
MCDM : Multi-Criteria Decision Making
MCGP : Multi-Choice Goal Programming
MCWR : Multi-Criteria Weighting and Ranking
MEP : Multi-Expression Programming
MOILP : Multi-Objective Integer Linear Programming
MOLP : Multi-Objective Linear Programming
NN : Neural Network
PCI : Process Capability Index
PLP : Possibilistic Linear Programming
QFD : Quality Function Deployment
SCM : Supply Chain Management
SMART : Simple Multi-Attribute Rating Technique
SPMEM : Supplier Portfolio Management Execution Model
SSCM : Sustainable Supply Chain Management
SSM : Soft Systems Methodology
TOPSIS : Techniques for order preference by similarity to ideal solution
TÜPRAŞ : Türkiye Petrol Rafineri A.Ş.
VIKOR : Vlse Kriterijumska Optimizacija I Kompromisno Resenje
VPRS : Variable Precision Rough Set

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ABSTRACT

In an increasingly competitive and rapidly changing business environment, supplier evaluation process and supplier selection decision are considered as some of the key issues faced by companies to survive. This thesis provides a hybrid approach to solve the supplier selection problem which includes qualitative and quantitative factors affecting the decision-making process. Companies can increase profitability and gain competitive advantage by deciding the best supplier. However, this decision becomes complicated in case of multiple suppliers, multiple conflicting criteria, and imprecise parameters. In this thesis, a literature review was performed on supplier selection problem. A new hybrid approach is provided to solve a supplier selection problem by the use of a defined technique, which derives from fuzzy sets theory, Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Goal Programming (GP). Evaluation criteria are indicated by experts and the objectives of the problem are determined. Supplier selection criteria are weighted using Fuzzy AHP method because of the uncertainty and vagueness of the experts' opinion. Alternative suppliers are evaluated and ranked by Fuzzy TOPSIS method. Then, the problem is modelled in terms of GP approach and solved via LINDO to offer a different perspective for decision making process. After the comparison of results, the most suitable supplier is selected by the decision maker using proposed hybrid approach among the alternatives for satisfying the firm's requirements. Finally, the proposed framework is illustrated through a case study in the Turkey petroleum market because of vital importance of supplier selection in the market. Five main evaluation criteria and twenty-two sub-criteria are used to select most suitable fuel oil distribution company for filling station in Turkey. The proposed methodology is applied for 5-years partnership contract. The results show that the proposed approach is very well-suited as a decision-making tool for supplier selection decisions.

ÖZET

Giderek daha çok rekabetçi ve hızla değişen iş ortamında, tedarikçi değerlendirme süreci ve tedarikçi seçim kararı şirketlerin hayatta kalabilmek için karşılaştığı önemli sorunlardan bazıları olarak düşünülür. Bu tez karar verme sürecini etkileyen niteliksel ve niceliksel faktörleri içeren tedarikçi seçim problemini çözmek için melez bir yaklaşım sunar. Şirketler, en iyi tedarikçiye karar vererek karlılığını arttırabilir ve rekabet avantajı sağlayabilir. Ancak, birden çok tedarikçi, çoklu çelişen kriterler ve kesin olmayan parametrelerin olması durumunda bu karar karmaşık hale gelir. Bu tezde, tedarikçi seçim problemi üzerine literatür taraması gerçekleştirildi. Bulanık Küme Teorisi, AHS, TOPSIS ve Amaç Programlamadan türemiş melez bir yaklaşım tedarikçi seçim problemini çözmek için sunulmuştur. Değerlendirme kriterleri uzmanlar tarafından belirlenmiştir ve problemin hedefleri tanımlanmıştır. Tedarikçi seçim kriterleri uzmanların görüşünün belirsizliği ve muğlaklığı nedeniyle Bulanık AHP yöntemi kullanılarak ağırlıklandırılmıştır. Alternatif tedarikçiler, Bulanık TOPSIS yöntemi ile değerlendirilir ve sıralanır. Problem karar verme sürecine farklı bir bakış açısı sunmak için Amaç Programlama yaklaşımına dayanarak modellenir ve LINDO ile çözülür. Sonuçların karşılaştırılmasından sonra en uygun tedarikçi, firmanın gereksinimlerini karşılamak için alternatifler arasından önerilen melez yaklaşım kullanarak karar verici tarafından seçilir. Son olarak, Türkiye petrol piyasasında tedarikçi seçimi hayati önem taşıdığı için önerilen yapı bir vaka çalışması ile gösterilmiştir. Türkiye'de bir benzin istasyonuna en uygun akaryakıt dağıtım şirketini seçmek için beş tane ana kriter ve yirmi iki tane alt kriter kullanılır. Önerilen metodoloji, 5 yıllık ortaklık sözleşmesi için uygulanır. Önerilen yaklaşımın tedarikçi seçim kararları için çok uygun bir karar verme aracı olduğunu sonuçlar göstermektedir.

1. INTRODUCTION

The petroleum industry includes the phases of exploration, extraction, refinery, transportation and delivery to dealers by distribution companies and retail sales by dealers. Petroleum Market participants are refinery companies (TÜPRAŞ etc.), distribution companies (Petrol Ofisi, Opet, Shell etc.) and filling stations. According to the 2012 Petroleum Market Sector Report by Energy Market Regulatory Authority, Top 5 Distribution License Holders based on Sales are OMV Petrol Ofisi A.Ş., Opet Petrolcülük A.Ş., Shell & Turcas Pet. A.Ş., BP Petrolleri A.Ş., Total Oil Türkiye A.Ş.. Total market share of top 10 companies with the largest share in 2010, 2011 and 2012 were 87%, 83.4% and 82.9% respectively as seen Figure 1.1. Therefore, it can be stated that the concentration level in fuel distribution market has had a downward trend throughout the years.

No	2010	Market Share (%)
1	Omv Petrol Ofisi A.Ş.	24,7
2	Shell & Turcas Pet. A.Ş.	19,1
3	Opet Petrolcülük A.Ş.	16,6
4	Bp Petrolleri A.Ş.	10,8
5	Total Oil Türkiye A. Ş.	5,6
6	Akpet Akaryakıt Dağ. A.Ş.	2,3
7	Altınbaş Pet. ve Tic. A Ş.	3
8	Tp Pet. Dağ. A.Ş.	1,9
9	Bölünmez Petrolcülük A.Ş.	1,4
10	Lukoil Eurasia Pet. A.Ş.	1,4
11	Other Distribution License Holder Companies Total	13

No	2011	Market Share (%)
1	Omv Petrol Ofisi A.Ş.	23,7
2	Shell & Turcas Pet. A.Ş.	17,6
3	Opet Petrolcülük A.Ş.	17,2
4	Bp Petrolleri A.Ş.	9,4
5	Total Oil Türkiye A. Ş.	5,2
6	Altınbaş Pet. ve Tic. A Ş.	3
7	Lukoil Eurasia Pet. A.Ş.	2,1
8	Tp Pet. Dağ. A.Ş.	2
9	Milan Pet. San. ve Tic. A.Ş.	1,7
10	Akpet Akaryakıt Dağ. A.Ş.	1,5
11	Other Distribution License Holder Companies Total	16,6

No	2012	Market Share (%)
1	Omv Petrol Ofisi A.Ş.	22,4
2	Opet Petrolcülük A.Ş..	17
3	Shell & Turcas Pet. A.Ş.	16,7
4	Bp Petrolleri A.Ş.	8,9
5	Total Oil Türkiye A. Ş.	6
6	Tp Pet. Dağ. A. Ş.	3,7
7	Altınbaş Pet. ve Tic. A Ş.	2,2
8	Milan Pet. San. ve Tic. A.Ş.	2,1
9	Lukoil Eurasia Pet. A.Ş.	2
10	Aytemiz Akar. Dağ. A.Ş.	1,9
11	Other Distribution License Holder Companies Total	17,1

Figure 1.1: Top 10 Distribution License Holders based on Sales

Turkish petroleum sector has seen a rapid growth especially since 2005 when Petroleum Market Law no.5015 was enacted and Energy Market Regulatory Authority was authorized for regulating and auditing the petroleum market. Turkish Competition Authority's Petroleum Market Law (No. 5015) limit the duration of dealership contracts to five years. According to the decision taken by the Competition Authority on September 18, 2010, utilization contracts and similar agreements shall be renewed once in five years. Thus, filling stations in the fuel oil sector must either renew their contracts with current companies or change their distribution firms. As a result of these, competition in the market increased, new players joined the market and quality, product and service range improved.

Distribution License Holder	With Stations		With Stations Total	Without Stations		Without Stations Total	TOTAL
	Fuel	Bunker		Fuel	Bunker		
Omv PO	2.266	4	2.270	53	12	65	2.335
Opet	1.316	8	1.324	28		28	1.352
Shell & Turcas	1.025		1.025	3	1	4	1.029
Bp	609	1	610	20		20	630
Termopet	575		575	24		24	599
Total	444		444	10		10	454
Balpet	429		429	9		9	438
Milan	428		428	9		9	437
Altınbaş	377	1	378	1		1	379
Starpet	320		320	9		9	329
Turkuaz	316		316	7		7	323
Teco	290		290	21		21	311
Aytemiz	309		309	1		1	310
Lukoil	306	1	307				307
Kadooğlu	288		288	7		7	295
Akpet	264		264	28		28	292
Siyam	288		288	4		4	292
Enerji	238		238	36		36	274
Kaleli Best	238		238	4		4	242
Can Aslan	211		211	13		13	224
Petline	222		222	2		2	224
N-pet	209		209	11		11	220
Tp	182		182	1		1	183
Parkoil	145		145	7		7	152
Vtm	141		141	3		3	144

Figure 1.2: Number of Vendors of Distribution License Holders in 2012

The interest in petroleum supply chain has increased and supplier selection becomes critically important in recent years. As, firms become involved in strategic partnerships with their suppliers in terms of a new set of supplier selection criteria in the petroleum market. The law shortened a period of the contracts between distributors and dealers, and filling stations select their distributors at least once in a five years. So, supplier selection process has become more vital for the market in terms of profitability. The vendors of the distribution license holders' status is presented in Figure 1.2.

Most of the existing research on supplier selection considers only quantifiable aspects of the supplier selection decision. However, several factors such as incomplete information, qualitative criteria and imprecision preferences are not taken into account during the decision making process. These criteria are subjective factors that are difficult to quantify. The uncertainty of subjective judgment is present when carrying out a supplier selection process. Moreover, decision-making becomes more complicated when the available information is incomplete or imprecise. Before making a decision of which suppliers to choose, all suppliers should be carefully analyzed in terms of the company's needs and strategies. This is the reason why each supplier selection problem unique.

The main objective of this study is to provide an insight of supplier selection process for petroleum market actors. The thesis provide a literature review for supplier selection, propose suitable analytical methods as hybrid approach for supplier selection and reveal an application related to fuel products distributor selection for filling station. Generally, the company's primary aim is to determine suppliers that ensure brand awareness, high sales opportunity, customer satisfaction, payment alternatives, on-time delivery, quality in terms of the characteristics of the purchased products or services in supplier selection process. Then, the company wants to select the most suitable fuel oil distribution company for new contract period. Thus, the filling station requires analytical supplier selection model. Although many studies reveal various supplier selection methodology in the literature, petroleum market specific study is unavailable.

The paper is organized as follows: Section 2 reviews the literature of supplier selection, related analytical methods and selecting criteria. Section 3 expresses the proposed

hybrid approach, provides their stepwise representations and introduces the basic definitions and notations of the Fuzzy AHP, Fuzzy TOPSIS and GP methods. Section 4 presents the application of a real case study to demonstrate the usage of the proposed methodology. Finally, discussion about the study, concluding observations and directions for future research will be given in Section 5.

2. LITERATURE REVIEW

In this section, an extensive literature search about supplier selection was presented. Several excellent papers exist that have focused on reviewing earlier research. There are many studies since the 1960s about factors, which affect supplier selection such as (Busch, 1962), (Dickson, 1966) , (Weber, et al., 1991).

This thesis extends the literature up to 2010 and provides an up-to-date version by surveying the literature of "supplier selection" from 2010 to 2015 as seen Table 2.1. This thesis presents a taxanomy of the supplier selection criteria and methods by classifying the published articles except "green" concept. The 62 articles were analyzed as a result of search using major electronic databases such as EBSCO, Emerald, IEEE Xplore, ProQuest, ScienceDirect, SpringerLink, and Taylor & Francis. Generally, this study focus on the journal articles, whereas proceeding papers, theses and other manuscripts are not included. The distribution of analyzed articles with respect to the years and journals are summarized in Table 2.2 and Table 2.3, respectively.

Table 2.1 : Literature Review for Supplier Selection (SCI, SCI-E, SSCI)

Reference	**Industry**	**Main Criteria**	**Approach**
(Wu. & Pearn, 2013)	Manufacturing	-	PCI
(Nazari-Shirkouhi, et al., 2013)	Manufacturing	cost, quality, delivery	Fuzzy MOLP
(Roshandel, et al., 2013)	Production	quality, delivery, cost/price, technology, flexibility, services, responsiveness	Fuzzy TOPSIS
(Wu, et al., 2013)	Production	quality	PCI
(Aliabadi, et al., 2013)	Manufacturing	speed, quality	GA
(Ahmady, et al., 2013)	-	cost, price, reputation, time, quality, variety	Fuzzy DEA

(Sadigh, et al., 2013)	Production	cost, delivery, quality	GA
(Arikan, 2013)	Textile	net price, quality, delivery	Fuzzy Multi-Objective Programming
(Mansini, et al., 2012)	-	cost, quantity discount, price	Stochastic IP
(Amin & Zhang, 2012)	Manufacturing	cost, delivery, quality, experience, part safety, lightweight, recyclable, process capability, design process, reduction of wastes, using clean technology	Multi-Objective MILP
(Shen & Yu, 2012)	Digital Multimedia	quality, service, organization, relationship, cycle time	PCI
(Rezaei & Davoodi, 2012)	Production	price, lot-size, delivery, demand, cost, capacity	GA
(Kang, et al., 2012)	Semiconductor	cost, quality, delivery, new product development, risk	Fuzzy ANP
(Kilincci & Onal, 2011)	White Good	lead time, technical support, product quality, product price, capacity, quality systems, technical ability, financial status	Fuzzy AHP
(Vinodh, et al., 2011)	Manufacturing	business improvement, extent of fitness, quality, service, risks	Fuzzy ANP
(Chena & Yanga, 2011)	Architecture	price of the product, quality of the product, delivery, risk, service performance, cost	Constrained Fuzzy AHP and Fuzzy TOPSIS
(Yücel & Güneri, 2011)	Textile	net price, quality, on-time delivery	Fuzzy MOLP
(Shemshadi, et al., 2011)	-	products quality, effort to establish cooperation, technical level, delay on delivery, price/cost	Fuzzy VIKOR
(Feng, et al., 2011)	Service Outsourcing	interface management compatibility , service system sharing , mutual technology supports	Tabu Search
(Vahdani & Zandieh, 2010)	High Technology Manufacturing	Profitability, relationship closeness, technological capability, conformance quality, conflict resolution	Fuzzy Balancing and Ranking
(Talluri & Lee, 2010)	Manufacturing	discount factor, investment cost, market price uncertainty, suppliers'capacities	MIP
(Yang, 2010)	LED Manufacturing	finance, customer service, manufacturing, learning, reaction	GA
(Sanayei, et al., 2010)	Automobile Part Manufacturing	product quality, on-time delivery, price/cost, technological level, flexibility	Fuzzy VIKOR
(Wua, et al., 2010)	Outsourcing Product manufacturing	costs, quality acceptance levels, on-time delivery distributions, economic environment, vendor rating	Fuzzy Multi-Objective Programming
(Kuo, et al., 2010)	Auto Lighting System OEM	implementation capability, manufacturing capability, quality system, flexibility, supplier relationship	Integrating Fuzzy AHP and Fuzzy DEA
(Sevkli, 2010)	Real Industry	delivery performance, price/cost, financial strength, management, organizational strength	Fuzzy Electre
(Wu, 2010)	Manufacturing	quality, price, performance, facilities/capabilities	Stochastic DEA
(Díaz-Madroñero, et al., 2010)	Automobile	cost, late delivered, rejection, capacity, flexibility	Fuzzy MOLP
(Azadeh & Alem, 2010)	-	costs, quality of acceptance levels, on-time delivery	Fuzzy DEA
(Tsai, et al., 2010)	-	cost, service, and quality, financial	Ant Colony Optimization
(Juniora, et al., 2015)	Automotive	quality, price, delivery , supplier profile, supplier relationship	Fuzzy AHP and Fuzzy TOPSIS

(Jadidi, et al., 2015)	-	price, rejection rate, late delivery rate, capacity	MCGP
(Moghaddam, 2015)	Manufacturing	total profit, defective parts, late delivery, economic risk	Hybrid Monte Carlo Sim. and GP
(Hanafizadeh & Zadeh, 2014)	Oil	-	combination of Cognitive Mapping and SSM
(Keskin, 2015)	Polyester	quality, financial, performance, trust, information sharing	Integrated fuzzy DEMATEL and fuzzy C (clustering)
(Thakur & Anbanandam, 2015)	Banking	quality, cost/price, flexibility/responsibility/service level, location/assets/ facilities, delivery/reliability, long term relationship	Grey Theory
(Abdollahi, et al., 2015)	Manufacturing	cost, quality, delivery, human, technological, managerial, cultural, capability	DEMATEL-ANP-DEA Model
(Cheaitou & Khan, 2015)	Lubricant	on-time delivery, geographical location, product quality, quality of service, and product price, dynamic viscosity, kinematic viscosity	MILP and AHP
(Fallahpour, et al., 2015)	Textile	quality, delivery, technology, cost, flexibility	Integration of AHP and MEP
(Karsak & Dursun, 2015)	Health Sector	cost, quality, product conformity, availability, customer support , efficacy of corrective action	Fuzzy MCDM and QFD
(Geng & Liu, 2014)	Manufacturing	tangibles, reliability and assurance, responsiveness, empathy	SERVQUAL Model , VPRS and Vague VIKOR.
(Kar, 2015)	Iron and Steel Manufacturing Firm and Food	product quality, delivery compliance, price, production capability, technological capability, financial position, e-transaction capability, consistency measures, consensus index, product price, geographical distance, lead time, delivery reliability, supply variety	Integrated Fuzzy AHP and Fuzzy NN
(Gitinavard, et al., 2015)	Automobile Manufacturing Company	cost, quality, delivery, technology capability, environmental competency, Investment cost	IVHF-MCWR Model,
(Naira, et al., 2015)	Manufacturing	cost, quality, delivery, flexibility, innovation.	CFA and EFA
(Igoulalene, et al., 2015)	-	performance strategy, quality of service, innovation, risk	Combined the Fuzzy Consensus-based Possibility Measure and Fuzzy TOPSIS, Combined the Fuzzy Consensus-based Neat OWA and GP
(Silva1, et al., 2015)	Motor Repair Services - Sanitation	facilities, professionals, safety and environment, experience	ELECTRE and PROMETHEE
(Beikkhakhian, et al., 2015)	Manufacturing	uncertainty customer satisfaction, price, lead time, cost, delivery speed, data accuracy, transportation, information technology, quality	ISM and Fuzzy AHP-TOPSIS
(Zhang, et al., 2015)	-	cost, quality, service performance, supplier's profile, risk factor	Fuzzy Extended ANP (FEANP)
(Nekooie, et al., 2015)	Manufacturing	capacity, fixed ordering cost, risk factors, quality of the final product,	a Fuzzy GP Multi-Objective

		suppliers' delay, expected number of repairs, mean time to repair, defect rate, repair cost, purchasing price	Mathematical Model, Sensitivity Analyses
(Dowlatshahi, et al., 2015)	Automobile Industry	quality, finance, delivery, service, technical capability, cooperation, strategic view, history, management, work order & discipline,	Fuzzy TOPSIS
(Rouyendegh & Saputro, 2014)	Fertilizers Manufacturer	supply capacity, production capacity, response time, production technology, price, warranty, procedural compliance, purchase transaction, communication system, quality, completed shipping document, quantity, On time delivery, financial position, location, reputation, management and organization	Integrated fuzzy TOPSIS and MCGP
(Choudhary & Shankar, 2014)	Distributor-Retailer	unit procuring cost, percentage of items late delivered, capacity of supplier, cost of ordering, percentage of rejected items delivered, transportation cost	MOILP and GP
(Karsak & Dursun, 2014)	Medical	cost, quality, product conformity, availability and customer support, efficacy of corrective action product volume, delivery, payment method, supply variety , reliability, experience, earlier business relationship, management, geographical location	Integrating QFD and DEA
(Kar, 2014)	Steel Manufacturing	product quality, delivery compliance, price, technological capability, production capability, financial strength, electronic transaction capability	Fuzzy AHP, Geometric Mean Method, Ordinal Consensus Improvement Approach, Fuzzy GP
(Sharma & Balan, 2013)	Heavy Commercial Vehicles – Automotive	product quality, price, delivery, service satisfaction, warranty degree	Taguchi Loss Function, TOPSIS and Multi-Criteria GP
(Sepehri, 2013)	Oil and Gas	cost/price, materials management, long-term availability, functional efficiency, cost management, reliable short-term source	Kraljic's model, SPMEM
(Senvar, et al., 2014)	-	reliability, responsiveness, agility, costs, assets	Fuzzy PROMETHEE
(Choudhary & Shankar, 2014)	Service	rejections, cost, delivery	MOILP, GP, IP
(Sharma & Srinivasan, 2013)	Heavy Commercial Vehicles	product quality, price, delivery, service satisfaction and warranty	Taguchi Loss Function, TOPSIS, Multi-Criteria GP
(Mukherjee & Kar, 2012)	Integrated Special Steel and Alloy Steel Casting	product quality, service quality, delivery time, price	MADM based on Fuzzy Logic
(Liao & Kao, 2011)	Manufacturer	relationship closeness, quality of product, delivery capabilities, warranty level, experience time,	MCDM, TOPSIS, MCGP
(Ku, et al., 2010)	Electrical and Electronic Manufacturer	cost, quality, service and risk	Fuzzy AHP, Fuzzy GP

Table 2.2: The distribution of the articles according to the years

Years	# of Journals
2010	12
2011	7
2012	6
2013	11
2014	7
2015	19

Table 2.3: The distribution of the articles according to the journals

Journal Name	# of Journal
Applied Intelligence	1
Applied Mathematical Modelling	3
Applied Mathematics and Computation	1
Applied Soft Computing	1
Computers & Industrial Engineering	3
Computers and Mathematics with Applications	1
European Journal of Operational Research	1
Expert Systems with Applications	16
International Journal of Computer Integrated Manufacturing	1
International Journal of Logistics Research and Applications	1
International journal of production economics	1
International Journal of Production Research	9
International Journal on Interactive Design and Manufacturing	1
Journal of Computational Science	1
Journal of Enterprise Information Management	1
Journal of Intelligent Manufacturing	3
Mathematical and Computer Modelling	1
Neural Computing and Applications	2
Omega	1
Operations and Supply Chain Management	1
Procedia-Social and Behavioral Sciences	1
Production Engineering	1
Production Planning & Control	1
Quality & Quantity	1
Quality and Reliability Engineering International	1
Supply Chain Management Under Fuzziness	1
Systemic Practice and Action Research	1
The International Journal of Advanced Manufacturing Technology	3

Decision making is a process of selecting the most appropriate one among the potential alternatives according to predefined set of criteria, objectives and constraints. Supplier selection is a decision-making process comprising several steps. As reported by (De Boer, et al., 2001) a supplier selection problem consists of four phases such as problem definition, decision criteria formulation, qualification of suitable suppliers, and making a final choice. Selection is abroad comparison of suppliers using a common set of criteria and measures. It involves the determination of quantitative and qualitative factors so as to select the best possible suppliers. However, the level of detail used for examining potential suppliers may vary depending on firms' needs. Supplier selection decisions are complicated by the fact that various qualitative and quantitative criteria must be considered in decision making process. The analysis of criteria for selection and measuring the performance of suppliers has been the focus of many researchers since the 1960's.

