GALATASARAY UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

A FUZZY DECISION MAKING APPROACH FOR DISTRIBUTOR SELECTION IN AUTOMATION SECTOR

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Feb 2020

A FUZZY DECISION MAKING APPROACH FOR DISTRIBUTOR SELECTION IN AUTOMATION SECTOR

(OTOMASYON SEKTÖRÜNDE BAYİ SEÇİMİ İÇİN BİR BULANIK KARAR VERME YAKLAŞIMI)

by

Mustafa YUMURTACI, B.S.

Thesis

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

in

LOGISTICS AND FINANCIAL MANAGEMENT

in the

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

Feb 2020

This is to certify that the thesis entitled

A FUZZY DECISION MAKING APPROACH FOR DISTRIBUTOR SELECTION IN AUTOMATION SECTOR

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ACKNOWLEDGEMENTS

I express my deepest gratitude to Assist. Prof. Zeynep Şener for her perpetual guidance, advice and encouragement throughout this research study. Her continuous support and her feedback helped me to accomplish this project successfully.

I would also like to thank my family, my father Prof. Dr. Selahattin YUMURTACI, my mother Canan YUMURTACI, and my sister Nergis YUMURTACI for their great support throughout my life. Their endless support and understanding were the biggest motivation to complete this process.

Finally, I would like to thank my friends. Their creative ideas and suggestions played a vital role in my research study.

Feb 2020
Mustafa YUMURTACI

TABLE OF CONTENTS

LIST OF SYMBOLS

RC	**:** Risk Criteria
SS	**:** Supplier Selection
ALT	**:** Alternative
OWA	**:** Ordered Weighted Averaging
PLC	**:** Programmable Logic Controller
RIM	**:** Regular Increasing Monotone
R&D	**:** Research And Development
MCDM	**:** Multiple Criteria Decision Making

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The purpose of this thesis is to investigate the importance of distributor selection in automation sector. A lot of criteria should be considered in selection process. In today's world, all companies take the risk minimization into consideration. As a result of globalization, risk minimization is an effective tool in order not to face with negative results in the future. For that purpose, some criteria should be applied in order to find the right distributor or partner. Also, in other aspect, using these criteria in selection process can increase the companies' profits by selecting the most beneficial distributor. It is also crucial to emphasize that this research study is a Multiple Criteria Decision Making (MCDM) problem since it includes some criteria and the decision process of selection among alternatives uses these criteria.

Distributor selection as a research study is not directly a popular topic in academic world. When the previous research studies have been investigated, the obtained findings were very limited. However, the topic, which is supplier selection and their risk factors, has a lot of similarities with the distributor selection process. When the risk criteria were examined, it was found that some parameters could also be used for distributor selection. Besides the criteria which are related to the both topics, some criteria, proposed by the experts, are also added. Moreover, the pre-existing criteria were reinterpreted according to the current topic. In total, nine criteria were used for the selection and calculations.

In this work, the risk factors which were affecting the distributor selection were analyzed. Also, the significance of applying the method on multi criteria distributor selection problem was shown by the obtained findings. The risk factors were defined by literature review and the expertise of the decision makers. Also, their importance degrees were identified by decision makers. The final crisp weights of each criteria were also sorted according to show their importance degrees. However, the crisp weights were not used in

calculations; the calculated aggregated fuzzy weights were used to find the most appropriate alternative.

According to the criteria which were taken into consideration, the distributor which was selected as a partner was found by the proposed fuzzy MCDM approach based on the ordered weighted averaging (OWA) technique. For this purpose, as it is mentioned before, the criteria were defined. Then, their importance levels were assigned by the experts. The experts' assessments on criteria were aggregated using OWA method and the results were presented according to this model. Before the distributor alternatives which met these criteria were determined, the final risk scores of all candidates were calculated. Their risk levels were sorted from less risky to most risky alternative.

However, there was a constraint which affected the selection process. The constraint was the margin rate that distributors requested from the main company. For this purpose, the experts of the main company also defined a limit value for the margin that could be demanded by distributors. If a distributor wants to sell the products with the margin that exceeds the threshold value, it will be eliminated from the selection process.

According to the results, the less risky alternative which satisfies the margin rate constraint was chosen as the most appropriate distributor among the other candidates.

The resulting model will help the companies who want to make a partnership with distributor model in terms of business partner selection and risk minimization.

Key Words: Distributor Selection, Risk Criteria, Risk Minimization, OWA Technique

ÖZET

Bu çalışmanın amacı otomasyon sektöründeki bayi seçiminin öneminin araştırılmasıdır. Seçim aşamasında birçok ölçütün düşünülüp, incelenmesi gerekmektedir. Günümüzün dünyasında tüm firmalar risk faktörlerini ve riskin en aza indirilmesini dikkate almaktadırlar. Globalleşmenin bir sonucu olarak risk indirgenmesi gelecekteki kötü sonuçlarla karşılaşmamak adına önemli bir araç olup, bize seçim yapılacak alternatiflerin durumunu etüt yapma imkânı sağlamaktadır. Bu nedenden dolayı bazı ölçütlerin doğru bayinin bulunması adına uygulanması gerekmektedir. Ayrıca, başka bir açıdan, seçim sürecinde bu ölçütleri kullanmak, en faydalı distribütörü seçerek şirketlerin kârını artırabilmektedir. Bu çalışmanın, farklı ölçütler içermesi ve alternatifler arasından seçim yapma aşamasında bu ölçütlerden yararlanması ile bir Çok Ölçütlü Karar Verme (ÇÖKV) problemi olduğunu vurgulamak da önemlidir.