Comprehensive literature survey for supplier selection, its applications, evaluation criteria and solution methodologies are provided by (Ho, et al., 2010), (Agarwal, et al., 2011), (Warea, et al., 2012), (Abdolshah, 2013), (Govindan, et al., 2015), (Dursun & Karsak, 2016).

2.1 Supplier Selection Criteria

In the literature, the most popular criterion is ‘cost’, followed by ‘quality’ and ‘delivery’ as seen the papers of (Nazari-Shirkouhi, et al., 2013), (Sadigh, et al., 2013), and (Naira, et al., 2015). (Kahraman, et al., 2003) addressed the selection criteria into four categories: supplier criteria, product performance criteria, service performance criteria, or cost criteria. The study of (Bhutta, 2003) diversified criteria are primarily quantitative and qualitative stating the basic criteria as pricing structure, delivery (lead-time and reliability), product quality, and service (i.e., personnel, facilities, research and development, capability, etc.).

The paper of (Kılıçoğulları, et al., 2009) presents five basic criteria for the fuel distribution company selection and evaluation process; these criteria are profit, brand value, advertising budget, grant support and financial facility. The paper of (Sepehri, 2013) stated that selection criteria are cost/price, materials management, long-term availability, functional efficiency, cost management, reliable short-term source for the oil and gas industry. (Wu, et al., 2013)’s study stated that high quality substantially increases profitability by lowering operating costs and improving market share.

(Vahdani & Zandieh, 2010)’s’s study mentions about profitability criteria, and almost all articles evaluate cost criteria. Recent articles like (Yang, 2010), (Sevkli, 2010), (Tsai, et al., 2010), (Keskin, 2015), (Kar, 2015), (Dowlatshahi, et al., 2015), (Kilincci & Onal, 2011) deal with finance criteria. The papers of (Rouyendegh & Saputro, 2014) and (Ahmady, et al., 2013) reveal reputation criteria.

The 23 criteria presented by (Dickson, 1966) still cover the majority of the criteria presented in the literature. These criteria are: price/cost, quality, delivery, service, technology, production facilities and capacity, relationship, amount of past business, geographical location, financial position, warranties and claim policies, environmental issues, flexibility, management and organization, reliability, risk, lead time,

performance history, product/service design, research and development, training aids, manufacturing capability, profitability. (Weber, et al., 1991) reviewed 47 articles in which more than one criteria was taken into account for supplier selection approaches. The articles of (Roa & Kiser, 1980), (Ellram, 1990), and (Stamm & Golhar, 1993) stated that more than 10 criteria for supplier selection in their articles.

Hundreds of criteria were observed about green supplier selection with articles published research from 1997 to 2011 by (Govindan, et al., 2015)'s extensive research. (Kar, 2014) listed seventy-five generic criteria which have been used across different purchasing contexts across industries. (Aguezzoul, 2014)**'s** analysis listed the most commonly used criteria in terms of 3PL are cost, relationship, services, quality, information/equipment system, flexibility, and delivery. These criteria represent 79.59%, while professionalism, financial position, location, and reputation represent the remaining 20.41%. (Zimmer, et al., 2015) determined the ten most common economic, environmental and social criteria. Also, they provide Hierarchical structure (Dimension, Main theme, Theme) for Sustainable supplier management criteria.

The paper of (Ho, et al., 2010) provides comprehensive literature survey for supplier selection applications and evaluating criteria. They reviewed 78 articles between 2000 and 2008. The one of most important objective of this paper is to discover the most popular criterion considered by the decision makers for evaluating and selecting the most appropriate supplier. Hundreds of criteria were proposed. The most popular criterion is quality, followed by delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment.

(Agarwal, et al., 2011) reviewed sixty-eight research articles for supplier evaluation and selection from 2000 to 2011. According to them, supplier selection belongs to the class of multi-criteria decision making (MCDM) problem in which the firms need to identify the top priorities of selecting the best supplier based on its working style and the

industry type. The study lays emphasis on key characteristics of the sector or company to identify selection criteria.

(Warea, et al., 2012) provide state-of-the-art review for supplier selection problem, more than 200 published and unpublished works from 1991 to 2011 are gathered and analyzed. They provide most of criteria and their sub-criteria which are directly or indirectly influencing on supplier decision process: main criteria are cost, quality, service, backgrounds, risk-factors, IT knowledge, availability, and environment. Cost criterion associated with the product cost, tariff and taxes, total logistics/freight cost as sub-criteria. Conformance to specification, lead time, quality assessment techniques and process capability are the sub-criteria to quality. Service criterion deals with delivery reliability, information sharing, flexibility and responsiveness. R & D development, new technology, financial background, market reputation, communication openness, and supplier's ethical standards assumed as supplier's background sub-criteria. Terrorism, foreign policies, political stability, geographical location, corruption perception considered as risk factors. IT standards, IT experience, adaptability to IT, availability of Software are other sub-criteria. Breadth of product line, geographic proximity, human skill, waste management system, attractive discount, cultural similarity and refund policies are the availability sub-criteria. Environment criterion associated with management competencies, green image, design for environment, environmental management system, environmental competencies, environmental cost (improvement & pollutant effect).

(Moliné & Coves, 2014)' study classified the criteria of the articles according to their family (Assets and Infrastructure, Costs, Logistics and Quality) and typology (strategic, tactical and operational). The study shows the most mentioned criteria, a total of 11, which have 5 or more repeats, and which show a high degree of concentration, as the 11 criteria (5.85%) have a total of 123 citations (32.36%). Mentioned criteria are Delivery performance, price, quality performance, production capacity, general demand, financial stability, communication openness, location, transportation, design capability, quality management practices and systems.

(Abdolshah, 2013) reviewed 21 articles and he investigated 42 selection criteria. Most important ones are price (cost), delivery and quality. Nearly, all articles mention about them. Semi-important ones are After sales service, Technical capability, Reputation and position in industry, Management and organization, Financial position, Geographical location, E-commerce capability, Production facilities and capacity, Amount of past business, Reciprocal arrangements, Impression, Environmentally friendly products.

(Dursun & Karsak, 2016)'s paper presented a supplier selection review based on an extensive search in the academic literature from 2001 to 2013 and classified their research papers in terms of (Dickson, 1966)'s criteria. According the study of (Dursun & Karsak, 2016), the most popular criterion in supplier selection is determined to be 'cost'. The 'quality' criterion follows 'cost' while the third most widely used criterion is 'delivery'. Eighty-two out of ninety-three research articles published between 2010 and 2013 used 'cost' as a decision criterion. Likewise, 78 and 50 papers appeared in the 2010–2013 term considered 'quality' and 'delivery', respectively, among decision criteria. 'Cost' is the most widely utilized evaluation criterion in 28 articles followed by 'quality' and 'delivery' in 24 and 18 papers, respectively, out of a total number of 28 articles published in 2013.

91 studies that were performed between 2001 and 2014 on the multi-criteria supplier selection were reviewed by (Yayla & Aytac, 2015). The paper presents sector-based distribution of the reviewed papers; the sectors are: Hypothetical Example (28%), Electrical-Electronics (20%), Automotive (16%), Manufacturing (13%), Furniture-White Goods (6%), Health (4%), Informatics (3%), Transportation-Logistics (4%), Agriculture-Construction (4%), Textile (2%). According to (Yayla & Aytac, 2015)'s review, the supplier selection criteria are: quality is 22%, delivery is 17%, cost is 15%, and price is 14%; others: service, financial status, flexibility, technology, geographic location, technical capability.

The study of (Feng, et al., 2011) stated that the criteria (or objectives) focused in service supplier selection differ from those for manufacturing supplier selection. Revenue, cost or the number of suppliers is usually considered in manufacturing supplier selection. However, service price and waiting time are the two most important and irreplaceable objectives for supplier selection in multi-service outsourcing (Allon & Federgruen, 2009). Finally, unlike part or product purchasing, service outsourcing is ordinarily conducted by a long-term contract, not by repeated orders. The outsourcing cost does not contain ordering, transportation, inspection and storage costs. Therefore, the existing decision methods cannot be directly used to solve the problem of supplier selection in multi-service outsourcing. Clearly, there is a need for a straightforward and routine decision method for solving the multi-service outsourcing problem.

Table 2.4 reports an extract of a survey of the criteria. 11 main criteria which are quality, delivery, cost, price, service, finance, capability, technology, risk, flexibility and capacity in decreasing order, are frequently used criteria in the literature considered 62 articles' review of this thesis in Table 2.1.

Table 2.4: The distribution of the articles according to the main criteria

Main Criteria	**# of Articles**	**%**
Quality	49	79%
Delivery	36	58%
Cost	32	52%
Price	26	42%
Service	12	19%
Finance	10	16%
Capability	9	15%
Technology	8	13%
Risk	8	13%
Flexibility	8	13%
Capacity	7	11%

2.2 Supplier Selection Methods

Since 1960s, the new methodologies have been developed to assist the decision-making process, especially in the development of procedures in multi-criterion decision-making and in multi-objective programming. In the literature, researchers have used various approaches to solve the supplier selection problems. (Dursun, 2013) classified existing methods in three principal categories to solve the supplier selection problem as seen Table 3.1. (Aruldoss, et al., 2013)'s study depicts the hierarchical view of MCDM methods and its types and provide the merits and demerits of various MCDM methods. The paper of (Aguezzoul, 2014) discussed some strengths and weaknesses of the methods: MCDM, Statistical methods, mathematical programming, artificial intelligence. (Zimmer, et al., 2015)'s paper provides the classification in terms of modelling approaches; they are divided into two groups: Single Models (Qualitative, Mathematical Programming, Mathematical Analytical, Artificial Intelligence) and Combined Models.

Table 2.5: Analytical approaches for supplier evaluation and selection

1.Deterministic approaches	2.Non-deterministic approaches	3.Integrated approaches
1.1.Mathematical programming	2.1.Non-deterministic optimization methods	3.1.Optimization based
1.1.1.Data envelopment analysis	2.1.1.Imprecise data envelopment analysis	3.1.1.DEA based
1.1.2.Linear programming	2.1.2.Stochastic/fuzzy integer programming	3.1.2.Integer programming based
1.1.3.Integer programming	2.1.3.Non-linear programming	3.1.3.Non-linear programming based
1.1.4.Non-linear programming	2.1.4.Stochastic/fuzzy multi-objective programming	3.1.4.Multi-objective programming based
1.1.5.Goal programming	2.2.Non-deterministic multi-attribute decision making	3.2.Multi-attribute decision making based
1.1.6.Multi-objective programming	2.2.1.Fuzzy analytic hierarchy process	3.2.1.AHP based
1.2.Multi-attribute decision making	2.2.2.Fuzzy analytic network process	3.2.2.ANP based
1.2.1.Analytic hierarchy process	2.2.3.Fuzzy TOPSIS	3.2.3.MAUT based
1.2.2.Analytic network process	2.2.4.Fuzzy VIKOR	3.2.4.TOPSIS based
1.2.3.Multi-attribute utility theory	2.2.5.Fuzzy ELECTRE	3.2.5.Fuzzy integral based
	2.2.6.Tuple linguistic representation model	3.3.Quality function deployment based
	2.2.7.Fuzzy balancing and ranking	3.4.Metaheuristic methods based
	2.2.8.Fuzzy data mining	3.4.1.Genetic algorithm based
	2.3.Metaheuristic methods	3.4.2.Particle swarm optimization based
	2.3.1.Genetic algorithms	3.5.CBR based
	2.3.2.Ant Colony optimization	
	2.4.Process capability indices based	
	2.5.Case-based reasoning	

(Moliné & Coves, 2014) notice 25 different methods in a total of 35 articles. This survey shows that 48.6% of the articles use the AHP or its variations (ANP, Fuzzy

AHP, Fuzzy ANP). (Khodadadzadeha & Sadjadib, 2013), (Ho, et al., 2010), (Agarwal, et al., 2011), Integrated approaches have been proposed by many researchers (Igoulalene, et al., 2015), (Fallahpour, et al., 2015) and (Kuo, et al., 2010). Fuzzy set theory combined with MCDM methods has been extensively used to deal with uncertainty in the supplier selection decision process as seen (Karsak & Dursun, 2015) and (Shemshadi, et al., 2011).

AHP is one of the most widely-used multi-criteria decision-making methods. It is easier to understand and it can effectively handle both qualitative and quantitative data. (Saaty, 2008) defined the analytic hierarchy process (AHP) as a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. Although, AHP includes the opinions of experts, it is not capable of reflecting human's vague thoughts and has some short-comings. As well evaluation, improvement and selection based on preference of decision-makers have great influence on the AHP results (Toloie-Eshlaghy, et al., 2011)To overcome short-comings, several researchers integrate fuzzy approach with AHP, called the Fuzzy Analytic Hierarchy Process (FAHP or Fuzzy AHP). The comparison of various fuzzy AHP methods was provided by (Büyüközkan, et al., 2004) considering includes advantages and disadvantages of each method. A number of fuzzy AHP methods or their applications have been published in recent years. These methods are systematic approaches to the prioritization of criteria, alternative selection and justification problem (Beskese, et al., 2015).

The use of fuzzy set theory allows the decision-makers to incorporate unquantifiable information, incomplete information, non-obtainable information, and partially ignorant facts into decision model (Kulak, et al., 2005). Fuzzy TOPSIS is one of the methods which are used for decision making in fuzzy environment. (Hwang & Yoon, 1981) originally developed The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in which the chosen alternative should not only have the shortest distance from the positive ideal reference point, but also have the longest distance from the negative ideal reference point. Systematic approach was provided by (Chen, 2000) to extend the TOPSIS to the fuzzy environment. (Ta-Chung & Lin, 2002) improved

extensions of TOPSIS for group decision-making under fuzzy environment. (Wang & Elhag, 2006) proposed a fuzzy TOPSIS model, where ratings of alternatives under criteria and importance weights of criteria are assessed in linguistic values represented by fuzzy numbers. (Wang, et al., 2009) used fuzzy hierarchical TOPSIS for supplier selection. Personal judgments are represented with crisp values by traditional TOPSIS method. However, in many practical cases the human preference model is uncertain and decision-makers might be reluctant or unable to assign crisp values to the comparison judgments (Chan, et al., 2008)The fuzzy TOPSIS method is more appropriate to solve MCDM problems under a fuzzy environment. There have been lots of studies in the literature using Fuzzy TOPSIS to solve MCDM problems (Igoulalene, et al., 2015), (Dowlatshahi, et al., 2015), (Roshandel, et al., 2013).

(Toloie-Eshlaghy, et al., 2011)' study states that there are two main differences between AHP and TOPSIS. (1) Pair-wise comparisons for attributes and alternatives are made in AHP, although there is no pair-wise comparison in TOPSIS (2) AHP uses a hierarchy of attributes and alternatives, whereas TOPSIS does not. (Ertuğrul & Karakaşoğlu, 2008) provides a comparison of fuzzy AHP and Fuzzy TOPSIS methods applied to facility location decision making. (Juniora, et al., 2015) presents a comparative analysis of the methods fuzzy AHP and Fuzzy TOPSIS applied to the problem of supplier selection. In the literature, there have been lots of studies which weight criteria using Fuzzy AHP and evaluate alternatives using Fuzzy TOPSIS methods (Chena & Yanga, 2011)., (Juniora, et al., 2015), (Beskese, et al., 2015).

The paper of (Ho, et al., 2010) provides comprehensive literature survey for supplier selection applications and evaluating criteria. According to their reviewed seventy-eight articles, (17.95%) DEA, (11.54%) mathematical programming models, (8.97%) AHP, (8.97%) CBR, (3.85%) ANP, (3.85%) fuzzy set theory, (2.56%) SMART, (1.28%) GA, (17.95%) integrated AHP, (11.54%) integrated fuzzy approaches, (11.54%) other integrated approaches are widely used in the literature.

The paper of (Agarwal, et al., 2011) reviewed sixty articles from various journals and conferences about supplier evaluation and selection from 2000 to 2011 to find out the

most prominent MCDM methodology followed by the researchers. The distribution of the articles under various classes of MCDM methods is 30% DEA, 17% Mathematical Programming, 15% AHP, 11% Case Based Reasoning, 5% ANP, 10% Fuzzy Set Theory, 3% SMART, 2% Genetic Algorithm, 7% Criteria Based Method.

The study of (Warea, et al., 2012) presented the list of research papers between 1991 and 2011 where various solution techniques are applied in solving supplier selection problem. According to the (Khodadadzadeha & Sadjadib, 2013)'s survey on MCDM methods for supplier selection problems over the period 2000-2012, DEA method has become the most significant technique for ranking supplier selection followed by TOPSIS, AHP. (Chai, et al., 2013)'s paper provides a systematic literature review on articles published from 2008 to 2012 on the application of DM techniques for SS. 123 journal articles were reviewed and 26 applied DM techniques from three perspectives: MCDM, MP and AI was presented. (Moliné & Coves, 2014) notice 25 different methods in a total of 35 articles. The survey shows that 48.6% of the articles use the AHP or its variations (ANP, Fuzzy AHP, Fuzzy ANP). Based on the analysis of 67 articles published within 1994–2013 period, (Aguezzoul, 2014) discussed some strengths and weaknesses of the methods: MCDM, Statistical methods, mathematical programming, artificial intelligence. (Govindan, et al., 2015) summarized literature from 1997 to 2011 for various approaches related to the green supplier evaluation and selection process.

(Dursun & Karsak, 2016) presented advantages and limitations of stochastic optimisation approaches, metaheuristic methods, process capability indices based approaches, case-based reasoning, fuzzy optimization approaches, fuzzy MADM approaches and fuzzy process capability indices based approaches with comprehensive literature survey from 2001 to 2013.

According to (Yayla & Aytac, 2015)'s analyze, 91 papers, most popular individual methods are AHP, LP and ANP. In addition, the study reveal that a great majority of

hybrid methods used in supplier selection consisted of AHP. Also, fuzzy AHP, fuzzy TOPSIS, and fuzzy ANP are frequently used in the hybrid fuzzy methods due to the research. The paper state while AHP is mostly used in the electrical-electronics and manufacturing sectors, ANP is mainly used in the electrical-electronics sector, and GP, fuzzy AHP, and fuzzy TOPSIS are often used in the automotive sector.

The paper of (Zimmer, et al., 2015) provides the classification in terms of modelling approaches for Sustainable Supplier Management. Modelling approaches are divided into two groups: Single Models (Qualitative, Mathematical Programming, Mathematical Analytical, Artificial Intelligence) and Combined Models. (Orji & Wei, 2015)'s study provides an understanding of how supplier behavior evolves with time and selected the best possible sustainable supplier with dynamic multi-criteria decision making model based on fuzzy TOPSIS. In the literature Lots of recent articles deal with the concept of sustainability and green such as (Galankashi, et al., 2015) and (Kannan, et al., 2013).

Mathematical programming is basically a static optimization problem, consisting of different models such as linear programming, goal programming, dynamic programming and game theory. The GP is one of the many models which have been developed to deal with the multiple objectives decision-making problems. GP is a branch of multi-objective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM). It can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved. GP has been a very powerful technique in multiple objective problems. After the basic idea of GP was traced, the term of Goal Programming was appeared by (Charnes & Cooper, 1961). (Romero, 2004) stated that GP models have been classified based on the achievement function that is used to combine the unwanted deviations : (1) Weighted GP (also known as 'non-preemptive GP') where the weighted sum of deviations from the targets are minimized. (2) Preemptive priority GP (also known as 'Lexicographic GP'), where a deviation from a higher priority level goal is considered to be infinitely more important than a deviation

from a lower priority goal. (3) MinMax GP (also known as ‘Chebyshev GP’) where minimization of the maximum weighted deviation from the target values is sought. Regarding methodological development, many extensions can be noted for GP model such as: weighted GP, lexicographical GP, integer GP, nonlinear GP, stochastic GP, fractional GP, interactive GP, GP with intervals, fuzzy GP, the “MINMAX GP”, the “chance constrained GP”, and the “GP and constrained regression”. In recent decades, new techniques which are variations of GP have arisen such as Integer goal programming, interactive goal programming and fuzzy goal programming. The purpose of GP is to minimize the deviations between the achievement of goals and their aspiration levels (Chang, 2007). In the literature, GP is accepted as suitable method to solve supplier selection method such as (Choudhary & Shankar, 2014), (Ku, et al., 2010), (Rouyendegh & Saputro, 2014), (Moghaddam, 2015), (Nekooie, et al., 2015), (Igoulalene, et al., 2015).

3. METHODOLOGY

3.1 Proposed Hybrid Approach

In this section, a systematic hybrid algorithm composed of fuzzy set theory, AHP, TOPSIS, GP is presented briefly for the supplier selection problem. The first phase involves a fuzzy AHP structure developed to determine the ratings of the supplier selection criteria in accordance with decision makers' opinion. The second phase requires decision makers' judgements about alternatives and fuzzy TOPSIS method is applied for ranking alternatives. Then, Mathematical Model is constructed in scope of Goal Programming and the problem is solved via LINDO. Finally, the results of two methods are compared and decision maker decide which alternative is the most suitable one. The objective of this study is to analyze the potential of suppliers, and to choose the best one by using a multi-criteria approach. If the measures are vague, the decision process begins to become difficult. For this reason, the usage of the fuzzy sets in describing uncertainties in different factors simplifies the complex structure of the decision phase.

MCDM approach is one of the most widely used aids in supplier selection. When solving the supplier selection problems with MCDM methods, decision makers should follow some of the MCDM procedures. The framework of the procedure is determined considering the problem, the goal of study, requirements and limits of the business. Creative thinking techniques and analytical approaches can be used to describe a problem. Decision makers are selected and evaluation criteria are revealed with the Delphi method which enables to elicit expert opinion. All possible alternatives are examined and unacceptable alternatives are eliminated with respect to the goal and the limits. When the problem, evaluation criteria and alternatives is accurately described, hierarchy of the model is structured to accomplish the problem. Criteria are weighted via fuzzy AHP method. Then, TOPSIS method is used to rank alternatives in

descending order. Also, mathematical model of the problem based on fuzzy AHP is constructed and solved

Table 3.1: Phases of Proposed Approach

RESEARCH PHASE	Define the supplier selection problem
	Analyze the operational characteristics of the company and the sector
	Form a committee of decision makers
	Determine the goals and Identify the current and ideal conditions
	Define evaluation criteria and alternatives for supplier selection problem
	Establish the hierarchical model of the problem
FUZZY AHP PHASE	Construct the structural hierarchy of the model
	Identfy the linguistic ratings
	Ask pair-wise comparisons of the criteria to DM linguistically
	Construct the fuzzy pair-wise comparison matrices
	Construct the aggregated decision matrices
	Calculate geometric means of fuzzy comparison values
	Calculate relative fuzzy weights of each criterion
	Calculate averaged and normalized relative weights of criteria
	Construct fuzzy weighted matrix
FUZZY TOPSIS PHASE	Identfy the linguistic ratings
	Obtain the opinions of each DMs about each alternative supplier linguistically
	Construct aggregated fuzzy decision matrix
	Construct normalized fuzzy decision matrix
	Construct weighted normalized fuzzy decision matrix
	Determine FPIS and FNIS
	Calculate the distance of each alternative from FPIS and FNIS
	Calculate the closeness coefficient of each alternative.
	Rank alternatives due to the closeness coefficients
GP PHASE	Construct mathematical model
	Solve mathematical model via LINDO

In general, an algorithm of proposed approach is presented in Table 3.1 After the phases are accomplished, the results of Fuzzy TOPSIS and Goal Programming are compared and decision makers decide which alternative is the most suitable supplier.

3.2 Fuzzy AHP

AHP is an analytical method which can be applied to problems having multiple alternatives and multiple criteria. AHP doesn't require complex mathematical operations. It is based on developing synthesized pairwise comparison matrix and identifying priority vector. Classic AHP uses integers in computing importance scale, however, real-world problems involve substantial vagueness and uncertainty, which necessitates using fuzzy numbers. Therefore, AHP and fuzzy logic were combined and transformed into an integrated model called fuzzy AHP. It was considered that fuzzy AHP can be effective in solving supplier selection problems which require a fuzzy approval due to inherent uncertainties inherent in selecting the best supplier.

(Lo & Sudjatmika, 2015) and (Colombo, et al., 2015) show the AHP hierarchical structure which formulate the supplier selection problem. Decision makers decide the importance level of criteria by using pair-wise comparison matrix with linguistic scale and corresponding triangular fuzzy numbers as shown in Table 2 which is used in recent studies such as (Kahraman & Çebi, 2009), (Beskese, et al., 2015). Related membership function of the linguistics variables for criteria comparisons as seen Figure 3.1.

Table 3.2: Linguistic variables for the importance weight of each criterion

Linguistic scales	Triangular fuzzy number
Just Equal (Je)	(1,1,1)
Equally Important (Eq)	(1,1,3)
Weakly Important (Wk)	(1,3,5)
Essentially Important (Es)	(3,5,7)
Very Strongly Important (Vs)	(5,7,9)
Absolutely Important (Ab)	(7,9,9)

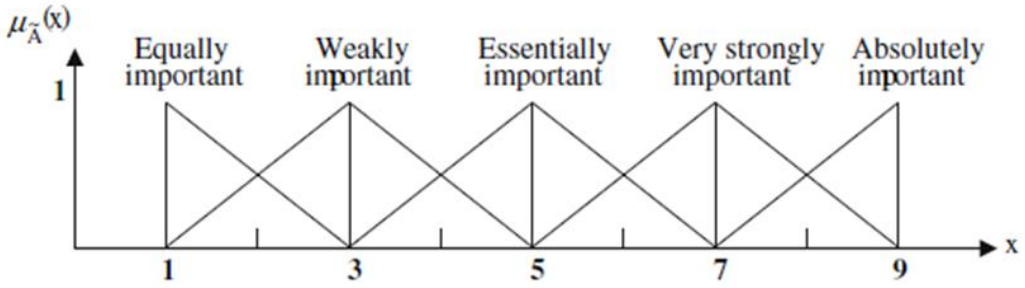

Figure 3.1: Membership function of the linguistics variables for criteria comparisons

(Lo & Sudjatmika, 2015), (Colombo, et al., 2015) show the AHP hierarchical structure which formulate the supplier selection problem as seen Figure 2.

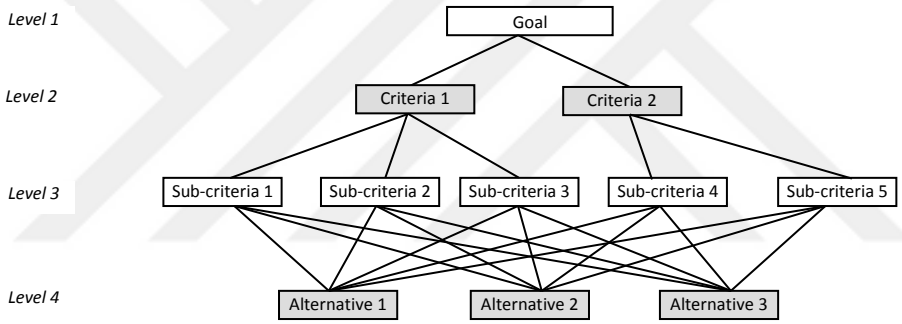

Figure 3.2: The AHP hierarchy structure

In this study, Buckley's FAHP is used to find the fuzzy weights. The procedure can be summarized as follows (Chen & Hwang, 1992):

- **Step 1:** The individual pair-wise comparisons are combined to construct fuzzy judgement matrix C is given by Eq. 1.

$$C^k = \begin{matrix} 1 & c_{12}^k & \dots & c_{1n}^k \\ c_{21}^k & 1 & \cdots & c_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ c_{m1}^k & c_{m2}^k & \cdots & 1 \end{matrix} \quad (1)$$

Through expert questionnaires, each expert is asked to assign linguistic terms by TFN to the pair-wise comparisons among all criteria in the dimensions of a hierarchy system. The result of the comparisons is constructed as fuzzy pair-wise comparison matrix.

- **Step 2:** The judgement matrix C is m×n fuzzy matrix using triangular fuzzy numbers c_{ij}^{k} corresponding to comparison of criteria *i* and *j* decision maker *k* as expressed in Eq. 2. where $i > j$ denotes that criterion *i* is more important than criterion *j*.

$$c_{ij}^{k} = \begin{cases} i > j, & 1,1,3\ ,\ 1,3,5\ ,\ 3,5,7\ ,\ 5,7,9\ ,\ 7,9,9 \\ i = j, & (1,1,1) \\ i < j, & 1,1,3^{-1},\ 1,3,5^{-1},\ 3,5,7^{-1},\ 5,7,9^{-1},\ 7,9,9^{-1} \end{cases} \quad (2)$$

- **Step 3:** An aggregated decision matrix (A) is constructed to satisfy each decision maker. Geometric mean is considered for every pair-wise comparison calculated as Eq. 3 where *K* is the number of decision makers, and ⊗ is the fuzzy multiplication sign.

$$a_{ij} = \sqrt[K]{c_{ij}^{-1} \otimes c_{ij}^{-2} \otimes \dots \otimes c_{ij}^{-K}} \quad (3)$$

- **Step 4:** Fuzzy weight matrix is calculated as Eq. 4 where a_{ij} is the fuzzy aggregate comparison value of criterion *i* to criterion *j*, r_i is the geometric mean of fuzzy comparison value of criterion *i* to each criterion, w_i is the weight of criterion *i*, and ⊕ is the fuzzy summation sign.

$$r_i = \sqrt[n]{a_{i1} \otimes a_{i2} \otimes \dots \otimes a_{in}} \quad (4)$$

$$w_i = r_i \otimes \left(r_1 \oplus r_2 \oplus \dots \oplus r_n\right)^{-1} \quad (5)$$

After the importance of weight matrix is obtained, defuzzification process and normalization procedure are applied. Centroid method, which provides a crisp value

based on the center of the gravity, is selected since it is most widely used method (Opricovic & Tzeng , 2004).

- **Step 5:** Once defuzzification is completed, normalization is applied simultaneously using Eq. 5 where the importance weight of r^{th} criterion, w_r is a crisp number and n is the number of criteria.

$$w_r = \frac{w_r}{\sum_{i=1}^{n} w_i} = \frac{w_{rl}+w_{rm}+w_{ru}}{\sum_{i=1}^{n} w_i} \quad (6)$$

3.3 Fuzzy TOPSIS

Fuzzy TOPSIS is well-known tool used for ranking a finite number of potential suppliers by considering a finite number of criteria under uncertainty. The initial requirements of using the proposed fuzzy TOPSIS were provided in the previous steps. The linguistic variables for the ratings can be expressed with triangular fuzzy numbers as shown in Table 3 (Chen C. , 2000).

Table 3.3: Linguistic variables for the ratings

Linguistic scales	Triangular fuzzy number
Very poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very good (VG)	(9,10,10)

Linguistic variables are used by the decision makers D_r ($r=1,2,\ldots,k$) to asses the importance weights of the criteria (w_j) and the ratings of the alternatives A_i ($i=1,2,\ldots,n$). Given that, the method comprises the following steps:

- Step 1: Aggregate the weights of the criteria and the rating of alternatives given by *K* decision makers, as expressed in Eq. 7 and Eq. 8 where $\tilde{x}_{ij}^{k}$ and $\tilde{w}_{j}^{k}$ are the rating and the importance weight of the k^{th} decision maker.

$$x_{ij} = \frac{1}{K}\left[x_{ij}^{1} + x_{ij}^{2} + \cdots + x_{ij}^{K}\right] \tag{7}$$

$$w_{j} = \frac{1}{K}\left[w_{j}^{1} + w_{j}^{2} + \cdots + w_{j}^{K}\right] \tag{8}$$

- Step 2: Assemble the fuzzy decision matrix (*D*) of the alternatives and the criteria (*W*) as expressed respectively in Eq. 9 and Eq. 10 where $\tilde{x}_{ij}, \forall_{i,j}$ and $\tilde{w}_{j}, j = 1,2,\ldots,n$ are the linguistic variables. These linguistic variables can be described by triangular fuzzy numbers, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_{j} = (w_{j1}, w_{j2}, w_{j3})$.

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{9}$$

$$W = \left[w_1, w_2, \ldots, w_n\right] \tag{10}$$

- **Step 3:** Normalize the fuzzy decision matrix of the alternatives (*D*) using linear scale transformation. The normalized fuzzy decision matrix *R* is given by Eqs. 11 and 12 where *R* is normalized fuzzy decision matrix and B and C are the set of benefit criteria and cost criteria, respectively. $R = [r_{ij}]_{m\times n}$ where $i=1,2,\ldots,m,$ and $j=1,2,\ldots,n$.

$$r_{ij} = \left[\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right], j \in B; \text{ and } c_j^* = \max_i c_{ij} \text{ (benefit criteria)} \tag{11}$$

$$r_{ij} = \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}, j \in C; \text{ and } a_j^- = \min_i a_{ij} \text{ cost criteria} \quad (12)$$

- **Step 4:** Construct the weighted normalized fuzzy decision matrix $\tilde{v}$ as seen Eq. 13 where $\tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j$ and we know that all elements $\tilde{v}_{ij}, \forall_{i,j}$ are positive triangular fuzzy numbers and the ranges of normalized triangular fuzzy numbers belongs to [0,1].

$$V = v_{ij}{}_{m.n}, i = 1,2,\dots,m, j = 1,2,\dots,n; \quad (13)$$

Step 5: Define the fuzzy positive-ideal solution (FPIS, A+) and fuzzy negative-ideal solution (FNIS, A−) as Where $\tilde{v}_j^* = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$, j =1,2,…n.

$$A^* = v_1^*, v_2^*, \dots, v_n^*, \quad (14)$$

$$A^- = v_1^-, v_2^-, \dots, v_n^- \quad (15)$$

- **Step 6:** Calculate the distance of each alternative from A* and A− as calculated respectively where d (-,-) is the distance measurement between two fuzzy numbers according to the vertex method. The distance between two triangular fuzzy numbers $A_1 = (a_1,b_1,c_1)$ and $A_2 = (a_2,b_2,c_2)$ is calculated as Eq. 18.

$$d_i^* = \sum_{j=1}^{n} d(v_{ij}, v_j^*), \ i = 1,2,\dots,m. \quad (16)$$

$$d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-), \ i = 1,2,\dots,m. \quad (17)$$

$$d(A1, A2) = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2\right]} \quad (18)$$

- **Step 7:** Calculate closeness coefficient for each alternative A_i (i=1, 2,…, m) as Eq. 19.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1,2, \dots, m. \quad (19)$$

- **Step 8:** Define the ranking order of all alternatives according to the closeness coefficient CC_i in decreasing order.

  The chosen alternative should be closer to the FPIS (A*) and farther to the FNIS (A−) as CC_i approaches to 1. The priority order of alternatives are provided according to closeness coefficient values (Chen, et al., 2006). According to some researchers, The alternative with the highest CC_i value is the best choice.

3.4 Goal Programming

Model formulation is the process of transforming a real world decision problem into operations research model. (Schniederjans, 1995) stated that the relationship of GP to MS/OR and MCDM is one of subordination. GP is subordinated within the field of MCDM, which in turn is subordinated within the the field of MS/OR as seen in Figure X. (Lee, et al., 2009) stated that a goal programming (GP) model is useful in dealing with multi-criteria decision problems where the goals cannot simultaneously be optimized and GP allows decision makers to consider several objectives together in finding a set of acceptable solutions and to obtain an optimal compromise. There are many different types of methods available in GP such as Lexicographic GP, Weighted GP and MINMAX GP, Reference point method, Compromise programming, etc.

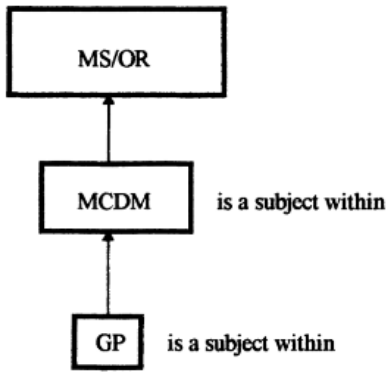

Figure 3.4: Summary Relationship of GP with MS/OR and MCDM

Goal Programming, a variation of LP considering more than one objective (goals) in the objective function, is one technique that can be used in such situations. The paper of (Schniederjans, 1995) provides that since the origin of GP can be traced to LP, a starting point for the GP model can be found by restating the LP model, its assumptions and modelling notation. One version of the LP model can be stated in what is called the canonical form as seen in Eqs.1-3 where the $x_1, x_2, \ldots, x_n$ are nonnegative decision variables or unknowns and the $c_1, c_2, \ldots, c_n$ are contribution coefficients that represent the marginal contribution to Z for each unit of their respective decision variable. This LP model seeks a single objective or goal of minimizing the objective function or Z.

$$\text{Minimize: } Z = \sum_{j=1}^{n} c_j x_j \tag{20}$$

$$\text{subject to: } \sum_{j=1}^{n} a_{ij} x_j \geq b_i, \ for\ i = 1, \dots, m \tag{21}$$

$$x_j \geq 0, \ for\ i = 1, \dots, n \tag{22}$$

If the relative importance of the goals can be found, then weighted GP can be used. In weighted GP, all goals are expressed in the same objective function with their weights computed. Hence, only one mathematical model is solved. In the same priority level, the assigning of relative weights to goals revealed. (Charnes & Cooper, 1977) stated the weighted GP model as seen in Eq. 4.

$$\text{Minimize } Z = \sum_{i=1}^{m} (w_i^+ d_i^+ + w_i^- d_i^-) \tag{23}$$

The study of (Chang, 2007) proposed an MCGP approach. The formulation of MCGP is shown in Eq. where d_i is the deviation from the target value g_i; w_i represents the weight attached to the deviation; $d_i^+ = \max(0, f_i\ X\ - g_i)$ and $d_i^- = \max(0, g_i - f_i\ X\ )$ are, respectively, over- and under-achievements of the i^{th} goal; $S_{ij}(B)$ represents a function of binary serial number; and $U_i(x)$ is the function of resources limitations. Also, d_i^+ is called as positive deviation variable and d_i^- is called as negative deviation variable in the literature.

$$\text{Min} \quad \sum_{i=1}^{n} w_i (d_i^+ + d_i^-) \tag{24}$$

$$\text{s.t. } f_i\ X\ - d_i^+ + d_i^- = \sum_{i=1}^{m} g_{ij} S_{ij}\ B\ , \quad i = 1,2, \dots, n \tag{25}$$

$$d_i^+, d_i^- \geq 0, \quad i = 1,2, \dots, n \tag{26}$$

$$S_{ij}\ B\ \epsilon U_i\ x\ , \quad i = 1,2, \dots, n$$

$$X \epsilon F (F\ is\ feasible\ set)$$

4. CASE STUDY

In this section, the main contribution of the proposed approach is provided as a real case study in Turkey petroleum market. The case study represents that a filling station (the company) wants to select new fuel oil distribution company and makes a strategic partnership contract for 5 years period. The long term partnership seems mutual beneficial to both of them because of the market characteristics. Detailed survey is conducted through face-to-face interviews, the publications of governmental agencies, opinion of the market authorities, and sector reports. There are mainly three decision makers who are more than 15 years experienced professionals of the market. Decision criteria are selected, hierarchical model is constructed and integrated methodology is revealed to evaluate alternative suppliers specific to the business. Due to distributor-dealer strategic partnership which is restricted with 5 years agreement, the decision of distributor selection have importance for filling station owners considering 5-years profitability, their firm reputation, customers' reaction, etc.

A filling station is a facility which generally sells petrol, diesel, LPG and engine lubricants for motor vehicles in Turkey. Filling station can also be known as a fuelling station, garage (South Africa and United Kingdom), gasbar (Canada), gas station (United States and Canada), petrol pump or petrol bunk (India), petrol garage, petrol station (Australia, Hong Kong, Ireland, Malaysia, New Zealand, Singapore, South Africa and United Kingdom), service station (Australia, New Zealand and United Kingdom), a services (United Kingdom), or servo (Australia).

4.1 Hierarchical Model

For constructing hierarchical model, different perspectives are taken into account with an analytical point of view for decision making process. The main framework of the supplier selection for the related company can be represented in Figure 4.1. To select the best alternative, six potential suppliers were evaluated against 5 main criteria and 22 sub-criteria. Here, both the weight of criteria and the ranking on alternative weights should be calculated. Also, the mathematical model of the problem is presented. Therefore, these three sections will be analyzed separately. Fuzzy AHP method is applied to calculate the weights of criteria, the alternative suppliers are ranked using Fuzzy TOPSIS method, and the problem is modelled and solved by Goal Programming approach.