Bayi seçim problemi daha önceden çalışma alanı olarak pek tercih edilmiş bir konu değildir. Bayi seçimi ile ilgili daha önceki çalışmalar araştırıldığında bulunanların çok sınırlı olduğu görülmüştür. Bununla birlikte tedarikçi seçimi ve tedarikçi risk faktörleri incelendiğinde iki konu arasında benzerlikler bulunduğuna kanaat getirilmiştir. Tedarikçi seçimi için risk faktörleri araştırıldığında, bazı parametrelerin aynı zamanda bayi seçiminde de kullanılabileceği bulunmuştur. Benzer bulunan ölçütlerin dışında ayrıca uzmanlar tarafından önerilen farklı ölçütler de seçim faktörü olarak işleme alınıp, değerlendirilmiştir. Mevcut daha önceden de kullanılmış olan ölçütler bu konuya uygun olarak tekrar değerlendirilip, yorumlanmıştır. Toplamda dokuz ölçüt seçim sürecine dahil edilip, hesaplamalarda kullanılmıştır.

Bu çalışmada risk faktörlerinin tanımı ve bayi seçimine olan etkisi analiz edilmiştir. Aynı zamanda yöntemin çok ölçütlü bayi seçim problemine uygulanmasındaki önemi elde edilen bulgular ile gösterilmiştir. Kullanılan risk faktörleri yayın taraması ve karar vericilerin uzmanlığı ile belirlenmiştir. Ayrıca risk faktörlerinin önem dereceleri karar

vericiler tarafından değerlendirilmiştir. Risk faktörlerinin en son ulaşılan kesin sayılı ağırlıkları ölçütlerin önem derecelerini göstermek için sıralanmıştır. Ama kesin sayılı ağırlıklar hesaplamalarda kullanılmamış olup, bunun yerine birleştirilmiş bulanık ağırlıklar alternatifler arasından seçim aşamasında kullanılmıştır.

Göz önünde bulundurulan ölçütlere göre, partner olarak seçilen bayi, önerilen Sıralı Ağırlıklandırılmış Ortalama (OWA-Ordered Weighted Averaging) tekniği temelli ÇÖKV yaklaşımı ile bulunmuştur. Bu amaçla, daha önce de belirtildiği gibi, ölçütler tanımlanmıştır. Ardından, önem düzeyleri uzmanlar tarafından belirlenmiştir. Uzmanların ölçütlere ilişkin değerlendirmeleri OWA yöntemi ile birleştirilmiş ve sonuçlar bu modele göre sunulmuştur. Bu ölçütleri karşılayan bayi alternatifleri belirlenmeden önce, tüm adayların net risk puanları hesaplanmıştır. Adayların risk skorları en az riskliden, en riskliyi gösterecek şekilde tablolarda sunulmuştur.

Ancak, seçim sürecini etkileyen bir kısıtlama vardır. Kısıt, distribütörlerin ana şirketten talep ettiği marj oranıdır. Bu amaçla, ana şirketin uzmanları da distribütörler tarafından talep edilebilecek marj için bir sınır değer tanımlamaktadır. Eğer bir distribütör, ürünleri eşik değerini aşan marjla satmak isterse, seçim sürecinden çıkarılır.

Elde edilen hesaplamalara göre, en küçük risk değerine sahip ve marj oranı kısıtını sağlayan en uygun bayi, alternatifler arasından seçilmiştir.

Ortaya çıkan model, bayi seçimi ve risk azaltma konusunda bayi modeli ile ortaklık yapmak isteyen firmalara yardımcı olacaktır.

Anahtar Sözcükler: Distribütör Seçimi, Risk Ölçütleri, Risk Enküçültme, OWA Tekniği

1. INTRODUCTION

This chapter introduces an overview of the study which is conducted on decision making for distributor selection. Firstly, an overview of the theoretical framework is presented, and then the problem statement and the significance of the study are provided. The significance of the study is indicated in the end. Before deepening into details, the meaning of distributor and selection criteria are explained below.

A distributor is a person or a company which buys or supplies some products, stores them, and resells them to the retailers and customers. According to their territory, it is expected from them to market these goods of the manufacturer. The selection criteria are lists of the essential and desirable skills, attributes that an organization finds necessary for the business. Various methods are employed for the selection process.

1.1. Theoretical Framework

Supply chain is a network which makes a connection between the facilities and companies. Mainly, it aims to decrease costs while increasing the efficiency of system in order not to face with negative situation in the future. One of the other purpose is to make production and management cycle more faster. For this purpose, there are a lot of units and sub-unit which contribute to the operations. In general, units are also known as suppliers. In each part of the cycle, supplier maintains its own duties according to the requirements. Most of the time, companies prefer to work with different suppliers for risk diversification. If a problem occurs in a supplier, company can transfer the material or products to other supplier in order to continue its operations.

The supplier’s profile and working principles play a vital role in order not to encounter with problems. Therefore, supplier selection process should be managed carefully.

Supplier selection mainly consists of four phases. First stage is the realizing of the need for a new supplier. Even if the main company has its own sales channel in the local market, they may need a partner to increase its sales. For that reason, in the second stage, the company determines the possible partner companies and forms a formulation for selection criteria. After that, the final supplier selection is chosen by main company. At the last part, the chosen distributor's activities and approach are started to monitor.