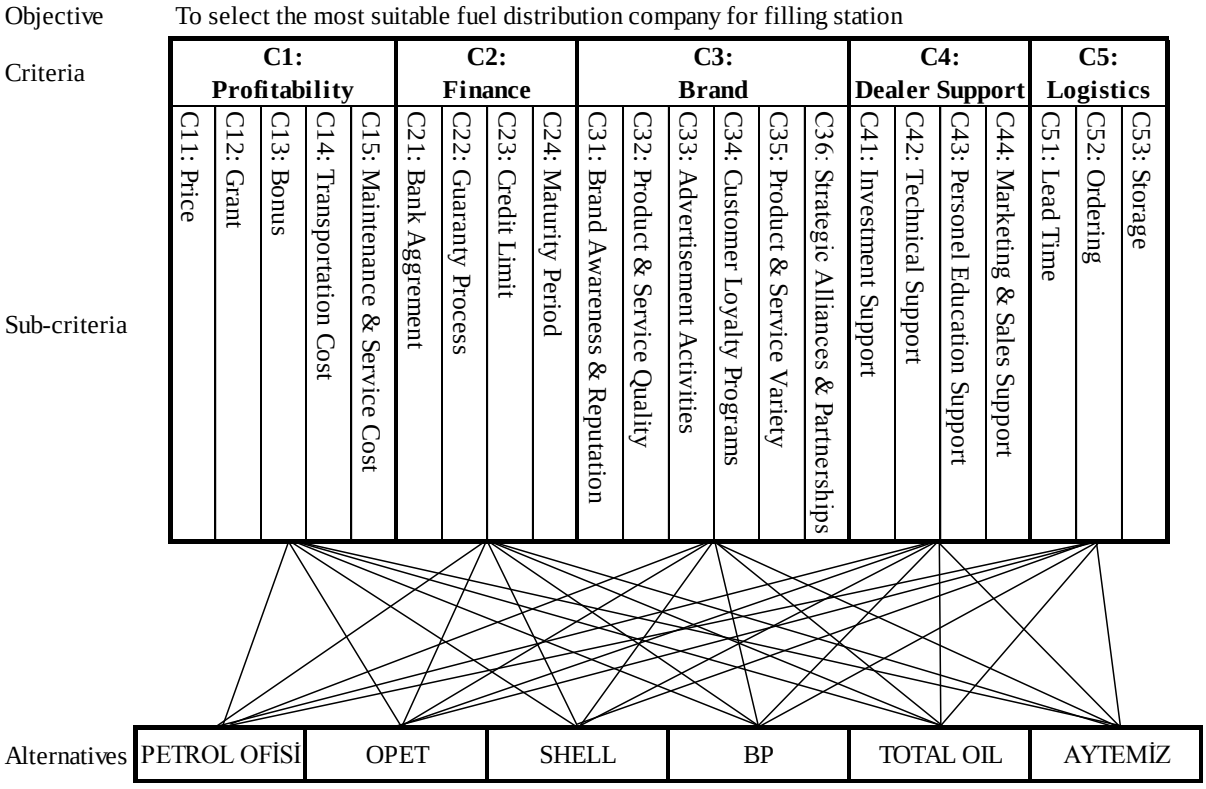

Figure 4.1: The hierarchy of the criteria and the alternatives

According to EPDK market reports, top 10 distributors are chosen based on market share and sales quantity. These fuel oil distribution companies are evaluated by decision makers and partners of the filling stations due to retail strategies, expectations and

requirements. As a result, Petrol Ofisi, OPET, SHELL, BP, Total Oil and Aytemiz are determined as supplier alternatives.

According to the problem of the case study, decision makers choose 5 main criteria and 22 sub-criteria for each main criteria which are identified below:

- **Profitability (C1):** The most important criteria for supplier selection is profitability. Any company cannot survive without profits. Also, researchers agree to the idea in the academic literature. Three profitability sub-criteria appear; price, grant, bonus and transportation cost considering the requirements of filling station. In the literature, (Vahdani & Zandieh, 2010)'s study mentions about profitabiliy criteria, and almost all articles evaluate cost criteria. This criteria is examined into 5 sub-criteria; price, grant, bonus, transportation cost and maintenance & service cost.

  - **Price (C11):** Purchase price and max sales price are regulated by distributors considering partnership contract. According to the market price cap and competition conditions, distributors set their maximum sales price which vary from city to city. Filling station cannot sell above distributor's price cap. Purchase price is stated due to dealer-distributor agreement which show general rules of the partnership and basic profitability of the filling station. Unit product profitability value occurs through regulated purchasing and sales price. For instance, Exurban filling stations have to compete with low price. If Distributor has strong market share, low price can be provided by dealer

  - **Grant (C12):** Distributors give non-repayable money called as grant considering filling station sales capacity and expected profitability when 5 years dealership contract signed.

  - **Bonus (C13):** All distributors have their own Bonus Program. Also, special bonus system can be applied according to dealer-distributor agreement. Bonus which is the main profit source in the petroleum market, gain according to gain more than expected sales.

- **Transportation Cost (C14):** Transportation is significant factor for business operations, is accepted as main criteria such as the paper of (Choudhary & Shankar, 2014). Lots of filling stations don't have their own transportation vehicle. So, the delivery of the products is outsourced. Although free market economy system, filling stations usually prefer their own distributor's logistics channel because of security, quality, technology and environment effects. Thus, transportation cost which determined by the fuel oil distribution company is important expenditure item.

- **Maintenance & Service Cost (C15):** All distributors provide standard maintenance and service at their own price due to the market regulations. Filling stations have to buy this service from its own distributor.

- **Finance (C2):** Distributors alleviate financial burdens of dealers. Namely, distributors provide financial facility to their dealer network. In the literature, the recent articles of (Yang, 2010), (Sevkli, 2010), (Tsai, et al., 2010), (Keskin, 2015), (Kar, 2015), (Dowlatshahi, et al., 2015), (Rouyendegh & Saputro, 2014). (Kilincci & Onal, 2011)'s study deals with finance criteria. This criteria is examined into 4 sub-criteria; bank agreement, guaranty process, credit limit and maturity period.

  - **Bank Agreement (C21):** Distributors make an strategic partnership agreement with banks. Banks offer special commission rates, special direct debiting system rates and other special banking services to the dealer based on the distributors' partnership agreement.

  - **Guaranty Process (C22):** Distributors can request guarantee like guarantee letter, blocked currency, usufruct, lien etc. from their dealers against credit limit, grant, bonus, etc. Distributors' guaranty process differs from each other. The financial status of the firms is important to give the assurance. If firms financial performance is not suitable for guarantee letter, they want to provide lien. But, distributor cannot accept lien as guarantee due to their procedures. In

conclusion, problem arise when dealer and distributor don't compromise about guarantee way.

- **Credit Limit (C23):** Distributor can provide credit limit to receive goods without simultaneous payment. The credit limit enable to financial facility for the dealer. Also, dealer can increase their credit customers' sales via credit limit. As a result, win-win arise due to the increased sales.

- **Maturity Period (C24):** Received goods can be paid within maturity period stated by the distributor. Generally, dealers' own financial power is not enough for liquidation. So, Distributors should provide financial facility to their dealers considering their 5 years agreement.

- **Brand (C3):** Brand represents the distributor which is the only partner of filling station when receiving and selling goods. In the literature, recent articles of (Rouyendegh & Saputro, 2014) and (Ahmady, et al., 2013) reveal reputation criteria. This criteria is examined into 6 sub-criteria; brand awareness & reputation, product & service quality, advertisement activities, customer loyalty programs, product & service variety and strategic alliances & partnerships.

  - **Brand Awareness & Reputation (C31):** Brand awareness and reputation of the distributor influence consumers' perception and filling station sales. Especially, downtown filling station sales are affected by brand awareness and reputation substantially. Because, the large part of sales pertain to random arrival customer.

  - **Product & Service Quality (C32):** The level meeting the requirements and expectations of the customers. Fuel oil distribution companies should provide product and service quality considering customer preferences and perception.

  - **Advertisement Activities (C33):** The activities usually increase sales and brand awareness.

- **Customer Loyalty Programs (C34): D**istributor can make an agreement with customers at special price to enable big sales channel for filling station. Vehicle Identification System (VIS) is most popular customer loyalty program in the market. Distributor can make an agreement with customers at special price within the context of program. The program is big sales channel for the dealer.

- **Product & Service Variety (C35):** Distributors try to increase product and service variety to gain competitive advantage. Product and service variety enable to increase customer satisfaction, reach more customer and meet an expectation.

- **Strategic Alliances & Partnerships (C36):** Distributors make an agreement with external market companies to offer advantage to their dealers. In addition to fuel products, market products, vehicle accessories, varied services can be provided at special prices due to distributor's strategic alliances and partnership. For example, OMV Petrol Ofisi A.Ş. get into partnership with COCA COLA. Thus, OMV Petrol Ofisi's dealers purchase coca cola products at reduced price. Also, OMV Petrol Ofisi provide Aktif Point service which enable to pay bills, purchase match ticket etc.

- **Support (C4):** Distributors provide consulting services and transfer know-how to their dealers. This criteria is examined into 4 sub-criteria; Grant Support, Technical Support, Personnel Education Support, Project Investment Support, Marketing & Advertisement Support.

  - **Investment Support (C41):** Renewal and replacement of necessary equipments according to brand identity of distributor.

  - **Technical Support (C42):** KNOW-HOW is really important in the petroleum market due to regulations, security, environment rules etc. So technical support and know-how transfer Distributors transfer their technical know-how and make a technical audit to the dealers.

- **Personnel Education Support (C43):** Workers get training according to distributor's rules and procedures to gain customer satisfaction and increase sales.

- **Marketing & Sales Support (C45):** If Distributor enables marketing & advertisement budget, flyers, posters, billboard, promotional gifts, special offers can be provided to filling stations to increase the sales.

- **Logistics (C5):** Products are transported from filling facilities of distributors to filling station's storage. In the literature, (Warea, et al., 2012) and (Moliné & Coves, 2014) mention about this main criteria.

  - **Lead Time (C51):** It is a time period from ordering to delivery of goods. Lead time is significant in the market. Because, unavailable products cause to reject customer's demand. Disappointed customer may not come back to the filling station to purchase. In the literature, (Kilincci & Onal, 2011) and (Kar, 2015) mention about this main criteria.

  - **Ordering (C52):** All distributors have their special ordering procedures (ordering sytem, time limits etc.). Some of them specify ordering time period for delivery of goods within the same day via intranet system. If filling station doesn't catch the period, earliest next day delivery becomes possible.

  - **Storage (C53):** Emission rate and fuel density calculation differ from filling facilities of distributors.

4.2 Determining Weights of Selection Criteria

In the literature, lots of criteria were proposed for supplier selection problem. In our study, the most suitable criteria based on the firm's requirements and key factors of the market are determined by decision makers and professionals. The weighted importance of the criteria (w_j) are calculated using fuzzy AHP with appropriate linguistic variables.

Decision makers compare criteria with each other individually and the crisp values were transformed to the corresponding set of triangular fuzzy numbers. Questions which are answered by all decision makers are attached as seen in Appendix A. According to decision makers' preferences in questions, the six pair-wise comparison matrices are evolved to the matrices for 5 main criteria and 22 sub criteria for each decision maker. Totally, 18 pair-wise comparison matrices are revealed to use fuzzy AHP as seen in Appendix B. Decision makers' preferences are transformed to the linguistic terms presented in Section 3. The corresponding fuzzy numbers are contributed the comparison matrix. If there is more than one decision maker, preferences of each decision maker are averaged and recalculated. According to averaged preferences, pair-wise contribution matrix is updated by normalization.

Table 4.2 represents experts' linguistic evaluations of main criteria with respect to the study goal, is called as Fuzzy Decision Matrix for main criterion (C1-C6). Then, Fuzzy Aggregated Decision Matrix is calculated as seen Table 4.3. Also, it is attached in Appendix C. According to Buckley, the geometric mean of fuzzy comparison values of each criterion is calculated.

Table 4.2: Fuzzy decision matrices by decision makers with respect to main criterion (C1-C6)

DM1	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	3.00	5.00	7.00	5.00	7.00	9.00	5.00	7.00	9.00	7.00	9.00	9.00
C2	0.14	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00	5.00	7.00
C3	0.11	0.14	0.20	1.00	1.00	1.00	1.00	1,00	1.00	1.00	3.00	5.00	5.00	7.00	9.00
C4	0.11	0.14	0.20	0.33	1.00	1.00	0.20	0.33	1.00	1.00	1.00	1.00	5.00	7.00	9.00
C5	0.11	0.11	0.14	0.14	0.20	0.33	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

DM2	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	5.00	7.00	9.00	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C2	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
C3	1.00	1.00	1.00	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C4	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C5	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

DM3	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	5.00	7.00	9.00	0.11	0.11	0.14	3.00	5.00	7.00	7.00	9.00	9.00
C2	0.11	0.14	0.20	1.00	1.00	1.00	0.11	0.11	0.14	5.00	7.00	9.00	7.00	9.00	9.00
C3	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00
C4	0.14	0.20	0.33	0.11	0.14	0.20	0.11	0.11	0.14	1.00	1.00	1.00	3.00	5.00	7.00
C5	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	0.14	0.20	0.33	1.00	1.00	1.00

Table 4.3: Fuzzy Aggregated Decision Matrix with respect to main criterion (C1-C6)

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	4.22	6.26	8.28	0.82	0.92	1.09	4.22	6.26	8.28	6.26	8.28	9.00
C2	0.12	0.16	0.24	1.00	1.00	1.00	0.82	0.92	1.09	2.92	3.66	6.24	4.72	6.80	8.28
C3	0.92	1.09	1.22	0.92	1.09	1.22	1.00	1.00	1.00	3.27	5.74	7.40	5.59	7.61	9.00
C4	0.12	0.16	0.24	0.16	0.27	0.34	0.14	0.17	0.31	1.00	1.00	1.00	4.22	6.26	8.28
C5	0.11	0.12	0.16	0.12	0.15	0.21	0.11	0.13	0.18	0.12	0.16	0.24	1.00	1.00	1.00

Hence, the geometric means of fuzzy comparison values of all criteria are shown in Table 4.4. In addition, the total values and the reverse values are also presented. After defuzzification procedure, the fuzzy weight vector of the criteria (w_i) is obtained. Fuzzy weights (w_r) are obtained after defuzzifications and normalization. Later, the fuzzy weight of criterion is found by the help of equation below: $w_i = r_i \otimes r_1 \oplus r_2 \oplus \ldots \oplus r_n)^{-1}$. Example: 0,27=(2,58*(4,02+3,30+1,55+0,42+0,31)^-1).

Hence the relative fuzzy weights of each criterion are given in Table 7. In the final step, the fuzzy weight of each criterion is calculated by equation as below: 0,41=(0,27+0,41+0,63)/(0,27+0,41+0,63+0,24+0,36+0,52+0,1+0,16+0,24+0,03+0,04 +0,07+0,02+0,03+0,05). The normalized weights of each criterion are calculated and tabulated in Table 7.

Table 4.4: Geometric means of fuzzy comparison values (r_i), Relative fuzzy weights of each criterion (w_i), Averaged and normalized relative weights of criteria (w_r) with respect to main criterion (C1-C6).

r_i		
2.47	3.13	3.68
1.07	1.30	1.68
1.73	2.20	2.50
0.41	0.54	0.73
0.18	0.21	0.27

w_i		
0.28	0.42	0.63
0.12	0.18	0.29
0.20	0.30	0.43
0.05	0.07	0.12
0.02	0.03	0.05

w_r	
0.42	**C1**
0.18	**C2**
0.29	**C3**
0.08	**C4**
0.03	**C5**

Pairwise comparison matrices are formed using experts' linguistic evaluations. Later all matrices are put through consistency check and found to be consistent. The weights of each sub-criteria are calculated using the Fuzzy AHP procedure. Fuzzy weight matrix is calculates by Buckley's Method as seen Table 4.5. Also, it is attached in Appendix D.

Table 4.5: Fuzzy Weighted Matrix

C11	0.27	0.41	0.63	**C33**	0.06	0.09	0.14
C12	0.24	0.36	0.52	**C34**	0.07	0.11	0.19
C13	0.10	0.16	0.24	**C35**	0.06	0.09	0.13
C14	0.03	0.04	0.07	**C36**	0.02	0.03	0.06
C15	0.02	0.03	0.05	**C41**	0.40	0.63	0.92
C21	0.12	0.18	0.34	**C42**	0.12	0.19	0.29
C22	0.09	0.15	0.24	**C43**	0.05	0.08	0.15
C23	0.28	0.47	0.70	**C44**	0.08	0.11	0.16
C24	0.12	0.20	0.35	**C51**	0.44	0.63	0.89
C31	0.24	0.36	0.57	**C52**	0.12	0.17	0.25
C32	0.19	0.32	0.50	**C53**	0.14	0.20	0.28

4.3 Ranking Supplier Alternatives

This case study focused on selecting the best supplier for the filling station out of the six available suppliers. The preferences of decision makers are conducted to evaluate and select the suppliers and they have given their preferences in terms of linguistic variables according to the evaluation criteria. The proposed method is applied based on a hierarchical model composed of a set of criterion and sub-criterion as developed by Saaty. All assessment of decision makers for alternatives are attached in Appendix E. For instance, the ratings of the 6 alternatives by decision makers for criteria C11 (price) is shown in Table 4.6.

Table 4.6: Decision-makers' Evaluations of Alternatives Based on the Criterion C11

C11: Price	1st DM			2nd DM			3rd DM		
OMV Petrol Ofisi	0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70
OPET	0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00
SHELL	0.70	0.90	1.00	0.70	0.90	1.00	0.50	0.70	0.90
BP	0.70	0.90	1.00	0.90	1.00	1.00	0.50	0.70	0.90
TOTAL OIL	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00
AYTEMIZ	0.90	1.00	1.00	0.50	0.70	0.90	0.90	1.00	1.00

After achieving the normalized weights for criteria, the fuzzy TOPSIS methodology is applied to find the respective values for alternatives. But now, the alternatives should be pair-wise compared with respect to each criterion particularly. Pair-wise comparison of alternatives with respect to one of the criterion is interviewed and According to decision makers' choice; pair-wise comparison matrix is formed.

Similar to fuzzy AHP methodology, the comparison matrices of each decision makers are averaged and normalized using linear scale transformation. Aggregated Fuzzy Decision Matrix is attached in Appendix F and Normalized Fuzzy Decision Matrix is attached in Appendix G. Consecutively the decision matrix is obtained as seen Table 4.7. Afterwards, the fuzzy weighted matrix is constructed by multiplying normalized

comparison matrix and matrix of the weights of criteria obtained by fuzzy AHP methodology.

Table 4.7: Weighted normalized fuzzy decision matrix

	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.15	0.32	0.57	0.12	0.25	0.47	0.05	0.10	0.20	0.01	0.03	0.06	0.01	0.02	0.04
OPET	0.19	0.37	0.63	0.18	0.33	0.52	0.05	0.10	0.20	0.02	0.03	0.06	0.02	0.03	0.05
SHELL	0.17	0.34	0.61	0.09	0.20	0.40	0.05	0.10	0.20	0.01	0.03	0.06	0.01	0.02	0.05
BP	0.19	0.36	0.61	0.13	0.26	0.45	0.07	0.13	0.23	0.02	0.03	0.06	0.01	0.02	0.04
TOTAL OIL	0.22	0.40	0.63	0.12	0.25	0.43	0.05	0.11	0.20	0.02	0.03	0.06	0.01	0.03	0.05
AYTEMIZ	0.21	0.37	0.61	0.17	0.30	0.47	0.07	0.13	0.24	0.03	0.04	0.07	0.01	0.03	0.05

	C21			C22			C23			C24			C31		
OMV Petrol Ofisi	0.08	0.17	0.34	0.05	0.11	0.22	0.13	0.33	0.67	0.04	0.10	0.25	0.20	0.35	0.57
OPET	0.09	0.17	0.34	0.07	0.14	0.24	0.15	0.37	0.70	0.07	0.15	0.33	0.21	0.36	0.57
SHELL	0.08	0.16	0.32	0.03	0.09	0.18	0.13	0.33	0.67	0.05	0.12	0.29	0.21	0.36	0.57
BP	0.09	0.17	0.34	0.04	0.10	0.20	0.13	0.33	0.67	0.05	0.12	0.29	0.20	0.35	0.57
TOTAL OIL	0.06	0.13	0.30	0.07	0.13	0.22	0.18	0.39	0.70	0.07	0.15	0.33	0.10	0.23	0.48
AYTEMIZ	0.04	0.10	0.26	0.04	0.10	0.19	0.15	0.37	0.70	0.09	0.18	0.35	0.10	0.23	0.48

	C32			C33			C34			C35			C36		
OMV Petrol Ofisi	0.16	0.30	0.50	0.04	0.08	0.14	0.04	0.09	0.18	0.04	0.08	0.13	0.01	0.03	0.06
OPET	0.17	0.32	0.50	0.05	0.09	0.14	0.05	0.10	0.18	0.05	0.09	0.13	0.02	0.03	0.06
SHELL	0.15	0.29	0.50	0.04	0.07	0.13	0.05	0.10	0.19	0.05	0.09	0.13	0.02	0.03	0.06
BP	0.16	0.30	0.50	0.05	0.09	0.14	0.05	0.10	0.19	0.05	0.08	0.13	0.01	0.03	0.06
TOTAL OIL	0.12	0.26	0.48	0.02	0.06	0.11	0.02	0.06	0.14	0.03	0.07	0.12	0.01	0.02	0.05
AYTEMIZ	0.08	0.20	0.40	0.02	0.06	0.12	0.02	0.06	0.13	0.03	0.06	0.12	0.01	0.02	0.05

	C41			C42			C43			C44			C51		
OMV Petrol Ofisi	0.25	0.52	0.89	0.11	0.19	0.29	0.02	0.05	0.12	0.06	0.09	0.14	0.37	0.61	0.89
OPET	0.31	0.59	0.92	0.10	0.18	0.29	0.04	0.07	0.15	0.07	0.10	0.16	0.37	0.61	0.89
SHELL	0.31	0.56	0.89	0.11	0.19	0.29	0.03	0.05	0.12	0.03	0.06	0.12	0.37	0.61	0.89
BP	0.23	0.48	0.86	0.11	0.19	0.29	0.04	0.07	0.15	0.05	0.08	0.14	0.40	0.63	0.89
TOTAL OIL	0.20	0.44	0.83	0.07	0.14	0.27	0.02	0.05	0.12	0.01	0.03	0.08	0.31	0.57	0.89
AYTEMIZ	0.23	0.48	0.83	0.05	0.12	0.24	0.01	0.02	0.06	0.03	0.06	0.12	0.28	0.53	0.86

	C52			C53		
OMV Petrol Ofisi	0.11	0.17	0.25	0.13	0.20	0.28
OPET	0.11	0.17	0.25	0.13	0.20	0.28
SHELL	0.11	0.17	0.25	0.13	0.20	0.28
BP	0.10	0.16	0.25	0.10	0.17	0.27
TOTAL OIL	0.07	0.13	0.24	0.06	0.12	0.23
AYTEMIZ	0.07	0.13	0.24	0.05	0.11	0.22

The distance of each alternative from FPIS and FNIS with respect to each criterion is calculated by using vertex method. The results of all alternatives' distances from the FPIS and FNIS are shown in Table 11. Also, Distance Matrix is attached in Appendix I.

Table 4.8: FPIS and FNIS values of each criterion

FPIS	**C11**	**C12**	**C13**	**C14**	**C15**	**C21**	**C22**	**C23**	**C24**	**C31**	**C32**	**C33**
OMV Petrol Ofisi	0.33	0.28	0.14	0.04	0.03	0.18	0.14	0.39	0.24	0.25	0.23	0.07
OPET	0.30	0.22	0.14	0.04	0.02	0.17	0.12	0.37	0.20	0.24	0.22	0.06
SHELL	0.32	0.32	0.14	0.04	0.03	0.18	0.15	0.39	0.22	0.24	0.24	0.07
BP	0.30	0.27	0.12	0.04	0.03	0.17	0.14	0.39	0.22	0.25	0.23	0.06
TOTAL OIL	0.27	0.28	0.14	0.03	0.02	0.20	0.12	0.35	0.20	0.34	0.26	0.08
AYTEMIZ	0.29	0.24	0.12	0.03	0.02	0.22	0.15	0.37	0.18	0.34	0.30	0.08

	C11	**C12**	**C13**	**C14**	**C15**	**C21**	**C22**	**C23**	**C24**	**C31**	**C32**	**C33**
OMV Petrol Ofisi	0.31	0.24	0.10	0.03	0.02	0.18	0.11	0.33	0.13	0.31	0.28	0.07
OPET	0.36	0.29	0.10	0.03	0.02	0.19	0.13	0.36	0.18	0.32	0.28	0.08
SHELL	0.34	0.19	0.10	0.03	0.02	0.18	0.09	0.33	0.16	0.32	0.27	0.07
BP	0.34	0.23	0.12	0.03	0.02	0.19	0.10	0.33	0.16	0.31	0.28	0.08
TOTAL OIL	0.37	0.22	0.10	0.03	0.02	0.16	0.12	0.36	0.18	0.23	0.25	0.05
AYTEMIZ	0.35	0.26	0.13	0.03	0.02	0.13	0.10	0.36	0.20	0.23	0.20	0.06

FNIS	**C34**	**C35**	**C36**	**C41**	**C42**	**C43**	**C44**	**C51**	**C52**	**C53**	**SUM**
OMV Petrol Ofisi	0.10	0.06	0.03	0.45	0.12	0.09	0.07	0.34	0.10	0.10	3.77
OPET	0.10	0.05	0.03	0.40	0.12	0.07	0.06	0.34	0.10	0.10	3.47
SHELL	0.09	0.05	0.03	0.41	0.12	0.09	0.10	0.34	0.10	0.10	3.75
BP	0.09	0.06	0.03	0.47	0.12	0.07	0.08	0.32	0.10	0.12	3.69
TOTAL OIL	0.12	0.07	0.03	0.50	0.15	0.09	0.12	0.38	0.13	0.16	4.07
AYTEMIZ	0.13	0.07	0.03	0.47	0.17	0.12	0.10	0.41	0.13	0.17	4.14

	C34	**C35**	**C36**	**C41**	**C42**	**C43**	**C44**	**C51**	**C52**	**C53**	**SUM**
OMV Petrol Ofisi	0.10	0.06	0.03	0.44	0.16	0.07	0.10	0.40	0.12	0.16	3.76
OPET	0.10	0.07	0.03	0.47	0.16	0.09	0.11	0.40	0.12	0.16	4.06
SHELL	0.11	0.07	0.03	0.45	0.16	0.07	0.07	0.40	0.12	0.16	3.74
BP	0.11	0.07	0.03	0.41	0.16	0.09	0.09	0.41	0.12	0.15	3.82
TOTAL OIL	0.08	0.06	0.02	0.39	0.13	0.07	0.04	0.39	0.10	0.11	3.49
AYTEMIZ	0.07	0.06	0.03	0.40	0.11	0.03	0.07	0.36	0.10	0.10	3.38

The closeness coefficients of alternatives are calculated. According to the closeness coefficient of alternatives, the ranking order of alternatives is determined. Value of this parameters and final ranking order of alternatives are presented in Table12. Alternatives sorted in descending order by looking at the values of the relative distance of the alternatives. Accordingly, OPET should be chosen as fuel Distribution Company with the highest value of the relative distance.

Table 4.9: The closeness of alternatives

The closeness coefficient of each alternative	
OMV Petrol Ofisi	0,50
OPET	0,54
SHELL	0,50
BP	0,51
TOTAL OIL	0,46
AYTEMIZ	0,45

The hierarchical structure of importance of the criteria is given after the application of fuzzy AHP procedure as seen Figure 2.

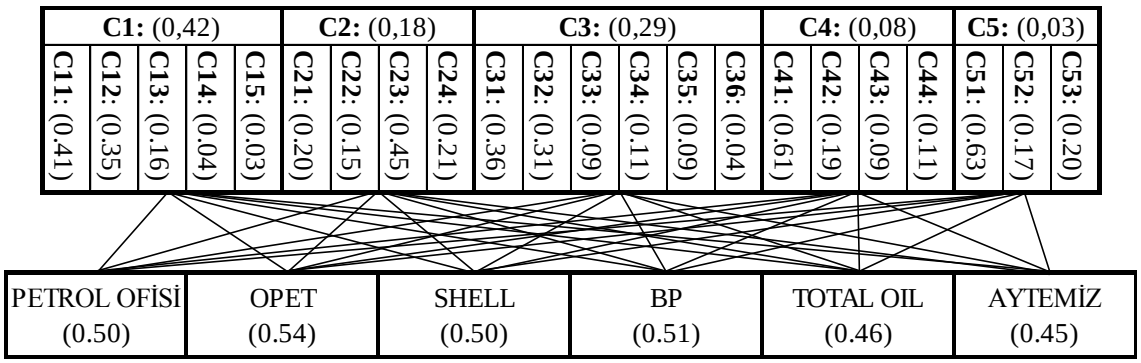

Figure 4.2: The hierarchical structure of criteria and alternatives for importance level

4.4 Mathematical Model for Selection Alternatives

In this section, the application of the goal programming approach is provided. Research data for modelling is presented in Table 4.10. The relationship between sub-criteria and constraint is provided in Table 4.11. The term of "sales quote" is previously unexpressed. Particularly, sales quota represents individual sales target during specific time unit. Fuel oil distribution companies submit a proposal with determined sales quote which specified according to the potential sales capacity of the filling station. Namely, all offers are submitted to filling station based on sales quota.

Table 4.10: Values of the constraints used in Goal Programming Modelling

Constraint		OMV PO x_1	OPET x_2	SHELL x_3	BP x_4	TOTAL x_5	AYTEMIZ x_6
H_i	Grant	80%	75%	75%	75%	85%	85%
L_i	Lead Time	2 hr	1,5 hr	1 hr	1 hr	1 hr	1 hr
Ms_i	Market Share	24%	17%	16%	9%	5%	2%
Ts_i	Market Share for VIS	29%	17%	32%	14%	5%	1%
I_i	Investment Support	50%	100%	30%	50%	50%	100%
C_i	Credit Limit	100%	100%	100%	100%	125%	125%
P_i	Price up to Sales Quota	45%	43%	45%	43%	50%	55%
B_i	Price over Sales Quota	5%	5%	5%	5%	10%	15%
Sk_i	Sales Quota	1762 lt.	1468 lt.	1033 lt.	659 lt.	452 lt.	474 lt.

Table 4.11: Related criteria for the constraints used in Goal Programming Modelling

Constraint		Related Sub-Criteria	Sub-Criteria Weight (AHP)
H_i	Grant	C12	0,35
L_i	Lead Time	C51	0,63
Ms_i	Market Share	C31	0,36
Ts_i	Market Share for VIS	C34	0,11
I_i	Investment Support	C41	0,61
C_i	Credit Limit	C23	0,45
P_i	Price up to Sales Quota	C11	0,41
B_i	Price over Sales Quota	C13	0,16
Sk_i	Sales Quota	-	-

Mathematical model of the case study problem is provided below;

Mathematical Model:

x_i: altenatives for i=1,2,3,4,5,6.

(x_1: PO, x_2: OPET, x_3: SHELL, x_4: BP, x_5: TOTAL, x_6: AYTEMİZ)

$$MIN\ Z = \sum_{i=1}^{6} w_i d_i \quad \rightarrow$$

$$MIN\ Z = w_{12}d_{12}^- + w_{51}d_{51}^+ + w_{31}d_{31}^- + w_{34}d_{34}^- + w_{41}d_{41}^- + w_{23}d_{23}^- + w_{11}d_{11}^- + w_{13}d_{13}^- + d_0^-$$

s.t.

$$\sum_{i=1}^{6} H_i x_i \geq 0{,}75 \quad \rightarrow \quad \sum_{i=1}^{6} H_i x_i - d_{12}^- + d_{12}^+ = 0{,}75 \qquad (1)$$

$$\sum_{i=1}^{6} L_i x_i \leq 2 \quad \rightarrow \quad \sum_{i=1}^{6} L_i x_i - d_{51}^- + d_{51}^+ = 2 \qquad (2)$$

$$\sum_{i=1}^{6} MS_i x_i \geq 0{,}10 \quad \rightarrow \quad \sum_{i=1}^{6} MS_i x_i - d_{31}^- + d_{31}^+ = 0{,}10 \qquad (3)$$

$$\sum_{i=1}^{6} TS_i x_i \geq 0{,}10 \quad \rightarrow \quad \sum_{i=1}^{6} TS_i x_i - d_{34}^- + d_{34}^+ = 0{,}10 \qquad (4)$$

$$\sum_{i=1}^{6} I_i x_i \geq 0{,}50 \quad \rightarrow \quad \sum_{i=1}^{6} I_i x_i - d_{41}^- + d_{41}^+ = 0{,}50 \qquad (5)$$

$$\sum_{i=1}^{6} C_i x_i \geq 1 \quad \rightarrow \quad \sum_{i=1}^{6} C_i x_i - d_{23}^- + d_{23}^+ = 1 \qquad (6)$$

$$\sum_{i=1}^{6} P_i x_i \geq 0{,}40 \quad \rightarrow \quad \sum_{i=1}^{6} P_i x_i - d_{11}^- + d_{11}^+ = 0{,}40 \qquad (7)$$

$$\sum_{i=1}^{6} B_i x_i \geq 0{,}05 \quad \rightarrow \quad \sum_{i=1}^{6} B_i x_i - d_{13}^- + d_{13}^+ = 0{,}05 \qquad (8)$$

$$\sum_{i=1}^{6} SK_i x_i \geq 1500 \quad \rightarrow \quad \sum_{i=1}^{6} SK_i x_i - d_0^- + d_0^+ = 1500 \qquad (9)$$

$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 1$ (10)

$x_i \in \{0,1\}$ (11)

$$d_i = d_i^- - d_i^+ \qquad (12)$$

$$d_i^+ = \begin{cases} d_i, & If\ d_i \geq 0 \\ 0, & otherwise \end{cases} \qquad (13)$$

$$d_i^- = \begin{cases} d_i\ , & If\ d_i \leq 0 \\ 0, & otherwise \end{cases} \qquad (14)$$

Appendix J shows extended model of the problem. Appendix K presents LINDO Model and Appendix L presents LINDO Results. In addition, Appendix M reveals simplex table of the model's iterations.

5. DISCUSSION AND CONCLUSION

In this research, we attempt to answer the following questions: What are the important criteria for distribution company selection for filling station in petroleum market? What is the relative or absolute importance of each supplier selection criterion? How could we aggregate expert opinion via integrated decision-making process? What efficient approach could be used for ranking and evaluation of potential suppliers? Which one is the most suitable distribution company for the filling station for 5 years strategic partnership? This study aims to review literature for supplier selection problem, propose suitable analytical approaches and illustrate a specific case study in petroleum market selecting fuel oil distribution company for filling station. This study evaluates the application of two widely used reliable methods and developed a comprehensive procedure to solve the problem. The novelty of this research lies in the application of a hybrid approach to a petroleum market case.

This study has dealt with one of the most important subjects in supply chain management providing a better decision for supplier selection using analytical approaches. The methodologies and calculations involved in each technique are easily understandable. Supplier selection is considered a difficult process combining given the qualitative and quantitative criteria. The nature of the problem is complex and vague, involving different perspectives of different decision makers. Since selecting the best supplier involves complex decision variables, it is considered to be a multi-criteria decision making problem. In this context, a case study is performed to decide the best distribution company for filling station. The proposed method to a real problem in a petroleum market while the partners of the company prefer making their decision based on their traditional commercial approaches.

Within the scope of this paper a model is proposed by combining fuzzy AHP and fuzzy TOPSIS. In this paper, fuzzy AHP will be used to evaluate the criteria in distribution company selection for filling station. After defining the priority weights of the

attributes, the most appropriate alternative will be selected using fuzzy TOPSIS. The considered criteria are prioritized using fuzzy AHP and the alternatives are ranked with respect to the criteria by using fuzzy TOPSIS.

This study implies that among the main criteria, the most important one is profitability as 0.42 and the following is brand as 0.29. These results are understandable as the market of petroleum is highly depended to financial conditions. Consecutively the brand is an efficient factor in managing distribution processes. Price and Grant are the most important sub-criteria as 0.41 and 0.35. Afterwards Brand Awareness & Reputation, Investment Support, Lead Time follow the rank with upper importance. The sub-criteria with the lowest importance are determined as Ordering followed by, Storage and Personal Educational Support. These insignificances could be explained by the effectiveness of their appropriate processes in which both employees' performance and ordering activities are less influential and relevant to select supplier.

The descending order of alternatives is OPET > BP > SHELL ≥ Petrol Ofisi > TOTAL > AYTEMIZ. According to the sort, OPET should be chosen as the fuel oil distribution company for filling station. As the results have shown that the well-known fuel oil distribution companies (such as OPET, BP, etc.) have differed from new Turkish entrant of distributors (such as AYTEMIZ) through their experience and reputation in the market.

Afterwards using multi-criteria methods on subject, the study tries to confirm the results obtained fuzzy AHP-fuzzy TOPSIS method by modeling the problem with goal programming aspects. Goal programming proposes a suitable method to combine multiple objectives and to evaluate multiple alternatives. In this study, the problem is modelled according to pre-specified values for each goals such as lead time, price, grant, bonus, credit limit, etc. while objective is minimization of the slack variables of the constraints. The objective function is constructed by multiplying slack variables by the weights of relevant criteria obtained by fuzzy AHP. The content of the model is determined by the decision maker in the market. The weights of the slack variables are selected from the weights of fuzzy AHP according to appropriate goals. Such as, the targeted value of the market share is presented in the constraint (3) and the relevant

slack variable is weighted in the objective function by the weight of Brand Awareness and Reputation calculated by fuzzy AHP. Lindo package program is used to solve the goal programming model. The result showed similarity with the previous method which OPET is selected as a supplier with an optimal solution.

Consecutively, the two methods (Fuzzy TOPSIS and GP) compromise at the same alternative: OPET. The proposed fuzzy hybrid models combine numerous advantages of the integrated methods. In addition, similar hybrid approach was not previously proposed for supplier selection in petroleum market. So, the effectiveness and efficiency of the proposed model makes it preferable and suitable for MCDM problems of different industries. In order to illustrate the application of the proposed decision making methods to Petroleum supplier selection problem, a case study is conducted in a filling station in Gebze, Kocaeli.

As a result of the study, the proposed methodology is found as a practical and efficient tool for ranking alternative suppliers and selecting the most suitable one. It provides powerful tools to rank alternatives and to analyze the relations between criteria. It has been shown that the methodology is suitable to select the best supplier among the given alternatives in petroleum market. Our real case study helps managers and partners of filling station in distribution selection problem. This study will contribute to the literature, because, it presents general outlook for Turkish petroleum market after the 2010 system change and it is beneficial to actors who need to make new strategic decision.

For further research, different hierarchical models and detailed objectives can be incorporated into the study. Metaheuristics can be combined with the existing approach. Also, other well-known multi-criteria methods and their integrations such as fuzzy VIKOR and fuzzy ELECTRE can be used to compare the results of this work. Similarly, different linguistic scale can be used to compare the results. Moreover, sensitivity analysis can be done in order to find out the influence of criteria weights. In addition, the sustainability and green concept for supplier selection are excluded in the thesis. Thus, this study can be applied within the scope of the sustainability and green concept in further research.

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APPENDICES

Appendix A. Questionnaire

Read the following questions and put check marks on the pairwise comparison matrices. If an attribute on the left is more important than the one matching on the right, put your check mark to the left of the importance "Equal" under the importance level you prefer. If an attribute on the left is less important than the one matching on the right, put your check mark to the right of the importance "Equal" under the importance level you prefer.

Questions for Decision Makers

*With respect to the overall goal **"Selection of Appropriate Fuel Distribution Company for Filling Station"**,*

How important is **Profitability (C_1)** when it is compared with **Finance (C_2)**?
How important is **Profitability (C_1)** when it is compared with **Brand (C_3)**?
How important is **Profitability (C_1)** when it is compared with **Dealer Support (C_4)**?
How important is **Profitability (C_1)** when it is compared with **Logistics (C_5)**?
How important is **Finance (C_2)** when it is compared with **Brand (C_3)**?
How important is **Finance (C_2)** when it is compared with **Dealer Support (C_4)**?
How important is **Finance (C_2)** when it is compared with **Logistics (C_5)**?
How important is **Brand (C_3)** when it is compared with **Dealer Support (C_4)**?
How important is **Brand (C_3)** when it is compared with **Logistics (C_5)**?
How important is **Dealer Support (C_4)** when it is compared with **Logistics (C_5)**?

*With respect to the main attribute "**PROFITABILITY (C_1)**",*

How important is **Price (C_{11})** when it is compared with **Grant (C_{12})**?
How important is **Price (C_{11})** when it is compared with **Bonus (C_{13})**?
How important is **Price (C_{11})** when it is compared with **Transportation Cost (C_{14})**?
How important is **Price (C_{11})** when it is compared with **Maintenance & Service Cost (C_{15})**?
How important is **Grant (C_{12})** when it is compared with **Bonus (C_{13})**?
How important is **Grant (C_{12})** when it is compared with **Transportation Cost (C_{14})**?
How important is **Grant (C_{12})** when it is compared with **Maintenance & Service Cost (C_{15})**?
How important is **Bonus (C_{13})** when it is compared with **Transportation Cost (C_{14})**?
How important is **Bonus (C_{13})** when it is compared with **Maintenance & Service Cost (C_{15})**?
How important is **Transportation Cost (C_{14})** when it is compared with **Maintenance & Service Cost (C_{15})**?

*With respect to the main attribute **"FINANCE (C_2)"**,*

How important is **Bank Agreement (C_{21})** when it is compared with **Guaranty Process (C_{22})** ?
How important is **Bank Agreement (C_{21})** when it is compared with **Credit Limit (C_{23})** ?
How important is **Bank Agreement (C_{21})** when it is compared with **Maturity Period (C_{24})** ?
How important is **Guaranty Process (C_{22})** when it is compared with **Credit Limit (C_{23})**?
How important is **Guaranty Process (C_{22})** when it is compared with **Maturity Period (C_{24})** ?
How important is **Credit Limit (C_{23})** when it is compared with **Maturity Period (C_{24})**?

*With respect to the main attribute **"BRAND (C_3)"**,*

How important is **Brand Awareness & Reputation (C_{31})** when it is compared with **Product & Service Quality (C_{32})**?
How important is **Brand Awareness & Reputation (C_{31})** when it is compared with **Advertisement Activities (C_{33})**?
How important is **Brand Awareness & Reputation (C_{31})** when it is compared with **Customer Loyalty Programs (C_{34})**?
How important is **Brand Awareness & Reputation (C_{31})** when it is compared with **Product & Service Variety (C_{35})**?
How important is **Product & Service Quality (C_{32})** when it is compared with **Advertisement Activities (C_{33})**?
How important is **Product & Service Quality (C_{32})** when it is compared with **Customer Loyalty Programs (C_{34})**?
How important is **Product & Service Quality (C_{32})** when it is compared with **Product & Service Variety (C_{35})**?
How important is **Advertisement Activities (C_{33})** when it is compared with **Customer Loyalty Programs (C_{34})**?
How important is **Advertisement Activities (C_{33})** when it is compared with **Product & Service Variety (C_{35})**?
How important is **Customer Loyalty Programs (C_{34})** when it is compared with **Product & Service Variety (C_{35})**?
How important is **Customer Loyalty Programs (C_{34})** when it is compared with **Strategic Alliances & Partnerships (C_{36})**?
How important is **Product & Service Variety (C_{35})** when it is compared with **Strategic Alliances & Partnerships (C_{36})**?

*With respect to the main attribute "**DEALER SUPPORT (C_4)**",*

How important is **Investment Support (C_{41})** when it is compared with **Technical Support (C_{42})**?
How important is **Investment Support (C_{41})** when it is compared with **Personel Education Support (C_{43})**?
How important is **Investment Support (C_{41})** when it is compared with **Marketing & Sales Support (C_{44})**?
How important is **Technical Support (C_{42})** when it is compared with **Personel Education Support (C_{43})**?
How important is **Technical Support (C_{42})** when it is compared with **Marketing & Sales Support (C_{44})**?
How important is **Personel Education Support (C_{43})** when it is compared with **Marketing & Sales Support (C_{44})**?

*With respect to the main attribute "**LOGISTICS (C_5)**",*

How important is **Lead Time (C_{51})** when it is compared with **Ordering (C_{52})**?
How important is **Lead Time (C_{51})** when it is compared with **Storage (C_{53})**?
How important is **Ordering (C_{52})** when it is compared with **Storage (C_{53})**?

With respect to the sub-attribute "(C_{xy})", respectively,

How important is A_1 when it is compared with A_2?
How important is A_1 when it is compared with A_3?
How important is A_2 when it is compared with A_3?