There are a lot of research studies about the optimization of selection among alternatives. When these articles are evaluated, it is noticed that there are a lot of similarities with the distributor selection process. As it is indicated previously, the objective of this research study is "Decision Making for Distributor Selection in Automation Sector". At this part, it will be beneficial to give details about automation sector.

Automation, which its roots start with the industrial revolution, is a demonstration of machine and human cooperation. In most of the companies, task sharing has started to be shared between man and machine with automation systems. The key issue is to keep transactions automatically without any human intervention . It can also be defined as manufacturing systems that perform operations and provide control without the need for human intervention. PLC automation systems can be given as an example. The significance of automation systems can be understood better in production systems.

Automation systems enable people to reach global market needs in today's rapidly developing world. As a result of globalization, it is necessary to be fast, safe and efficient in order to maintain its lifecycle in competitive conditions of market. It is crucial to emphasize that being safe, in other words, risk minimization is as important as being fast. For the risk minimization, some risk criteria should be identified. The main purpose of the thesis is to use the risk criteria in the selection of distributors, and an application has been made on the automation sector. The automation sector or distributor selection have not been addressed as a problem before. Therefore, the research study will shed light on distributor selection in automation sector.

Concept of the risk in science and engineering areas is linked with supplier selection in many previous studies. At this point, there is a crucial importance of explaining the real

meaning of the term ‘risk’. Risk is described as follows: “a situation involving exposure to danger” according to the English dictionary. The danger can occur from predicted or unpredicted reasons. In other words, risk is the possibility that an event can end up with negative consequences. The main risk factors which are in supply chain are country of origin, security, internal & external management process, social & economic conditions of country, and the quantity & accuracy rate of shipment.

In procurement management, the main objective is to define factors which are significant in selecting optimal suppliers. In supplier selection process, the other issue is to determine which criteria should be included into process while evaluating suppliers’ performances. According to the articles, each people who worked on this topic has emphasized different criteria in terms of their importance. To illustrate, Stanley and Wisner (2001) have made a survey on different industries to analyze which criteria are more crucial among the other criteria. They has come up with an explanation that quality and delivery performance of the company play a vital role in evaluation of purchasing activity. In addition, the other factors might affect the supplier selection are price, technical capability, and transportation cost. The view that generally accepted quality and price are the most important factor is also supported by Ghodsypour and O´Brien (1998) and their evaluation. Therefore, it is important to note that cost and quality dominated the supplier selection process. One of the crucial studies is the Lee’s (2009) criteria in terms of the supplier selection models with the consideration of benefits, opportunities, costs and risk. The study approaches the possible risks that companies can face with in broad perspective and helps the people in terms of giving an idea about how to deal with them.

1.2. Statement of the Problem

In today’s globalized world, people live in a competitive business environment, which makes companies strive for maximum profit. However, those companies make wrong decisions as they place importance on maximizing the profit rather than minimizing risks while selecting distributors. In automation industry, risk factors must be taken into consideration and distributors must be chosen accordingly. To this end, evaluating the risk of distributors is seen as an effective way to be successful in local and global markets.

1.3. Purpose of the Study

In today's world, the local and global companies are taking into consideration the risk factors that can lead to the downfall in their supply chain system. There are a lot of criteria that affect the supplier selection. The importance of distributor selection can be understood from the responsibility that is given to distributor. When their success and factors that affect their performance are considered, it is an undeniable fact that people should be aware of the risk factors in distributor selection.

It is found that many factors affect supplier selection. In addition to the previous factors, some criteria can be also listed as company profile, management philosophy, organizational structure, service levels, quality on-time delivery, trust, transportation, and communication (Verma & Pullman, 1998; Ghodsypour and O´Brien, 1998; Stanley & Wisner, 2001). Risk factors must be given importance since rapid changes and requirements of the materials make this issue more crucial in today's competitive business life. In the supply chain system, the companies should estimate the risk factors and implement their strategies according to the risk assessment. Risk factors can be applicable to each system which contains multiple criteria decision making (MCDM). For that purpose, in this study, the adoptability of risk factors is analyzed, and then synthesized considering the distributor selection. Finally, risk factors in selection of distributors and their inclusion in selection procedure are discussed.

The rest of the thesis is organized as follows;

Chapter 2 contains a literature review which shows the articles, research studies which are made on this topic previously. Chapter 3 contains risk criteria which are used in distributor selection and their explanations. In Chapter 4, there is information about the used method and the application of the method on defined criteria. Chapter 5 concludes the thesis and explains the further works which can be done in the future.

2. LITERATURE REVIEW

While reviewing the literature on decision making for distributor selection, the Web of Science and Google Scholar are used to choose appropriate research studies. When "Distributor Selection" is searched on these websites' databases, nothing is found related to the research and criteria. However, many studies are found for supplier selection. When the aim, criteria and methods of the research are compared with the studies which are made for supplier selection, it is noticed that similarities can be also used for distributor selection. The articles and journals which were found are in the reference part. According to these journals and articles, the risk criteria and factors are explained below.

This chapter is the review of literature related to the selection of supplier, risk factors, and criteria. As it is indicated in the previous part, supplier selection criteria and their risk factors can be used for the distributor selection and its risk factors.

During the literature review, it is found that a lot of research studies focus on techniques that contribute how to determine the right criteria. One of the most well-known studies is written by Dickson (1966) in which he represents 23 criteria which should be considered regarding evaluating a supplier. Chronologically, it is also one of the oldest articles in the supplier selection area. In his research, he prepared a questionnaire for the people who are responsible for supplier selection. According to managers' answers, he sorted the risk factors in four groups in terms of their importance (Benyoucef et al., 2003). His selection criteria are shown in Table 2.1. In today's world, it is still accepted as one of the most fundamental approaches. The approach helps the other researchers in terms of future developments.

Table 2.1: Dickson's Supplier Selection Criteria (Dickson, 1966)

Rank	Factor	Mean Rating	Evolution
1	Quality	3.508	Extreme Importance
2	Delivery	3.417	Considerable Importance
3	Performance History	2.998	
4	Warranties and Claim Policies	2.849	
5	Production Facilities and Capacity	2.775	
6	Price	2.758	
7	Technical Capability	2.545	
8	Financial Position	2.514	
9	Procedural Compliance	2.488	Average Importance
10	Communication System	2.426	
11	Reputation and Position in Industry	2.412	
12	Desire for Business	2.256	
13	Management and Organization	2.216	
14	Operating Controls	2.211	
15	Repair Services	2.187	
16	Attitude	2.120	
17	Impression	2.054	
18	Packaging Ability	2.009	
19	Labor Relations Record	2.003	
20	Geographical Location	1.872	
21	Amount of Past Business	1.597	
22	Training Aids	1.537	
23	Reciprocal Arrangements	0.610	Slight Importance

After Dickson's (1966) analysis of supplier selection, another study which is also profound is Weber et al. (1991)'s study. It basically covers vendors' selection criteria and methods. Weber et al. (1991) reviews Dickson's work and seventy-four different articles which are written on selection criteria and published between 1966 and 1990. According to the ranked criteria and findings, the research claims that the price, delivery, and quality are the most significant criteria as it can be seen in their article. Weber et al. (1991) also indicates the difficulty of producing low cost and getting high quality products. However, using the appropriate suppliers increases the possibility of meeting the demand of producing low cost and getting high quality products. Deshmukh & Chaudhari (2011) reviewed articles from 1992 to 2007 and made a comparison with Weber's findings. In addition, the different usage rates of criteria stress that the importance of selection criteria can be changeable and supplier selection decisions are multi-objective.

Besides the research study mentioned above, there is another research study which makes a comparison criteria usage between the years 1966-2001 and 2001-2010. Thiruchelvam and Tookey (2011) developed the study in terms of the frequency of criteria usage in articles. This research is also valuable in terms of showing all criteria that are used related to this topic in the history. Additionally, it gives an idea about parameter changes in researchers' significance level lists. The last but not least, overall column shows the criteria which are used the most, and also the criteria used rarely in the literature.

During the years, it can be seen that some criteria usage has been decreased while the other criteria usage increased. When the frequency values of both time periods compared with each other, it can be easily understood that criterion usage amount of 2001-2010 years are higher than 1966-2001 years. It can be briefly calculated as follows: when the value in the specified year range for each criterion is divided by the total number of specified years' ranges, in most of them, the unit values become higher for the dates which are closer to today

The other supplier evaluation process was made by Cebi and Bayraktar (2003) which is a more combined model for supplier evaluation. The classified factors are technology, relationship, business, and logistics. However, in addition to the previous models, the criteria base on the factors which consist of qualitative and quantitative. Therefore, according to the companies' priorities, the selection of the factors which are more crucial leads to a decrease in the number of categories.

The other article which belongs to Karsak and Dursun (2016) is also significant in terms of summarizing the criteria which are used in supplier selection. They reviewed articles using non-deterministic analytical methods between 2001 and 2013. According to their findings about the criteria which are mostly chosen, cost still comes at the top of supplier's preference lists. The quality and delivery criteria follow the cost criterion.

During the literature review part, a lot of contribution has been made by research studies. As it is mentioned in the introduction part, there is a connection between supplier selection and distributor selection. Therefore, the supplier selection, the supplier selection criteria, and risk factors have been searched in literature. The articles which are related to the research study are combined. The results can be seen in the Table 2.2.