Appendix B. Pairwise Comparisons for Decision Criteria

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C1) Profitability			X									(C2) Finance
(C1) Profitability		X										(C3) Brand
(C1) Profitability		X										(C4) Dealer Support
(C1) Profitability	X											(C5) Logistics
(C2) Finance						X						(C3) Brand
(C2) Finance					X							(C4) Dealer Support
(C2) Finance			X									(C5) Logistics
(C3) Brand				X								(C4) Dealer Support
(C3) Brand		X										(C5) Logistics
(C4) Dealer Support		X										(C5) Logistics

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C1) Profitability		X										(C2) Finance
(C1) Profitability						X						(C3) Brand
(C1) Profitability		X										(C4) Dealer Support
(C1) Profitability		X										(C5) Logistics
(C2) Finance		X										(C3) Brand
(C2) Finance		X										(C4) Dealer Support
(C2) Finance		X										(C5) Logistics
(C3) Brand		X										(C4) Dealer Support
(C3) Brand		X										(C5) Logistics
(C4) Dealer Support		X										(C5) Logistics

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C1) Profitability		X										(C2) Finance
(C1) Profitability											X	(C3) Brand
(C1) Profitability			X									(C4) Dealer Support
(C1) Profitability	X											(C5) Logistics
(C2) Finance											X	(C3) Brand
(C2) Finance		X										(C4) Dealer Support
(C2) Finance	X											(C5) Logistics
(C3) Brand	X											(C4) Dealer Support
(C3) Brand	X											(C5) Logistics
(C4) Dealer Support			X									(C5) Logistics

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C11) Price									X			(C12) Grant
(C11) Price								X				(C13) Bonus
(C11) Price	X											(C14) Transportation Cost
(C11) Price		X										(C15) Maintenance&Service Cost
(C12) Grant			X									(C13) Bonus
(C12) Grant	X											(C14) Transportation Cost
(C12) Grant	X											(C15) Maintenance&Service Cost
(C13) Bonus		X										(C14) Transportation Cost
(C13) Bonus		X										(C15) Maintenance&Service Cost
(C14) Transportation Cost						X						(C15) Maintenance&Service Cost

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C11) Price		X										(C12) Grant
(C11) Price		X										(C13) Bonus
(C11) Price		X										(C14) Transportation Cost
(C11) Price		X										(C15) Maintenance&Service Cost
(C12) Grant		X										(C13) Bonus
(C12) Grant		X										(C14) Transportation Cost
(C12) Grant		X										(C15) Maintenance&Service Cost
(C13) Bonus		X										(C14) Transportation Cost
(C13) Bonus		X										(C15) Maintenance&Service Cost
(C14) Transportation Cost		X										(C15) Maintenance&Service Cost

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C11) Price	X											(C12) Grant
(C11) Price	X											(C13) Bonus
(C11) Price	X											(C14) Transportation Cost
(C11) Price	X											(C15) Maintenance&Service Cost
(C12) Grant	X											(C13) Bonus
(C12) Grant	X											(C14) Transportation Cost
(C12) Grant	X											(C15) Maintenance&Service Cost
(C13) Bonus	X											(C14) Transportation Cost
(C13) Bonus	X											(C15) Maintenance&Service Cost
(C14) Transportation Cost					X							(C15) Maintenance&Service Cost

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C21) Bank Aggrement						X						(C22) Guaranty Process
(C21) Bank Aggrement									X			(C23) Credit Limit
(C21) Bank Aggrement								X				(C24) Maturity Period
(C22) Guaranty Process									X			(C23) Credit Limit
(C22) Guaranty Process							X					(C24) Maturity Period
(C23) Credit Limit						X						(C24) Maturity Period

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C21) Bank Aggrement			X									(C22) Guaranty Process
(C21) Bank Aggrement		X										(C23) Credit Limit
(C21) Bank Aggrement		X										(C24) Maturity Period
(C22) Guaranty Process						X						(C23) Credit Limit
(C22) Guaranty Process		X										(C24) Maturity Period
(C23) Credit Limit		X										(C24) Maturity Period

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C21) Bank Aggrement								X				(C22) Guaranty Process
(C21) Bank Aggrement											X	(C23) Credit Limit
(C21) Bank Aggrement										X		(C24) Maturity Period
(C22) Guaranty Process											X	(C23) Credit Limit
(C22) Guaranty Process											X	(C24) Maturity Period
(C23) Credit Limit				X								(C24) Maturity Period

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C31) Brand Awareness & Reputation				X								(C32) Product & Service Quality
(C31) Brand Awareness & Reputation					X							(C33) Advertisement Activities
(C31) Brand Awareness & Reputation					X							(C34) Customer Loyalty Programs
(C31) Brand Awareness & Reputation			X									(C35) Product & Service Variety
(C31) Brand Awareness & Reputation		X										(C36) Strategic Alliances&Partnerships
(C32) Product & Service Quality			X									(C33) Advertisement Activities
(C32) Product & Service Quality				X								(C34) Customer Loyalty Programs
(C32) Product & Service Quality			X									(C35) Product & Service Variety
(C32) Product & Service Quality			X									(C36) Strategic Alliances&Partnerships
(C33) Advertisement Activities				X								(C34) Customer Loyalty Programs
(C33) Advertisement Activities		X										(C35) Product & Service Variety
(C33) Advertisement Activities			X									(C36) Strategic Alliances&Partnerships
(C34) Customer Loyalty Programs			X									(C35) Product & Service Variety
(C34) Customer Loyalty Programs				X								(C36) Strategic Alliances&Partnerships
(C35) Product & Service Variety						X						(C36) Strategic Alliances&Partnerships

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C31) Brand Awareness & Reputation						X						(C32) Product & Service Quality
(C31) Brand Awareness & Reputation		X										(C33) Advertisement Activities
(C31) Brand Awareness & Reputation						X						(C34) Customer Loyalty Programs
(C31) Brand Awareness & Reputation			X									(C35) Product & Service Variety
(C31) Brand Awareness & Reputation						X						(C36) Strategic Alliances&Partnerships
(C32) Product & Service Quality		X										(C33) Advertisement Activities
(C32) Product & Service Quality		X										(C34) Customer Loyalty Programs
(C32) Product & Service Quality		X										(C35) Product & Service Variety
(C32) Product & Service Quality		X										(C36) Strategic Alliances&Partnerships
(C33) Advertisement Activities		X										(C34) Customer Loyalty Programs
(C33) Advertisement Activities						X						(C35) Product & Service Variety
(C33) Advertisement Activities						X						(C36) Strategic Alliances&Partnerships
(C34) Customer Loyalty Programs		X										(C35) Product & Service Variety
(C34) Customer Loyalty Programs		X										(C36) Strategic Alliances&Partnerships
(C35) Product & Service Variety		X										(C36) Strategic Alliances&Partnerships

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C31) Brand Awareness & Reputation	X											(C32) Product & Service Quality
(C31) Brand Awareness & Reputation	X											(C33) Advertisement Activities
(C31) Brand Awareness & Reputation	X											(C34) Customer Loyalty Programs
(C31) Brand Awareness & Reputation	X											(C35) Product & Service Variety
(C31) Brand Awareness & Reputation	X											(C36) Strategic Alliances&Partnerships
(C32) Product & Service Quality	X											(C33) Advertisement Activities
(C32) Product & Service Quality	X											(C34) Customer Loyalty Programs
(C32) Product & Service Quality						X						(C35) Product & Service Variety
(C32) Product & Service Quality	X											(C36) Strategic Alliances&Partnerships
(C33) Advertisement Activities											X	(C34) Customer Loyalty Programs
(C33) Advertisement Activities											X	(C35) Product & Service Variety
(C33) Advertisement Activities	X											(C36) Strategic Alliances&Partnerships
(C34) Customer Loyalty Programs											X	(C35) Product & Service Variety
(C34) Customer Loyalty Programs	X											(C36) Strategic Alliances&Partnerships
(C35) Product & Service Variety	X											(C36) Strategic Alliances&Partnerships

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C41) Investment Support		X										(C42) Technical Support
(C41) Investment Support				X								(C43) Personel Education Support
(C41) Investment Support			X									(C44) Marketing&Sales Support
(C42) Technical Support				X								(C43) Personel Education Support
(C42) Technical Support						X						(C44) Marketing&Sales Support
(C43) Personel Education Support									X			(C44) Marketing&Sales Support

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C41) Investment Support		X										(C42) Technical Support
(C41) Investment Support		X										(C43) Personel Education Support
(C41) Investment Support						X						(C44) Marketing&Sales Support
(C42) Technical Support		X										(C43) Personel Education Support
(C42) Technical Support		X										(C44) Marketing&Sales Support
(C43) Personel Education Support		X										(C44) Marketing&Sales Support

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C41) Investment Support	X											(C42) Technical Support
(C41) Investment Support	X											(C43) Personel Education Support
(C41) Investment Support	X											(C44) Marketing&Sales Support
(C42) Technical Support			X									(C43) Personel Education Support
(C42) Technical Support						X						(C44) Marketing&Sales Support
(C43) Personel Education Support						X						(C44) Marketing&Sales Support

Pairwise Comparison for selecting criteria in supplier selection problem by 1st decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C51) Lead Time			X									(C52) Ordering
(C51) Lead Time		X										(C53) Storage
(C52) Ordering			X									(C53) Storage

Pairwise Comparison for selecting criteria in supplier selection problem by 2nd decision maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C51) Lead Time		X										(C52) Ordering
(C51) Lead Time		X										(C53) Storage
(C52) Ordering		X										(C53) Storage

Pairwise Comparison for selecting criteria in supplier selection problem by 3rd decisin maker

Criteria	Absolutely Important	Very Strongly Important	Essentially Important	Weakly Important	Equally Important	Just Equal	Equally Important	Weakly Important	Essentially Important	Very Strangly Important	Absolutely Important	Criteria
(C51) Lead Time	X											(C52) Ordering
(C51) Lead Time											X	(C53) Storage
(C52) Ordering											X	(C53) Storage

Appendix C. Fuzzy Aggregated Decision Matrices

Fuzzy Decision Matrix by 1st Decision Maker

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	3.00	5.00	7.00	5.00	7.00	9.00	5.00	7.00	9.00	7.00	9.00	9.00
C2	0.14	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00	5.00	7.00
C3	0.11	0.14	0.20	1.00	1.00	1.00	1.00	1,00	1.00	1.00	3.00	5.00	5.00	7.00	9.00
C4	0.11	0.14	0.20	0.33	1.00	1.00	0.20	0.33	1.00	1.00	1.00	1.00	5.00	7.00	9.00
C5	0.11	0.11	0.14	0.14	0.20	0.33	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	5.00	7.00	9.00	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C2	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
C3	1.00	1.00	1.00	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C4	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C5	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	5.00	7.00	9.00	0.11	0.11	0.14	3.00	5.00	7.00	7.00	9.00	9.00
C2	0.11	0.14	0.20	1.00	1.00	1.00	0.11	0.11	0.14	5.00	7.00	9.00	7.00	9.00	9.00
C3	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00
C4	0.14	0.20	0.33	0.11	0.14	0.20	0.11	0.11	0.14	1.00	1.00	1.00	3.00	5.00	7.00
C5	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	0.14	0.20	0.33	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	4.22	6.26	8.28	0.82	0.92	1.09	4.22	6.26	8.28	6.26	8.28	9.00
C2	0.12	0.16	0.24	1.00	1.00	1.00	0.82	0.92	1.09	2.92	3.66	6.24	4.72	6.80	8.28
C3	0.92	1.09	1.22	0.92	1.09	1.22	1.00	1.00	1.00	3.27	5.74	7.40	5.59	7.61	9.00
C4	0.12	0.16	0.24	0.16	0.27	0.34	0.14	0.17	0.31	1.00	1.00	1.00	4.22	6.26	8.28
C5	0.11	0.12	0.16	0.12	0.15	0.21	0.11	0.13	0.18	0.12	0.16	0.24	1.00	1.00	1.00

r_i		
2.47	3.13	3.68
1.07	1.30	1.68
1.73	2.20	2.50
0.41	0.54	0.73
0.18	0.21	0.27

w_i		
0.28	0.42	0.63
0.12	0.18	0.29
0.20	0.30	0.43
0.05	0.07	0.12
0.02	0.03	0.05

w_r	
0.42	**C1**
0.18	**C2**
0.29	**C3**
0.08	**C4**
0.03	**C5**

Fuzzy Decision Matrix by 1st Decision Maker

	C11			C12			C13			C14			C15		
C11	1.00	1.00	1.00	0.14	0.20	0.33	0.20	0.33	1.00	7.00	9.00	9.00	5.00	7.00	9.00
C12	3.00	5.00	7.00	1.00	1.00	1.00	3.00	5.00	7.00	7.00	9.00	9.00	7.00	9.00	9.00
C13	1.00	3.00	5.00	0.14	0.20	0.33	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C14	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.14	0.20	1.00	1.00	1.00	1.00	1.00	1.00
C15	0.11	0.14	0.20	0.11	0.11	0.14	0.11	0.14	0.20	1.00	1.00	1.00	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker

	C11			C12			C13			C14			C15		
C11	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
C12	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
C13	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C14	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C15	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C11			C12			C13			C14			C15		
C11	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00
C12	0.11	0.11	0.14	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00
C13	0.11	0.11	0.14	0.11	0.11	0.14	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00
C14	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	1.00	1.00	1.00	1.00	1.00	3.00
C15	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	0.33	1.00	1.00	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C11			C12			C13			C14			C15		
C11	1.00	1.00	1.00	1.71	2.33	3.00	1.91	2.76	4.33	6.26	8.28	9.00	5.59	7.61	9.00
C12	0.33	0.43	0.58	1.00	1.00	1.00	4.72	6.80	8.28	6.26	8.28	9.00	6.26	8.28	9.00
C13	0.23	0.36	0.52	0.12	0.15	0.21	1.00	1.00	1.00	5.59	7.61	9.00	5.59	7.61	9.00
C14	0.11	0.12	0.16	0.11	0.12	0.16	0.11	0.13	0.18	1.00	1.00	1.00	1.71	1.91	3.00
C15	0.11	0.13	0.18	0.11	0.12	0.16	0.11	0.13	0.18	0.33	0.52	0.58	1.00	1.00	1.00

r_i		
2.58	3.32	4.02
2.28	2.89	3.30
0.97	1.25	1.55
0.30	0.33	0.42
0.21	0.26	0.31

w_i		
0.27	0.41	0.63
0.24	0.36	0.52
0.10	0.16	0.24
0.03	0.04	0.07
0.02	0.03	0.05

w_r	
0.41	**C11**
0.35	**C12**
0.16	**C13**
0.04	**C14**
0.03	**C15**

Fuzzy Decision Matrix by 1st Decision Maker

	C21			C22			C23			C24		
C21	1.00	1.00	1.00	1.00	1.00	1.00	0.14	0.20	0.33	0.20	0.33	1.00
C22	1.00	1.00	1.00	1.00	1.00	1.00	0.14	0.20	0.33	0.33	1.00	1.00
C23	3.00	5.00	7.00	3.00	5.00	7.00	1.00	1.00	1.00	1.00	1.00	1.00
C24	1.00	3.00	5.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker

	C21			C22			C23			C24		
C21	1.00	1.00	1.00	3.00	5.00	7.00	5.00	7.00	9.00	5.00	7.00	9.00
C22	0.14	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00	5.00	7.00	9.00
C23	0.11	0.14	0.20	1.00	1.00	1.00	1.00	1.00	1.00	5.00	7.00	9.00
C24	0.11	0.14	0.20	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C21			C22			C23			C24		
C21	1.00	1.00	1.00	0.20	0.33	1.00	0.11	0.11	0.14	0.11	0.14	0.20
C22	1.00	3.00	5.00	1.00	1.00	1.00	0.11	0.11	0.14	0.11	0.11	0.14
C23	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00	1.00	3.00	5.00
C24	5.00	7.00	9.00	7.00	9.00	9.00	0.20	0.33	1.00	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C21			C22			C23			C24		
C21	1.00	1.00	1.00	0.84	1.19	1.91	0.43	0.54	0.75	0.48	0.69	1.22
C22	0.52	0.84	1.19	1.00	1.00	1.00	0.25	0.28	0.36	0.57	0.92	1.09
C23	1.33	1.86	2.33	2.76	3.56	3.98	1.00	1.00	1.00	1.71	2.76	3.56
C24	0.82	1.44	2.08	0.92	1.09	1.75	0.28	0.36	0.58	1.00	1.00	1.00

r_i		
0.65	0.82	1.15
0.52	0.68	0.83
1.58	2.07	2.40
0.68	0.87	1.21

w_i		
0.12	0.18	0.34
0.09	0.15	0.24
0.28	0.47	0.70
0.12	0.20	0.35

w_r	
0.20	**C21**
0.15	**C22**
0.45	**C23**
0.21	**C24**

Fuzzy Decision Matrix by 1st Decision Maker

	C31			C32			C33			C34			C35			C36		
C31	1.00	1.00	1.00	1.00	3.00	5.00	1.00	1.00	3.00	1.00	1.00	3.00	3.00	5.00	7.00	5.00	7.00	9.00
C32	0.20	0.33	1.00	1.00	1.00	1.00	3.00	5.00	7.00	1.00	3.00	5.00	3.00	5.00	7.00	3.00	5.00	7.00
C33	0.33	1.00	1.00	0.14	0.20	0.33	1.00	1.00	1.00	1.00	3.00	5.00	5.00	7.00	9.00	3.00	5.00	7.00
C34	0.33	1.00	1.00	0.20	0.33	1.00	0.20	0.33	1.00	1.00	1.00	1.00	3.00	5.00	7.00	1.00	3.00	5.00
C35	0.14	0.20	0.33	0.14	0.20	0.33	0.11	0.14	0.20	0.14	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00
C36	0.11	0.14	0.20	0.14	0.20	0.33	0.14	0.20	0.33	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker

	C31			C32			C33			C34			C35			C36		
C31	1.00	1.00	1.00	1.00	1.00	1.00	5.00	7.00	9.00	1.00	1.00	1.00	5.00	7.00	9.00	1.00	1.00	1.00
C32	1.00	1.00	1.00	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
C33	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00
C34	1.00	1.00	1.00	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C35	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C36	1.00	1.00	1.00	0.11	0.14	0.20	1.00	1.00	1.00	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C31			C32			C33			C34			C35			C36		
C31	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00
C32	0.11	0.11	0.14	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00	7.00	9.00	9.00
C33	0.11	0.11	0.14	0.11	0.11	0.14	1.00	1.00	1.00	0.11	0.11	0.14	0.11	0.11	0.14	7.00	9.00	9.00
C34	0.11	0.11	0.14	0.11	0.11	0.14	7.00	9.00	9.00	1.00	1.00	1.00	0.11	0.11	0.14	7.00	9.00	9.00
C35	0.11	0.11	0.14	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00	7.00	9.00	9.00
C36	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	0.11	0.11	0.14	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C31			C32			C33			C34			C35			C36		
C31	1.00	1.00	1.00	1.91	3.00	3.56	3.27	3.98	6.24	1.91	2.08	3.00	4.72	6.80	8.28	3.27	3.98	4.33
C32	0.28	0.33	0.52	1.00	1.00	1.00	4.72	6.80	8.28	3.27	5.74	7.40	2.47	3.27	3.98	4.72	6.80	8.28
C33	0.16	0.25	0.31	0.12	0.15	0.21	1.00	1.00	1.00	0.82	1.33	1.86	0.82	0.92	1.09	2.76	3.56	3.98
C34	0.33	0.48	0.52	0.14	0.17	0.31	0.54	0.75	1.22	1.00	1.00	1.00	1.19	1.57	2.08	3.27	5.74	7.40
C35	0.12	0.15	0.21	0.25	0.31	0.41	0.92	1.09	1.22	0.48	0.64	0.84	1.00	1.00	1.00	3.27	3.98	4.33
C36	0.23	0.25	0.31	0.12	0.15	0.21	0.25	0.28	0.36	0.14	0.17	0.31	0.23	0.25	0.31	1.00	1.00	1.00

r_i		
2.39	2.96	3.66
1.92	2.57	3.19
0.57	0.74	0.90
0.67	0.91	1.20
0.59	0.71	0.85
0.25	0.28	0.36

w_i		
0.24	0.36	0.57
0.19	0.32	0.50
0.06	0.09	0.14
0.07	0.11	0.19
0.06	0.09	0.13
0.02	0.03	0.06

w_r	
0.36	**C31**
0.31	**C32**
0.09	**C33**
0.11	**C34**
0.09	**C35**
0.04	**C36**

Fuzzy Decision Matrix by 1st Decision Maker

	C41			C42			C43			C44		
C41	1.00	1.00	1.00	5.00	7.00	9.00	1.00	3.00	5.00	3.00	5.00	7.00
C42	0.11	0.14	0.20	1.00	1.00	1.00	1.00	3.00	5.00	1.00	1.00	1.00
C43	0.20	0.33	1.00	0.20	0.33	1.00	1.00	1.00	1.00	0.14	0.20	0.33
C44	0.14	0.20	0.33	1.00	1.00	1.00	3.00	5.00	7.00	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker

	C41			C42			C43			C44		
C41	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00	1.00	1.00	1.00
C42	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C43	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C44	1.00	1.00	1.00	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C41			C42			C43			C44		
C41	1.00	1.00	1.00	7.00	9.00	9.00	7.00	9.00	9.00	7.00	9.00	9.00
C42	0.11	0.11	0.14	1.00	1.00	1.00	3.00	5.00	7.00	1.00	1.00	1.00
C43	0.11	0.11	0.14	0.14	0.20	0.33	1.00	1.00	1.00	1.00	1.00	1.00
C44	0.11	0.11	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C41			C42			C43			C44		
C41	1.00	1.00	1.00	5.59	7.61	9.00	3.27	5.74	7.40	2.76	3.56	3.98
C42	0.11	0.13	0.18	1.00	1.00	1.00	2.47	4.72	6.80	1.71	1.91	2.08
C43	0.14	0.17	0.31	0.15	0.21	0.41	1.00	1.00	1.00	0.89	1.12	1.44
C44	0.25	0.28	0.36	0.48	0.52	0.58	0.69	0.89	1.12	1.00	1.00	1.00

r_i		
2.67	3.53	4.03
0.83	1.04	1.26
0.37	0.45	0.65
0.54	0.60	0.70

w_i		
0.40	0.63	0.92
0.12	0.19	0.29
0.05	0.08	0.15
0.08	0.11	0.16

w_r		
0.61	**C41**	
0.19	**C42**	
0.09	**C43**	
0.11	**C44**	

Fuzzy Decision Matrix by 1st Decision Maker

	C51			C52			C53		
C51	1.00	1.00	1.00	3.00	5.00	7.00	5.00	7.00	9.00
C52	0.14	0.20	0.33	1.00	1.00	1.00	3.00	5.00	7.00
C53	0.11	0.14	0.20	0.14	0.20	0.33	1.00	1.00	1.00