Table 2.2: Studies on Supplier Selection incorporating Risk Factors

Author(s)	Publication Year	Risk Factors
Alikhani, Reza; Torabi, S. Ali; Altay, Nezih	2019	Quality, Cost, Long-term cooperation, Bankruptcy, On-time delivery, Supply constraints, Supplier's profile, Continuity, Second-tier supplier, Contractual and opportunism
Hansen, Carsten; Mena, Carlos; Aktas, Emel	2019	Political risk factors
Phumchusri, Naragain; Tangsiriwattana, Supasit	2019	Financial credibility, location, environmental requirement, business loyalty, supply chain resilience
Urbaniak, Maciej	2019	Critical risk factors in relations with suppliers: Timely deliveries, Quality defects of products, Financial situation, Communication problems, Flexibility of supply, Assortment errors in deliveries, Limited production capacity, Technological problems, No emergency delivery plans
Yoon, Jiho; Talluri, Srinivas; Yildiz, Hakan; Ho, William	2018	Provides a literature review on supplier selection studies with risk consideration
Song, Wenyan; Ming, Xinguo; Liu, Hu-Chen	2017	Provides a literature review about sustainable supply chain management risk factors
Chatterjee, Kajal; Kar, Samarjit	2016	Environmental risk, Demand Risk, Supply Risk, Control Risk, Process Risk, Insurance Risk
Fang, Chao; Liao, Xiangxiang; Xie, Min	2016	Disruption risks, Operational risks
Govindan, Kannan; Jepsen, Martin Brandt	2016	Provides a list that contains risks in manufacturing supply chains collected from literature
Moghaddam, Kamran S.	2015(a)	Economic risk
Moghaddam, Kamran S.	2015(b)	Economic risk
Nekooie, Mohammad Ali; Sheikhalishahi, Mohammad; Hosnavi, Reza	2015	Supplier bankruptcy, Man-made disasters, Excessive handling, Cost uncertainty, Exchange rate risk, Data information security risks and legal risks, Natural disasters
Nepal, Bimal; Yadav, Om Prakash	2015	Port congestion, Equipment inefficiency at port, Custom inspection, Incorrect bill of lading, Supply chain length, Labor strikes, Price inflation; Currency fluctuation, Wage fluctuations, Supplier quality
Paul, Sanjoy Kumar	2015	Demand flexibility, Defective items, Delivery delay, Increment in price, Adequacy of transport & inventory management & disruption management, Supplier environmental performance, Financial stability, Response to technological change, Reputation, Compliance standard, Information technology system, Commitment to quality & continuous improvement, Lead time, Ability to respond to unexpected demand & meet specifications
Sivakumar, R.; Kannan, Devika; Murugesan, P.	2015	Risk factors in vendor selection mining industry: Demand fulfillment, Environmental training, OHS policy, Environmental activity control
Aghai, Shima; Mollaverdi, Naser; Sabbagh, Mohammad Saeed	2014	Late items, Rejected items, Environment conditions, Vendor rate
Sheikhalishahi, Mohammad; Torabi, S. Ali.	2014	Supplier bankruptcy, War and terrorism, Excessive handling, Cost uncertainty, Exchange rate risk, Data information security risks and legal risks, Natural disasters
Viswanadham, Nukala; Samvedi, Avinash	2013	Supply chain, Resources, Institutional, Delivery infrastructure
Mehralian, Gholamhossein; Gatari, Ali Rajabzadeh; Morakabati, Mohadese; Vatanpour, Hossein	2012	Quality, Delivery, Technology, Reputation, Environmental affairs, Flexibility, Information systems, Costs, Environmental risks
Xiao, Zhi; Chen, Weijie; Li, Lingling	2012	Rejection rate of the product, On-time delivery rate, Product qualification ratio, Remedy for quality problem, Response to changes, Technological and R&D support, Ease of communication, Financial status, Customer base, Performance history, Production facility and capacity, Supplier’s delivery ratio, Management level, Technological capability
Yucenur, G. Nilay; Vayvay, Ozalp; Demirel, Nihan Cetin	2011	Order delays, Political stability, Economy, Customer complaints, Geographical structure, Terrorism, Climate conditions, Cultural differences
Wu, Desheng Dash; Zhang, Yidong; Wu, Dexiang; Olson, David L.	2010	Cost, Quality, Logistics, Economic environmental factors, Vendor ratings
Lee, H. I. Amy	2009(a)	Detailed risk criteria concerning Supply constraint, Buyer-supplier constraint, and Supplier's profile
Lee, H. I. Amy	2009(b)	Management, Market, Cash Flow
Chan, T. S. Felix; Kumar, Niraj; Tiwari, K. Manoj; Lau, C. Hoong; Choy, K. Lun	2008	Geographical location, Political stability and foreign policies, Exchange rates and economic position, Terrorism and crime rate
Chan, Felix T. S.; Kumar, Niraj	2007	Geographical location, Political stability, Economy, Terrorism

The articles cover risk factors which are used for supplier selection by decision makers. As it can be seen from the risk definitions, most of the articles are influenced by each other. On the other hand, in many aspects, they have exclusive focusing points related to the topics and applied areas. In the articles, even the definitions of the same named risk factors are made independently from each other, the used methods are chosen from more limited area and applied more similarly. Some methods which are used in these articles are analytic hierarchic process (AHP), Fuzzy AHP, TOPSIS, Analytic Network Process (ANP) methodology, DEMATEL, DEMATEL-ANP approach, and VIKOR.

3. RISK CRITERIA USED IN DISTRIBUTOR SELECTION

The risk criteria which are used in the calculation should be defined properly. For this reason, decision makers defined the risk criteria. While they are arguing about the factors, the risk criteria which were used in previous research studies are taken into consideration.

The decision makers consist of the people who had an experience in automation sector. Moreover, they have the knowledge about dealing with the customer and the distributor. Having an experience in this sector facilitates managing distributors. Since they can understand the demands of the distributors better, it helps them to have stronger relationships. On the other hand, they are also able to guess how to guide distributors and which distributors can be good business partners.

The used risk criteria are defined by the committee of five decision-makers who have the knowledge in this field. Some risk factors which belong to the supplier selection problems are transformed and rearranged to the distributor selection problem. The ones who evaluate the problem consist of the sales engineers, business development and technical support engineers, and the general manager. Each decision maker contributes to the problem according to his/her proficiency. It is also beneficial in terms of gathering different perspectives of people who are expert in their own fields.

One of the sales engineers has been working for sixteen years in Bursa where it is accepted as the heart of automotive industry in Turkey. In the company, he is especially responsible for automotive industry and the distributors which operate in that region. The other sales engineer has an extensive experience in distributor and subsidiary management. His ten years of experience in this company plays an important role in determining what should be considered in the selection from both the distributors and company's perspectives. One

of the business development and technical support engineers especially gives technical support to the customers who encounter with a problem while establishing a connection between the product and the system. In addition, the sales team is supported by him in terms of equivalent product selection. The other business development and technical support engineer is always getting in touch with R&D departments of the companies. Presenting optimum products and solutions to their projects plays a vital role in terms of sales. Their evaluations for the distributors bring different points of view by considering the importance of technical solution. Finally, the general manager is responsible for managing sales activities of his team. Furthermore, he has an experience in automation sector more than thirty years. In the selection process, his opinion about distributors is valuable in terms of assessing distributors' attitudes and working principles.

As a consensus of the five decision makers, the names of the criteria have been defined. Furthermore, some articles have been added next to the Name of the Criteria column to show articles which help to assign risk criteria of the research study. The risk criteria can be seen in the Table 3.1.

Table 3.1: Risk Criteria & Risk Criteria in Literature

Criteria Number	**Name of the Criteria**	**Articles**
Criteria 1	Financial Power	(Dickson, 1966), (Yoon et al., 2018), (Paul, 2015), (Xiao et al., 2012), (Chan et al., 2008), (Chan and Kumar, 2007), (Wu et al., 2010), (Sheikhalishahi and Torabi, 2014), (Deshmukh and Chaudhari, 2011), (Urbaniak, 2019)
Criteria 2	Transparency / Cooperation	(Alikhani et al., 2019), (Yoon et al., 2018), (Song et al., 2017), (Nekooie et al., 2015), (Sheikhalishahi and Torabi, 2014), (Xiao et al., 2012)
Criteria 3	Technological Capability	(Lee, 2009), (Yoon et al., 2018), (Song et al., 2017), (Paul, 2015), (Mehralian et al., 2012), (Xiao et al., 2012), (Chan et al., 2008), (Chan and Kumar, 2007), (Deshmukh and Chaudhari, 2011), (Urbaniak, 2019)
Criteria 4	Stock Capacity / Late Delivery	(Ghodsypour and O´Brien, 1998), (Lee, 2009), (Verma and Pullman, 1998), (Dickson, 1966), (Benyoucef et al., 2003), (Wu et al., 2010), (Alikhani et al., 2019), (Phumchusri and Tangsiriwattana, 2019), (Yoon et al., 2018), (Moghaddam, 2015), (Nepal and Yadav, 2015), (Paul, 2015), (Viswanadham and Samvedi, 2013), (Mehralian et al., 2012), (Xiao et al., 2012), (Chan et al., 2008), (Chan and Kumar, 2007), (Deshmukh and Chaudhari, 2011), (Urbaniak, 2019)
Criteria 5	Geographical Location	(Dickson, 1966), (Hansen et al., 2019), (Yoon et al., 2018), (Chan et al., 2008), (Chan and Kumar, 2007), (Wu et al., 2010), (Deshmukh and Chaudhari, 2011)
Criteria 6	The Number of Sales Responsible	(Benyoucef et al., 2003), (Cebi and Bayraktar, 2003), (Deshmukh and Chaudhari, 2011), (Sheikhalishahi and Torabi, 2014)
Criteria 7	Marketing Activity	(Dickson, 1966), (Song et al., 2017), (Paul, 2015), (Mehralian et al., 2012), (Chan et al., 2008), (Deshmukh and Chaudhari, 2011)
Criteria 8	Maturity Date	
Criteria 9	Sales of Competitors' Products	

As it is shown in the Table 3.1, while the definition of risk criteria are being made, some similarities have been found with the previous studies. Moreover, the articles which match with the used risk criteria include some terms that contribute this matching operation. The following terms which are used in previous research studies explain why the defined criteria are matched with the previous research studies.

For instance, financial power also includes supplier bankruptcy risk or economic factors that pose high risks to an organization. In the same way, transparency and cooperation contain the terms which are information, information security, and data. Likewise the examples which are given above, stock capacity and late delivery are also related with the factors that are unavailability of raw material, supply chain length, inventory cost (inventory holding cost at plant), adequacy of inventory management, supplier's capacity limit, and supply chain delay. Furthermore, "the number of sales responsible" criterion is also related with the topic which is the after sales services. The last but not least, "marketing activity" parameter can be also thought as the marketing reputation.
The determined risk criteria have been selected from literature and adapted to this research study's content. At first glance, the name of the risk criteria might be understood differently; therefore, the explanations have been provided to show what they refer to.

At this part, it is crucial to indicate that the criteria 8 and the criteria 9 are added by the committee of decision makers while the other criteria's definitions are taken or inspired from other research studies. The importance of these criteria can be explained in detail. "Maturity Date" is significant in terms of the time period of getting the sales activity's worth. In general, people just focus on sales. However, getting the monetary value of sales on pre-agreed day is more important. If the one who receives a service or goods does not make a payment to the seller on maturity date, it leads to many problems in managing the seller's payment cycle. "Sales of Competitors' Products" creates a risk factor in terms of the sales of the company who gives its distributorship. The main issue is that the distributor might choose to sell other companies' products instead of the main company's. The main company can't be 100% sure about whether they are the first choice of the distributor's sales people. If the distributor firstly suggests other companies' products to the customers, this leads to a decrease in the sales of the main company's product range.

After the risk factors from different articles are analyzed, some similarities are also found with the topic of this article. The Table 3.2 shows that the criteria that are taken into consideration for risk minimization calculations. Moreover, it facilitates explaining the necessity of the supplier selection and the contribution of supplier selection criteria to the identification of distributor selection risk factors that forms an important part of this article.