Fuzzy Decision Matrix by 2nd Decision Maker (RB)

	C51			C52			C53		
C51	1.00	1.00	1.00	5.00	7.00	9.00	5.00	7.00	9.00
C52	0.11	0.14	0.20	1.00	1.00	1.00	5.00	7.00	9.00
C53	0.11	0.14	0.20	0.11	0.14	0.20	1.00	1.00	1.00

Fuzzy Decision Matrix by 3rd Decision Maker

	C51			C52			C53		
C51	1.00	1.00	1.00	7.00	9.00	9.00	0.11	0.11	0.14
C52	0.11	0.11	0.14	1.00	1.00	1.00	0.11	0.11	0.14
C53	7.00	9.00	9.00	7.00	9.00	9.00	1.00	1.00	1.00

Fuzzy Aggregated Decision Matrix

	C51			C52			C53		
C51	1.00	1.00	1.00	4.72	6.80	8.28	1.41	1.76	2.26
C52	0.12	0.15	0.21	1.00	1.00	1.00	1.19	1.57	2.08
C53	0.44	0.57	0.71	0.48	0.64	0.84	1.00	1.00	1.00

r_i		
1.88	2.29	2.66
0.52	0.61	0.76
0.60	0.71	0.84

w_i		
0.44	0.63	0.89
0.12	0.17	0.25
0.14	0.20	0.28

w_r	
0.63	**C51**
0.17	**C52**
0.20	**C53**

Appendix D. Fuzzy Weight Matrix

Fuzzy Weighted Matrix*

C11	0.27	0.41	0.63
C12	0.24	0.36	0.52
C13	0.10	0.16	0.24
C14	0.03	0.04	0.07
C15	0.02	0.03	0.05
C21	0.12	0.18	0.34
C22	0.09	0.15	0.24
C23	0.28	0.47	0.70
C24	0.12	0.20	0.35
C31	0.24	0.36	0.57
C32	0.19	0.32	0.50
C33	0.06	0.09	0.14
C34	0.07	0.11	0.19
C35	0.06	0.09	0.13
C36	0.02	0.03	0.06
C41	0.40	0.63	0.92
C42	0.12	0.19	0.29
C43	0.05	0.08	0.15
C44	0.08	0.11	0.16
C51	0.44	0.63	0.89
C52	0.12	0.17	0.25
C53	0.14	0.20	0.28

Appendix E. Assessment of Decision Makers for Alternatives

Assessment of 1st Decision Maker

Main Criteria	Sub-criteria	Petrol Ofisi	OPET	SHELL	BP	Total Oil	Aytemiz
Profitability	C11: Price	6	6	6	6	7	7
	C12: Grant	5	6	4	5	6	7
	C13: Bonus	4	4	4	4	4	6
	C14: Transportation Cost	5	5	5	5	6	7
	C15: Maintenance & Service Cost	4	5	4	5	5	5
Finance	C21: Bank Aggrement	6	6	6	6	5	5
	C22: Guaranty Process	5	6	4	5	4	4
	C23: Credit Limit	4	4	4	4	4	4
	C24: Maturity Period	4	5	5	5	5	6
Brand	C31: Brand Awareness & Reputation	7	7	7	7	5	5
	C32: Product & Service Quality	7	7	6	6	6	6
	C33: Advertisement Activities	6	7	5	7	6	5
	C34: Customer Loyalty Programs	6	6	6	6	4	4
	C35: Product & Service Variety	7	7	7	7	5	5
	C36: Strategic Alliances & Partnerships	4	4	4	4	4	4
Dealer Support	C41: Investment Support	6	6	5	5	5	6
	C42: Technical Support	7	7	7	7	5	5
	C43: Personel Education Support	4	6	4	6	3	2
	C44: Marketing & Sales Support	7	7	4	6	3	4
Logistics	C51: Lead Time	7	7	7	7	6	6
	C52: Ordering	7	7	7	7	5	5
	C53: Storage	7	7	7	5	4	4

Assessment of 2nd Decision Maker

Main Criteria	Sub-criteria	Petrol Ofisi	OPET	SHELL	BP	Total Oil	Aytemiz
Profitability	C11: Price	6	6	6	7	7	5
	C12: Grant	5	6	5	7	6	4
	C13: Bonus	4	4	4	7	4	6
	C14: Transportation Cost	5	5	5	6	6	7
	C15: Maintenance & Service Cost	5	5	4	5	5	5
Finance	C21: Bank Aggrement	6	6	5	7	5	5
	C22: Guaranty Process	5	6	4	7	4	4
	C23: Credit Limit	4	4	4	4	4	4
	C24: Maturity Period	4	5	5	5	5	6
Brand	C31: Brand Awareness & Reputation	7	7	7	7	4	5
	C32: Product & Service Quality	7	7	6	7	6	4
	C33: Advertisement Activities	6	7	5	7	4	5
	C34: Customer Loyalty Programs	6	5	6	7	4	4
	C35: Product & Service Variety	5	7	7	7	5	5
	C36: Strategic Alliances & Partnerships	4	4	4	4	4	4
Dealer Support	C41: Investment Support	6	6	7	5	5	4
	C42: Technical Support	7	6	7	7	5	5
	C43: Personel Education Support	4	6	4	7	6	1
	C44: Marketing & Sales Support	7	7	4	6	3	4
Logistics	C51: Lead Time	6	6	6	7	6	5
	C52: Ordering	7	7	7	7	5	5
	C53: Storage	7	7	7	7	4	4

Assessment of 3rd Decision Maker

Main Criteria	Sub-criteria	Petrol Ofisi	OPET	SHELL	BP	Total Oil	Aytemiz
Profitability	C11: Price	**4**	**6**	**5**	**5**	**6**	**7**
	C12: Grant	**5**	**7**	**4**	**4**	**3**	**7**
	C13: Bonus	**6**	**6**	**6**	**6**	**7**	**5**
	C14: Transportation Cost	**4**	**6**	**4**	**4**	**5**	**6**
	C15: Maintenance & Service Cost	**5**	**7**	**6**	**5**	**6**	**6**
Finance	C21: Bank Aggrement	**6**	**7**	**7**	**6**	**5**	**3**
	C22: Guaranty Process	**5**	**6**	**5**	**5**	**7**	**6**
	C23: Credit Limit	**5**	**6**	**5**	**5**	**7**	**6**
	C24: Maturity Period	**4**	**6**	**4**	**4**	**6**	**6**
Brand	C31: Brand Awareness & Reputation	**6**	**7**	**7**	**6**	**5**	**4**
	C32: Product & Service Quality	**6**	**7**	**7**	**7**	**5**	**4**
	C33: Advertisement Activities	**6**	**7**	**7**	**6**	**4**	**4**
	C34: Customer Loyalty Programs	**5**	**7**	**7**	**6**	**5**	**4**
	C35: Product & Service Variety	**7**	**7**	**7**	**6**	**6**	**5**
	C36: Strategic Alliances & Partnerships	**6**	**7**	**7**	**6**	**4**	**5**
Dealer Support	C41: Investment Support	**5**	**7**	**7**	**6**	**5**	**6**
	C42: Technical Support	**7**	**7**	**7**	**7**	**6**	**4**
	C43: Personel Education Support	**6**	**7**	**7**	**6**	**5**	**5**
	C44: Marketing & Sales Support	**4**	**6**	**5**	**4**	**3**	**5**
Logistics	C51: Lead Time	**7**	**7**	**7**	**7**	**6**	**6**
	C52: Ordering	**7**	**7**	**7**	**6**	**6**	**6**
	C53: Storage	**7**	**7**	**7**	**6**	**6**	**5**

Point	Determination	Linguistic Scales
1	VERY POOR	(0.0,0.0,0.1)
2	POOR	(0.0,0.1,0.3)
3	MEDIUM POOR	(0.1,0.3,0.5)
4	FAIR	(0.3,0.5,0.7)
5	MEDIUM GOOD	(0.5,0.7,0.9)
6	GOOD	(0.7,0.9,1.0)
7	VERY GOOD	(0.9,1.0,1.0)

Appendix F. Aggregated Fuzzy Decision Matrix

The ratings of the six candidates by 1st decision maker															
	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70
OPET	0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90
SHELL	0.70	0.90	1.00	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70
BP	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90
TOTAL OIL	0.90	1.00	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.70	0.90	1.00	0.50	0.70	0.90
AYTEMIZ	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.90	1.00	1.00	0.50	0.70	0.90

The ratings of the six candidates by 2nd decision maker															
	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90
OPET	0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90
SHELL	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90
BP	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.30	0.50	0.70
TOTAL OIL	0.90	1.00	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.70	0.90	1.00	0.50	0.70	0.90
AYTEMIZ	0.50	0.70	0.90	0.30	0.50	0.70	0.70	0.90	1.00	0.90	1.00	1.00	0.50	0.70	0.90

The ratings of the six candidates by 3rd decision maker															
	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.30	0.50	0.70	0.50	0.70	0.90	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90
OPET	0.70	0.90	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.90	1.00	1.00
SHELL	0.50	0.70	0.90	0.30	0.50	0.70	0.70	0.90	1.00	0.30	0.50	0.70	0.70	0.90	1.00
BP	0.50	0.70	0.90	0.30	0.50	0.70	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90
TOTAL OIL	0.70	0.90	1.00	0.10	0.30	0.50	0.90	1.00	1.00	0.50	0.70	0.90	0.70	0.90	1.00
AYTEMIZ	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.70	0.90	0.70	0.90	1.00	0.70	0.90	1.00

Aggregated Fuzzy Decision Matrix															
	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.57	0.77	0.90	0.50	0.70	0.90	0.43	0.63	0.80	0.43	0.63	0.83	0.43	0.63	0.83
OPET	0.70	0.90	1.00	0.77	0.93	1.00	0.43	0.63	0.80	0.57	0.77	0.93	0.63	0.80	0.93
SHELL	0.63	0.83	0.97	0.37	0.57	0.77	0.43	0.63	0.80	0.43	0.63	0.83	0.50	0.70	0.87
BP	0.70	0.87	0.97	0.57	0.73	0.87	0.63	0.80	0.90	0.50	0.70	0.87	0.43	0.63	0.83
TOTAL OIL	0.83	0.97	1.00	0.50	0.70	0.83	0.50	0.67	0.80	0.63	0.83	0.97	0.57	0.77	0.93
AYTEMIZ	0.77	0.90	0.97	0.70	0.83	0.90	0.63	0.83	0.97	0.83	0.97	1.00	0.57	0.77	0.93

The ratings of the six candidates by 1st decision maker											
C21			C22			C23			C24		
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70
0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90
0.70	0.90	1.00	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90
0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90
0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70	0.70	0.90	1.00

The ratings of the six candidates by 2nd decision maker											
C21			C22			C23			C24		
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70
0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90
0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90
0.90	1.00	1.00	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90
0.50	0.70	0.90	0.90	1.00	1.00	0.30	0.50	0.70	0.50	0.70	0.90
0.50	0.70	0.90	0.30	0.50	0.70	0.30	0.50	0.70	0.70	0.90	1.00

The ratings of the six candidates by 3rd decision maker											
C21			C22			C23			C24		
0.70	0.90	1.00	0.50	0.70	0.90	0.50	0.70	0.90	0.30	0.50	0.70
0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00
0.90	1.00	1.00	0.50	0.70	0.90	0.50	0.70	0.90	0.30	0.50	0.70
0.70	0.90	1.00	0.50	0.70	0.90	0.50	0.70	0.90	0.30	0.50	0.70
0.50	0.70	0.90	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00
0.10	0.30	0.50	0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00

Aggregated Fuzzy Decision Matrix											
C21			C22			C23			C24		
0.70	0.90	1.00	0.50	0.70	0.90	0.37	0.57	0.77	0.30	0.50	0.70
0.77	0.93	1.00	0.70	0.90	1.00	0.43	0.63	0.80	0.57	0.77	0.93
0.70	0.87	0.97	0.37	0.57	0.77	0.37	0.57	0.77	0.43	0.63	0.83
0.77	0.93	1.00	0.43	0.63	0.83	0.37	0.57	0.77	0.43	0.63	0.83
0.50	0.70	0.90	0.70	0.83	0.90	0.50	0.67	0.80	0.57	0.77	0.93
0.37	0.57	0.77	0.43	0.63	0.80	0.43	0.63	0.80	0.70	0.90	1.00

The ratings of the six candidates by 1st decision maker

C31			C32			C33			C34			C35			C36		
0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.70	0.90	1.00	0.50	0.70	0.90	0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.70	0.90	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.50	0.70	0.90	0.70	0.90	1.00	0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70
0.50	0.70	0.90	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70

The ratings of the six candidates by 2nd decision maker

C31			C32			C33			C34			C35			C36		
0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.70	0.90	0.90	1.00	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.70	0.90	1.00	0.50	0.70	0.90	0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.30	0.50	0.70
0.30	0.50	0.70	0.70	0.90	1.00	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70
0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.30	0.50	0.70

The ratings of the six candidates by 3rd decision maker

C31			C32			C33			C34			C35			C36		
0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.50	0.70	0.90	0.90	1.00	1.00	0.70	0.90	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.70	0.90	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00
0.50	0.70	0.90	0.50	0.70	0.90	0.30	0.50	0.70	0.50	0.70	0.90	0.70	0.90	1.00	0.30	0.50	0.70
0.30	0.50	0.70	0.30	0.50	0.70	0.30	0.50	0.70	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90

Aggregated Fuzzy Decision Matrix

C31			C32			C33			C34			C35			C36		
0.83	0.97	1.00	0.83	0.97	1.00	0.70	0.90	1.00	0.63	0.83	0.97	0.77	0.90	0.97	0.43	0.63	0.80
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.87	0.97	0.90	1.00	1.00	0.50	0.67	0.80
0.90	1.00	1.00	0.77	0.93	1.00	0.63	0.80	0.93	0.77	0.93	1.00	0.90	1.00	1.00	0.50	0.67	0.80
0.83	0.97	1.00	0.83	0.97	1.00	0.83	0.97	1.00	0.77	0.93	1.00	0.83	0.97	1.00	0.43	0.63	0.80
0.43	0.63	0.83	0.63	0.83	0.97	0.43	0.63	0.80	0.37	0.57	0.77	0.57	0.77	0.93	0.30	0.50	0.70
0.43	0.63	0.83	0.43	0.63	0.80	0.43	0.63	0.83	0.30	0.50	0.70	0.50	0.70	0.90	0.37	0.57	0.77

The ratings of the six candidates by 1st decision maker											
C41			C42			C43			C44		
0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70	0.90	1.00	1.00
0.70	0.90	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.90	1.00	1.00
0.50	0.70	0.90	0.90	1.00	1.00	0.30	0.50	0.70	0.30	0.50	0.70
0.50	0.70	0.90	0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00
0.50	0.70	0.90	0.50	0.70	0.90	0.10	0.30	0.50	0.10	0.30	0.50
0.70	0.90	1.00	0.50	0.70	0.90	0.00	0.10	0.30	0.30	0.50	0.70

The ratings of the six candidates by 2nd decision maker											
C41			C42			C43			C44		
0.70	0.90	1.00	0.90	1.00	1.00	0.30	0.50	0.70	0.90	1.00	1.00
0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.30	0.50	0.70	0.30	0.50	0.70
0.50	0.70	0.90	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00
0.50	0.70	0.90	0.50	0.70	0.90	0.70	0.90	1.00	0.10	0.30	0.50
0.30	0.50	0.70	0.50	0.70	0.90	0.00	0.00	0.10	0.30	0.50	0.70

The ratings of the six candidates by 3rd decision maker											
C41			C42			C43			C44		
0.50	0.70	0.90	0.90	1.00	1.00	0.70	0.90	1.00	0.30	0.50	0.70
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.90	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.70	0.90
0.70	0.90	1.00	0.90	1.00	1.00	0.70	0.90	1.00	0.30	0.50	0.70
0.50	0.70	0.90	0.70	0.90	1.00	0.50	0.70	0.90	0.10	0.30	0.50
0.70	0.90	1.00	0.30	0.50	0.70	0.50	0.70	0.90	0.50	0.70	0.90

Aggregated Fuzzy Decision Matrix											
C41			C42			C43			C44		
0.63	0.83	0.97	0.90	1.00	1.00	0.43	0.63	0.80	0.70	0.83	0.90
0.77	0.93	1.00	0.83	0.97	1.00	0.77	0.93	1.00	0.83	0.97	1.00
0.77	0.90	0.97	0.90	1.00	1.00	0.50	0.67	0.80	0.37	0.57	0.77
0.57	0.77	0.93	0.90	1.00	1.00	0.77	0.93	1.00	0.57	0.77	0.90
0.50	0.70	0.90	0.57	0.77	0.93	0.43	0.63	0.80	0.10	0.30	0.50
0.57	0.77	0.90	0.43	0.63	0.83	0.17	0.27	0.43	0.37	0.57	0.77

The ratings of the six candidates by 1st decision maker								
C51			C52			C53		
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.70	0.90
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70

The ratings of the six candidates by 2nd decision maker								
C51			C52			C53		
0.70	0.90	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.70	0.90	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.70	0.90	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.70	0.90	1.00	0.50	0.70	0.90	0.30	0.50	0.70
0.50	0.70	0.90	0.50	0.70	0.90	0.30	0.50	0.70

The ratings of the six candidates by 3rd decision maker								
C51			C52			C53		
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.70	0.90	1.00	0.70	0.90	1.00
0.70	0.90	1.00	0.70	0.90	1.00	0.70	0.90	1.00
0.70	0.90	1.00	0.70	0.90	1.00	0.50	0.70	0.90

Aggregated Fuzzy Decision Matrix								
C51			C52			C53		
0.83	0.97	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.83	0.97	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.83	0.97	1.00	0.90	1.00	1.00	0.90	1.00	1.00
0.90	1.00	1.00	0.83	0.97	1.00	0.70	0.87	0.97
0.70	0.90	1.00	0.57	0.77	0.93	0.43	0.63	0.80
0.63	0.83	0.97	0.57	0.77	0.93	0.37	0.57	0.77

Appendix G. Normalized Fuzzy Decision Matrix

	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.57	0.77	0.90	0.50	0.70	0.90	0.45	0.66	0.83	0.43	0.63	0.83	0.46	0.68	0.89
OPET	0.70	0.90	1.00	0.77	0.93	1.00	0.45	0.66	0.83	0.57	0.77	0.93	0.68	0.86	1.00
SHELL	0.63	0.83	0.97	0.37	0.57	0.77	0.45	0.66	0.83	0.43	0.63	0.83	0.54	0.75	0.93
BP	0.70	0.87	0.97	0.57	0.73	0.87	0.66	0.83	0.93	0.50	0.70	0.87	0.46	0.68	0.89
TOTAL OIL	0.83	0.97	1.00	0.50	0.70	0.83	0.52	0.69	0.83	0.63	0.83	0.97	0.61	0.82	1.00
AYTEMIZ	0.77	0.90	0.97	0.70	0.83	0.90	0.66	0.86	1.00	0.83	0.97	1.00	0.61	0.82	1.00

	C21			C22			C23			C24			C31		
OMV Petrol Ofisi	0.70	0.90	1.00	0.50	0.70	0.90	0.46	0.71	0.96	0.30	0.50	0.70	0.83	0.97	1.00
OPET	0.77	0.93	1.00	0.70	0.90	1.00	0.54	0.79	1.00	0.57	0.77	0.93	0.90	1.00	1.00
SHELL	0.70	0.87	0.97	0.37	0.57	0.77	0.46	0.71	0.96	0.43	0.63	0.83	0.90	1.00	1.00
BP	0.77	0.93	1.00	0.43	0.63	0.83	0.46	0.71	0.96	0.43	0.63	0.83	0.83	0.97	1.00
TOTAL OIL	0.50	0.70	0.90	0.70	0.83	0.90	0.63	0.83	1.00	0.57	0.77	0.93	0.43	0.63	0.83
AYTEMIZ	0.37	0.57	0.77	0.43	0.63	0.80	0.54	0.79	1.00	0.70	0.90	1.00	0.43	0.63	0.83

	C32			C33			C34			C35			C36		
OMV Petrol Ofisi	0.83	0.97	1.00	0.70	0.90	1.00	0.63	0.83	0.97	0.77	0.90	0.97	0.54	0.79	1.00
OPET	0.90	1.00	1.00	0.90	1.00	1.00	0.70	0.87	0.97	0.90	1.00	1.00	0.63	0.83	1.00
SHELL	0.77	0.93	1.00	0.63	0.80	0.93	0.77	0.93	1.00	0.90	1.00	1.00	0.63	0.83	1.00
BP	0.83	0.97	1.00	0.83	0.97	1.00	0.77	0.93	1.00	0.83	0.97	1.00	0.54	0.79	1.00
TOTAL OIL	0.63	0.83	0.97	0.43	0.63	0.80	0.37	0.57	0.77	0.57	0.77	0.93	0.38	0.63	0.88
AYTEMIZ	0.43	0.63	0.80	0.43	0.63	0.83	0.30	0.50	0.70	0.50	0.70	0.90	0.46	0.71	0.96