By using risk criteria which are listed with their explanations in Table 3.2, the distributor's attitude can be segmented. The definitions of the factors are given in the Table 3.2.

Table 3.2: Risk Criteria & Definitions

Risk Criteria Number	Name of the Criteria	Definitions
Risk Criteria 1 (RC1)	Financial Power	The criteria can be thought as turnover greatness. If the distributor have a smaller turnover, it means the distributor have more restricted financial power. This situtaion creates a more risky distributor profile. In crisis or in the economic shrinkage, the distributor should have other economical sources of income to provide its life cycle in order not to the inability to payback its debt. It also refers to the product variety of the distributor. The products that the distributor will sell should not create a rivalry with the products that have been owned by the main distributed products. It creates risky situation for sustainability. Furthermore, unsafe financial conditions(such as liquidiy) or instability increases the risk.
Risk Criteria 2 (RC2)	Transparency / Cooperation	It refers to the attitude of the distributor in terms of information sharing. The information includes sales amounts, customer information and customer visit reports. If distributor would not prefer to share data which are taken from market, it leads lacking of information by main company side. Each company would like to access these data as much as possible. On the contrary, it creates a risk. As a result, it can be considered as a risk factor.
Risk Criteria 3 (RC3)	Technological Capability	The criterion includes selecting the right product. We can expand the criterion as an equivalent product selection or right product selection for projects. In this process, if failure occurs, the sales activity will be affected negatively.As a result, it cretaes a risk.
Risk Criteria 4 (RC4)	Stock Capacity / Late Delivery	The bigger and varied stocked products that the distributor have, the more positive effects in terms of supplying the products to the customer fast. On the contrary, the risk of delayed delivery leads to failure, and financial lose. Therefore, the stock should be taken into consideration in order to minimize risk.
Risk Criteria 5 (RC5)	Geographical Location	The location of the distributor should be considered properly before the selection of local and global partner. In today's world, regional instability affects sustainability of business. In order to minimize risk, the selection of headquarter of the distributor plays a vital role for sales. Also, more branch offices increase the responsiveness of the demand.
Risk Criteria 6 (RC6)	The Number of Sales Responsible	If the distributor has more sales responsible people, it increases market popularity, and the relationship with customer. The distributors should regularly visit their customers in order not to lose their awareness or popularity. In other words, if company has more sales people, it reduces sales risk.
Risk Criteria 7 (RC7)	Marketing Activity	The term represents the distributor’s marketing performance. If the distributor gives an advertisement to the magazines, websites or attends a fair, it creates an awareness and increases its popularity. On the contrary, it can damage the company reputation in terms of sales. As a result, it can be considered as a risk factor.
Risk Criteria 8 (RC8)	Maturity Date	The term represents the payment period of the sales activity. Generally, shorter maturity is better and it is preferred by the companies for arranging their payment cycle. If the payment is not made on maturity date, it brings about obstacles in cashflow. Therefore, it can be thought as a risk factor.
Risk Criteria 9 (RC9)	Sales of Competitors’ Products	Selling the other firms’ products creates a risk factor in terms of the sales of the company who gives its distributorship. Distributor might choose to sell other companys’ products instead of main company. This leads to decrease in product range’s sales.

4. MCDM APPROACH FOR DISTRIBUTOR SELECTION IN AUTOMATION SECTOR

This paper considers the problem of evaluating risk criteria for distributor selection with the involvement of a group of experts. The OWA operator is employed for aggregating the ratings of multiple decision makers which are represented by linguistic variables.

There are various types of methods. In order to analyze the given problem, each of the mentioned methods might be more appropriate than others for achieving the goal; however, the ordered weighted averaging (OWA) approach has been chosen in order to solve the multiple criteria decision-making problem. Basically, the OWA method extracts two extreme values, and then, the weights are shared between the other criteria. After the calculations are done, the most significant criteria are indicated according to the threshold that is defined. As a result, the less risky distributor can be chosen among the given distributors

The OWA operators introduced by Yager (1988) provide aggregations which lie between two extreme cases of using *and* and *or* operators to combine the criteria functions in multiple criteria decision making problems.

An OWA operator of dimension *n* is a mapping $F : R^n \to R$ which has an associated weighting vector $w = \left[w_{1,} w_{2,} w_{3,} ....., w_{n,} \right]^T$ such that $\sum_{p=1}^{n} w_p = 1;\ \ w_p \in [0,1]$ and where $F(a_1, a_2, a_3, ..., a_n) = \sum_{p=1}^{n} w_p b_p$ with b_p being the p^{th} largest of the collection $a_1, a_2, a_3, ..., a_n$.

$$F(a_1, a_2, a_3, ..., a_n) = \sum_{p=1}^{n} w_p b_p \tag{4.1}$$

A key aspect of the OWA operator is the ordering of arguments by value; in particular, a_p is not associated with a particular weight w_p but rather a weight w_p is associated with a particular ordered position p of the arguments (Filev & Yager, 1998).