	C41			C42			C43			C44			C51		
OMV Petrol Ofisi	0.63	0.83	0.97	0.90	1.00	1.00	0.43	0.63	0.80	0.70	0.83	0.90	0.83	0.97	1.00
OPET	0.77	0.93	1.00	0.83	0.97	1.00	0.77	0.93	1.00	0.83	0.97	1.00	0.83	0.97	1.00
SHELL	0.77	0.90	0.97	0.90	1.00	1.00	0.50	0.67	0.80	0.37	0.57	0.77	0.83	0.97	1.00
BP	0.57	0.77	0.93	0.90	1.00	1.00	0.77	0.93	1.00	0.57	0.77	0.90	0.90	1.00	1.00
TOTAL OIL	0.50	0.70	0.90	0.57	0.77	0.93	0.43	0.63	0.80	0.10	0.30	0.50	0.70	0.90	1.00
AYTEMIZ	0.57	0.77	0.90	0.43	0.63	0.83	0.17	0.27	0.43	0.37	0.57	0.77	0.63	0.83	0.97

	C52			C53		
OMV Petrol Ofisi	0.90	1.00	1.00	0.90	1.00	1.00
OPET	0.90	1.00	1.00	0.90	1.00	1.00
SHELL	0.90	1.00	1.00	0.90	1.00	1.00
BP	0.83	0.97	1.00	0.70	0.87	0.97
TOTAL OIL	0.57	0.77	0.93	0.43	0.63	0.80
AYTEMIZ	0.57	0.77	0.93	0.37	0.57	0.77

Appendix H. Weighted Normalized Fuzzy Decision Matrix

	C11			C12			C13			C14			C15		
OMV Petrol Ofisi	0.15	0.32	0.57	0.12	0.25	0.47	0.05	0.10	0.20	0.01	0.03	0.06	0.01	0.02	0.04
OPET	0.19	0.37	0.63	0.18	0.33	0.52	0.05	0.10	0.20	0.02	0.03	0.06	0.02	0.03	0.05
SHELL	0.17	0.34	0.61	0.09	0.20	0.40	0.05	0.10	0.20	0.01	0.03	0.06	0.01	0.02	0.05
BP	0.19	0.36	0.61	0.13	0.26	0.45	0.07	0.13	0.23	0.02	0.03	0.06	0.01	0.02	0.04
TOTAL OIL	0.22	0.40	0.63	0.12	0.25	0.43	0.05	0.11	0.20	0.02	0.03	0.06	0.01	0.03	0.05
AYTEMIZ	0.21	0.37	0.61	0.17	0.30	0.47	0.07	0.13	0.24	0.03	0.04	0.07	0.01	0.03	0.05

	C21			C22			C23			C24			C31		
OMV Petrol Ofisi	0.08	0.17	0.34	0.05	0.11	0.22	0.13	0.33	0.67	0.04	0.10	0.25	0.20	0.35	0.57
OPET	0.09	0.17	0.34	0.07	0.14	0.24	0.15	0.37	0.70	0.07	0.15	0.33	0.21	0.36	0.57
SHELL	0.08	0.16	0.32	0.03	0.09	0.18	0.13	0.33	0.67	0.05	0.12	0.29	0.21	0.36	0.57
BP	0.09	0.17	0.34	0.04	0.10	0.20	0.13	0.33	0.67	0.05	0.12	0.29	0.20	0.35	0.57
TOTAL OIL	0.06	0.13	0.30	0.07	0.13	0.22	0.18	0.39	0.70	0.07	0.15	0.33	0.10	0.23	0.48
AYTEMIZ	0.04	0.10	0.26	0.04	0.10	0.19	0.15	0.37	0.70	0.09	0.18	0.35	0.10	0.23	0.48

	C32			C33			C34			C35			C36		
OMV Petrol Ofisi	0.16	0.30	0.50	0.04	0.08	0.14	0.04	0.09	0.18	0.04	0.08	0.13	0.01	0.03	0.06
OPET	0.17	0.32	0.50	0.05	0.09	0.14	0.05	0.10	0.18	0.05	0.09	0.13	0.02	0.03	0.06
SHELL	0.15	0.29	0.50	0.04	0.07	0.13	0.05	0.10	0.19	0.05	0.09	0.13	0.02	0.03	0.06
BP	0.16	0.30	0.50	0.05	0.09	0.14	0.05	0.10	0.19	0.05	0.08	0.13	0.01	0.03	0.06
TOTAL OIL	0.12	0.26	0.48	0.02	0.06	0.11	0.02	0.06	0.14	0.03	0.07	0.12	0.01	0.02	0.05
AYTEMIZ	0.08	0.20	0.40	0.02	0.06	0.12	0.02	0.06	0.13	0.03	0.06	0.12	0.01	0.02	0.05

	C41			C42			C43			C44			C51		
OMV Petrol Ofisi	0.25	0.52	0.89	0.11	0.19	0.29	0.02	0.05	0.12	0.06	0.09	0.14	0.37	0.61	0.89
OPET	0.31	0.59	0.92	0.10	0.18	0.29	0.04	0.07	0.15	0.07	0.10	0.16	0.37	0.61	0.89
SHELL	0.31	0.56	0.89	0.11	0.19	0.29	0.03	0.05	0.12	0.03	0.06	0.12	0.37	0.61	0.89
BP	0.23	0.48	0.86	0.11	0.19	0.29	0.04	0.07	0.15	0.05	0.08	0.14	0.40	0.63	0.89
TOTAL OIL	0.20	0.44	0.83	0.07	0.14	0.27	0.02	0.05	0.12	0.01	0.03	0.08	0.31	0.57	0.89
AYTEMIZ	0.23	0.48	0.83	0.05	0.12	0.24	0.01	0.02	0.06	0.03	0.06	0.12	0.28	0.53	0.86

	C52			C53		
OMV Petrol Ofisi	0.11	0.17	0.25	0.13	0.20	0.28
OPET	0.11	0.17	0.25	0.13	0.20	0.28
SHELL	0.11	0.17	0.25	0.13	0.20	0.28
BP	0.10	0.16	0.25	0.10	0.17	0.27
TOTAL OIL	0.07	0.13	0.24	0.06	0.12	0.23
AYTEMIZ	0.07	0.13	0.24	0.05	0.11	0.22

Appendix I. Distance Matrix

FPIS	C11	C12	C13	C14	C15	C21	C22	C23	C24	C31	C32	C33
OMV Petrol Ofisi	0.33	0.28	0.14	0.04	0.03	0.18	0.14	0.39	0.24	0.25	0.23	0.07
OPET	0.30	0.22	0.14	0.04	0.02	0.17	0.12	0.37	0.20	0.24	0.22	0.06
SHELL	0.32	0.32	0.14	0.04	0.03	0.18	0.15	0.39	0.22	0.24	0.24	0.07
BP	0.30	0.27	0.12	0.04	0.03	0.17	0.14	0.39	0.22	0.25	0.23	0.06
TOTAL OIL	0.27	0.28	0.14	0.03	0.02	0.20	0.12	0.35	0.20	0.34	0.26	0.08
AYTEMIZ	0.29	0.24	0.12	0.03	0.02	0.22	0.15	0.37	0.18	0.34	0.30	0.08

	C11	C12	C13	C14	C15	C21	C22	C23	C24	C31	C32	C33
OMV Petrol Ofisi	0.31	0.24	0.10	0.03	0.02	0.18	0.11	0.33	0.13	0.31	0.28	0.07
OPET	0.36	0.29	0.10	0.03	0.02	0.19	0.13	0.36	0.18	0.32	0.28	0.08
SHELL	0.34	0.19	0.10	0.03	0.02	0.18	0.09	0.33	0.16	0.32	0.27	0.07
BP	0.34	0.23	0.12	0.03	0.02	0.19	0.10	0.33	0.16	0.31	0.28	0.08
TOTAL OIL	0.37	0.22	0.10	0.03	0.02	0.16	0.12	0.36	0.18	0.23	0.25	0.05
AYTEMIZ	0.35	0.26	0.13	0.03	0.02	0.13	0.10	0.36	0.20	0.23	0.20	0.06

FNIS	C34	C35	C36	C41	C42	C43	C44	C51	C52	C53	SUM
OMV Petrol Ofisi	0.10	0.06	0.03	0.45	0.12	0.09	0.07	0.34	0.10	0.10	3.77
OPET	0.10	0.05	0.03	0.40	0.12	0.07	0.06	0.34	0.10	0.10	3.47
SHELL	0.09	0.05	0.03	0.41	0.12	0.09	0.10	0.34	0.10	0.10	3.75
BP	0.09	0.06	0.03	0.47	0.12	0.07	0.08	0.32	0.10	0.12	3.69
TOTAL OIL	0.12	0.07	0.03	0.50	0.15	0.09	0.12	0.38	0.13	0.16	4.07
AYTEMIZ	0.13	0.07	0.03	0.47	0.17	0.12	0.10	0.41	0.13	0.17	4.14

	C34	C35	C36	C41	C42	C43	C44	C51	C52	C53	SUM
OMV Petrol Ofisi	0.10	0.06	0.03	0.44	0.16	0.07	0.10	0.40	0.12	0.16	3.76
OPET	0.10	0.07	0.03	0.47	0.16	0.09	0.11	0.40	0.12	0.16	4.06
SHELL	0.11	0.07	0.03	0.45	0.16	0.07	0.07	0.40	0.12	0.16	3.74
BP	0.11	0.07	0.03	0.41	0.16	0.09	0.09	0.41	0.12	0.15	3.82
TOTAL OIL	0.08	0.06	0.02	0.39	0.13	0.07	0.04	0.39	0.10	0.11	3.49
AYTEMIZ	0.07	0.06	0.03	0.40	0.11	0.03	0.07	0.36	0.10	0.10	3.38

Appendix J. Extended Model of the Problem

MIN Z = W12*D121+W51*D512+W31*D311+W34*D341+W41*D411+W23*D231+W11*D111+W13*D13+D01

s.t.

(1) H1*X1+H2*X2+H3*X3+H4*X4+H5*X5+H6*X6-D121+D122=RH1

(2) L1*X1+L2*X2+L3*X3+L4*X4+L5*X5+L6*X6-D511+D512=RH2

(3) MS1*X1+MS2*X2+MS3*X3+MS4*X4+MS5*X5+MS6*X6-D311+D312=RH3

(4) TS1*X1+TS2*X2+TS3*X3+TS4*X4+TS5*X5+TS6*X6-D341+D342=RH4

(5) I1*X1+I2*X2+I3*X3+I4*X4+I5*X5+I6*X6-D411+D412=RH5

(6) C1*X1+C2*X2+C3*X3+C4*X4+C5*X5+C6*X6-D231+D232=RH6

(7) P1*X1+P2*X2+P3*X3+P4*X4+P5*X5+P6*X6-D111+D112=RH7

(8) B1*X1+B2*X2+B3*X3+B4*X4+B5*X5+B6*X6-D131+D132=RH8

(9) SK1*X1+SK2*X2+SK3*X3+SK4*X4+SK5*X5+SK6*X6-D01+D02=RH9

(10) X1+X2+X3+X4+X5+X6=1

INT X1

INT X2

INT X3

INT X4

INT X5

INT X6

END

Appendix K. LINDO Model

```
MIN
0.35D121+0.63D512+0.36D311+0.11D341+0.61D411+0.45D231+0.41D111+0.16D131+D01
s.t.
0.8X1+0.75X2+0.75X3+0.75X4+0.85X5+0.85X6-D121+D122=0.75
2X1+1.5X2+X3+X4+X5+X6-D511+D512=2
0.24X1+0.1674X2+0.1646X3+0.854X4+0.0541X5+0.0188X6-D311+D312=0.10
0.29X1+0.17X2+0.32X3+0.14X4+0.05X5+0.05X6-D341+D342=0.10
0.50X1+1X2+0.30X3+0.50X4+0.50X5+1X6-D411+D412=0.50
X1+X2+X3+X4+1.25X5+1.25X6-D231+D232=1
0.45X1+0.43X2+0.45X3+0.43X4+0.50X5+0.55X6-D111+D112=0.40
0.05X1+0.05X2+0.05X3+0.05X4+0.1X5+0.15X6-D131+D132=0.05
1762X1+1468X2+1033X3+659X4+452X5+474X6-D01+D02=1500
X1+X2+X3+X4+X5+X6=1
D121>=0
D511>=0
D311>=0
D341>=0
D411>=0
D231>=0
D111>=0
D01>=0
D122>=0
D512>=0
D312>=0
D342>=0
D412>=0
D232>=0
D112>=0
D02>=0
END
INT X1
INT X2
INT X3
INT X4
INT X5
INT X6
```

Appendix L. LINDO Results

```
LP OPTIMUM FOUND AT STEP     24
OBJECTIVE VALUE =  0.248335198

FIX ALL VARS.(    2)  WITH RC >  0.000000E+00
SET       X1 TO >=     1 AT    1, BND=  -262.1     TWIN=-0.6113         81

NEW INTEGER SOLUTION OF    262.109314     AT BRANCH      1 PIVOT      81
BOUND ON OPTIMUM: 0.4006702
FLIP       X1 TO <=         0 AT    1 WITH BND=  -0.61127919
SET       X2 TO >=     1 AT    2, BND= -0.6643     TWIN=-0.6980         84

NEW INTEGER SOLUTION OF   0.664264023     AT BRANCH      2 PIVOT      84
BOUND ON OPTIMUM: 0.4006702
DELETE       X2 AT LEVEL     2
DELETE       X1 AT LEVEL     1
RELEASE FIXED VARIABLES
ENUMERATION COMPLETE. BRANCHES=     2 PIVOTS=     100

LAST INTEGER SOLUTION IS THE BEST FOUND
RE-INSTALLING BEST SOLUTION...

      OBJECTIVE FUNCTION VALUE

      1)     0.6642640

 VARIABLE        VALUE          REDUCED COST
       X1        0.000000        -0.372200
       X2        1.000000         0.182764
       X3        0.000000         0.094456
       X4        0.000000         0.436640
       X5        0.000000         0.202476
       X6        0.000000         0.515268
     D121        0.000000         0.000000
     D512        0.500000         0.000000
     D311        0.067400         0.000000
     D341        0.070000         0.000000
     D411        0.500000         0.000000
     D231        0.000000         0.000000
     D111        0.030000         0.000000
     D131        0.000000         0.160000
      D01        0.000000         1.000000
     D122        0.000000         0.350000
     D511        0.000000         0.630000
     D312        0.000000         0.360000
     D342        0.000000         0.110000
     D412        0.000000         0.610000
     D232        0.000000         0.000000
```

D112	0.000000	0.410000
D132	0.000000	0.000000
D02	32.000000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	0.350000
3)	0.000000	-0.630000
4)	0.000000	0.360000
5)	0.000000	0.110000
6)	0.000000	0.610000
7)	0.000000	0.000000
8)	0.000000	0.410000
9)	0.000000	0.000000
10)	0.000000	0.000000
11)	0.000000	0.000000
12)	0.000000	0.000000
13)	0.000000	0.000000
14)	0.067400	0.000000
15)	0.070000	0.000000
16)	0.500000	0.000000
17)	0.000000	-0.450000
18)	0.030000	0.000000
19)	0.000000	0.000000
20)	0.000000	0.000000
21)	0.500000	0.000000
22)	0.000000	0.000000
23)	0.000000	0.000000
24)	0.000000	0.000000
25)	0.000000	0.000000
26)	0.000000	0.000000
27)	32.000000	0.000000

NO. ITERATIONS= 105
BRANCHES= 2 DETERM.= 1.000E 0

Appendix M. Range of optimal solution obtained by LİNDO

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	0.000000	INFINITY	0.000000
X2	0.000000	INFINITY	0.182764
X3	0.000000	INFINITY	0.094456
X4	0.000000	INFINITY	0.436640
X5	0.000000	INFINITY	0.202476
X6	0.000000	INFINITY	0.515268
D121	0.350000	INFINITY	0.350000

D512	0.630000	INFINITY	0.630000
D311	0.360000	INFINITY	0.360000
D341	0.110000	INFINITY	0.110000
D411	0.610000	INFINITY	0.610000
D231	0.450000	INFINITY	0.450000
D111	0.410000	INFINITY	0.410000
D131	0.160000	INFINITY	0.160000
D01	1.000000	INFINITY	1.000000
D122	0.000000	INFINITY	0.350000
D511	0.000000	INFINITY	0.630000
D312	0.000000	INFINITY	0.360000
D342	0.000000	INFINITY	0.110000
D412	0.000000	INFINITY	0.610000
D232	0.000000	INFINITY	0.000000
D112	0.000000	INFINITY	0.410000
D132	0.000000	INFINITY	0.000000
D02	0.000000	INFINITY	1.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	0.750000	0.000000	INFINITY
3	2.000000	INFINITY	0.500000
4	0.100000	0.067400	INFINITY
5	0.100000	0.070000	INFINITY
6	0.500000	0.500000	INFINITY
7	1.000000	0.000000	0.000000
8	0.400000	0.030000	INFINITY
9	0.050000	0.000000	0.000000
10	1500.000000	INFINITY	32.000000
11	1.000000	0.000000	0.000000
12	0.000000	0.000000	INFINITY
13	0.000000	0.000000	INFINITY
14	0.000000	0.067400	INFINITY
15	0.000000	0.070000	INFINITY
16	0.000000	0.500000	INFINITY
17	0.000000	0.000000	0.000000
18	0.000000	0.030000	INFINITY
19	0.000000	0.000000	INFINITY
20	0.000000	0.000000	INFINITY
21	0.000000	0.500000	INFINITY
22	0.000000	0.000000	INFINITY
23	0.000000	0.000000	INFINITY
24	0.000000	0.000000	INFINITY
25	0.000000	0.000000	INFINITY
26	0.000000	0.000000	INFINITY
27	0.000000	32.000000	INFINITY

Appendix M. Simplex Table of the Model's Iterations

THE TABLEAU

ROW	(BASIS)	X1	X2	X3	X4	X5	X6
1	ART	-0.372	0.183	0.094	0.437	0.202	0.515
2	D311	-0.240	-0.167	-0.165	-0.854	-0.054	-0.019
3	D512	2.000	1.500	1.000	1.000	1.000	1.000
4	SLK 14	-0.190	-0.117	-0.115	-0.804	0.046	0.131
5	D341	-0.290	-0.170	-0.320	-0.140	-0.050	-0.050
6	D411	-0.500	-1.000	-0.300	-0.500	-0.500	-1.000
7	ART	1.000	1.000	1.000	1.000	1.250	1.250
8	SLK 18	0.550	0.570	0.550	0.570	0.500	0.450
9	D231	0.000	0.000	0.000	0.000	0.000	0.000
10	D111	-0.450	-0.430	-0.450	-0.430	-0.500	-0.550
11	D121	-0.800	-0.750	-0.750	-0.750	-0.850	-0.850
12	SLK 12	-0.800	-0.750	-0.750	-0.750	-0.850	-0.850
13	SLK 13	0.000	0.000	0.000	0.000	0.000	0.000
14	ART	0.050	0.050	0.050	0.050	0.100	0.150
15	SLK 15	-0.290	-0.170	-0.320	-0.140	-0.050	-0.050
16	SLK 16	-0.500	-1.000	-0.300	-0.500	-0.500	-1.000
17	D02	1762.000	1468.000	1033.000	659.000	452.000	474.000
18	ART	1.000	1.000	1.000	1.000	1.000	1.000
19	SLK 19	0.000	0.000	0.000	0.000	0.000	0.000
20	SLK 20	0.000	0.000	0.000	0.000	0.000	0.000
21	SLK 21	2.000	1.500	1.000	1.000	1.000	1.000
22	SLK 22	0.000	0.000	0.000	0.000	0.000	0.000
23	SLK 23	0.000	0.000	0.000	0.000	0.000	0.000
24	SLK 24	0.000	0.000	0.000	0.000	0.000	0.000
25	SLK 25	0.000	0.000	0.000	0.000	0.000	0.000
26	SLK 26	0.000	0.000	0.000	0.000	0.000	0.000
27	SLK 27	1762.000	1468.000	1033.000	659.000	452.000	474.000

ROW	D121	D512	D311	D341	D411	D231	D111
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	1.000	0.000	0.000	0.000	0.000
3	0.000	1.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	1.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	1.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	1.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	1.000
11	1.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000

15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ROW	D131	D01	D122	D511	D312	D342	D412
1	0.160	1.000	0.350	0.630	0.360	0.110	0.610
2	0.000	0.000	0.000	0.000	-1.000	0.000	0.000
3	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
4	-1.000	0.000	0.000	0.000	-1.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	-1.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
12	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
14	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	-1.000
17	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	-1.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	-1.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	-1.000	0.000	0.000	0.000	0.000	0.000

ROW	D232	D112	D132	D02	SLK 12	SLK 13	SLK 14
1	0.000	0.410	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000

4	0.000	0.000	1.000	0.000	0.000	0.000	1.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	1.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	1.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	1.000	0.000
14	0.000	0.000	1.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	1.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ROW	SLK 15	SLK 16	SLK 17	SLK 18	SLK 19	SLK 20	SLK 21
1	0.000	0.000	0.450	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	1.000	0.000	0.000	0.000
9	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	1.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	1.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	1.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	1.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	1.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000

23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ROW	SLK 22	SLK 23	SLK 24	SLK 25	SLK 26	SLK 27
1	0.000	0.000	0.000	0.000	0.000	-0.664
2	0.000	0.000	0.000	0.000	0.000	0.067
3	0.000	0.000	0.000	0.000	0.000	0.500
4	0.000	0.000	0.000	0.000	0.000	0.067
5	0.000	0.000	0.000	0.000	0.000	0.070
6	0.000	0.000	0.000	0.000	0.000	0.500
7	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.030
9	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.030
11	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.070
16	0.000	0.000	0.000	0.000	0.000	0.500
17	0.000	0.000	0.000	0.000	0.000	32.000
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.500
22	1.000	0.000	0.000	0.000	0.000	0.000
23	0.000	1.000	0.000	0.000	0.000	0.000
24	0.000	0.000	1.000	0.000	0.000	0.000
25	0.000	0.000	0.000	1.000	0.000	0.000
26	0.000	0.000	0.000	0.000	1.000	0.000
27	0.000	0.000	0.000	0.000	0.000	1.000	32.000

BIOGRAPHICAL SKETCH

Elif Uçar is a Graduate Student of Industrial Engineering at Galatasaray University. She graduated with a BS from Bahçeşehir University in Industrial Engineering in 2011. Her research interests include decision analysis, multiple criteria decision making, supply chain management, logistics, energy.