The determination of weights is critical when applying OWA operator in decision making. The weights of the OWA operator from a regular increasing monotone (RIM) quantifier are generated as,

$$w_p = Q\left(\frac{p}{n}\right) - Q\left(\frac{p-1}{n}\right), p = 1, 2, 3, ..., n. \tag{4.2}$$

Because of the non-decreasing structure of Q, the weights couldn't be negative. It takes positive values. The non-decreasing relative quantifier Q is defined as (Herrera et al., 2000).

$$Q(y) = \begin{cases} 0, & \text{y < a,} \\ \dfrac{y-a}{b-a}, & \text{a} \le \text{y} \le \text{b,} \\ 1, & \text{y > b,} \end{cases} \tag{4.3}$$

with the terms, respectively, "most", "at least half", or "as many as possible", with parameters (a, b) given as (0.3, 0.8), (0, 0.5), and (0.5, 1) define some RIM quantifiers. (Dursun et al., 2011).

In multiple criteria decision-making problems, the linguistic terms reflect the opinions of decision-makers because the values of the attributes might not be defined precisely

(Bevilacqua et al., 2006). In this work, opinions of the experts about the importance levels of risk criteria are collected using linguistic variables. The linguistic term set can be shown in mathematical form where VL: (0.000, 0.000, 0.250), L: (0.000, 0.250, 0.500), M: (0.250, 0.500, 0.750), H: (0.500, 0.750, 1.000), VH: (0.750, 1.000, 1.000). Their mathematical graph is shown in Figure 4.1. Furthermore, the linguistic variables which are used are given in Table 4.1.

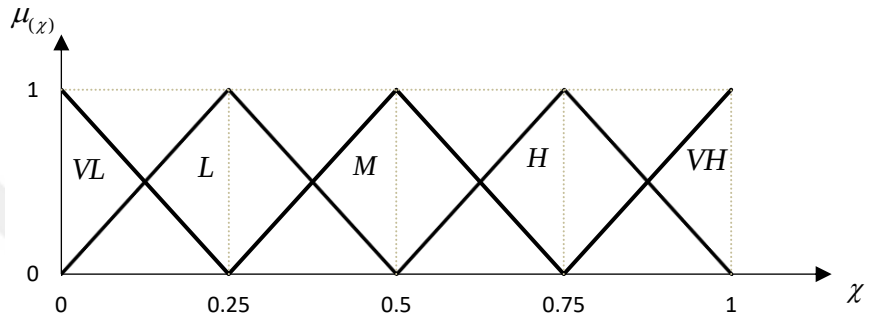

Figure 4.1: Linguistic term set (Dursun et al., 2011)

Table 4.1: Linguistic Variables Expressed by Fuzzy Numbers

	Linguistic Variables / Triangular Fuzzy Number
Very Low (VL)	(0.000, 0.000, 0.250)
Low (L)	(0.000, 0.250, 0.500)
Moderate (M)	(0.250, 0.500, 0.750)
High (H)	(0.500, 0.750, 1.000)
Very High (VH)	(0.750, 1.000, 1.000)

As it is explained at the previous part, the weights of the OWA operator should be generated in order to combine different ideas of decision makers. A term should be chosen among the terms; “most”, “at least half”, or “as many as possible” because of the RIM quantifier’s identification.

This paper uses the RIM quantifier “most” to create the weights of the OWA aggregation operator. The following Figure 4.2 facilitates the explanation of RIM quantifier “most”.

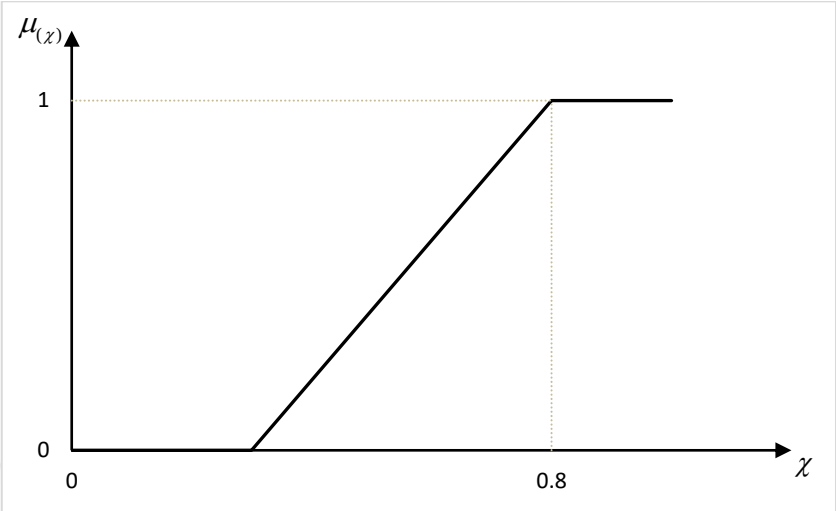

Figure 4.2: Weights obtained from the RIM quantifier “most”

The weights obtained from this linguistic quantifier by using Equation (4.2) and (4.3) should be calculated and the representation of the proposed algorithm is shown below:

$$w_1 = Q(1/5) - Q(0) = 0 - 0 = 0, \quad \mathrm{w}_1 = 0$$

$$w_2 = Q(2/5) - Q(1/5) = Q(2/5) - 0 = \frac{\frac{2}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} - 0 = \frac{\frac{1}{10}}{\frac{5}{10}} = 0.2, \quad \mathrm{w}_2 = 0.2$$

$$w_3 = Q(3/5) - Q(2/5) = \frac{\frac{3}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} - \frac{\frac{2}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} = \frac{\frac{3}{10}}{\frac{5}{10}} - \frac{\frac{1}{10}}{\frac{5}{10}} = 0.4, \quad \mathrm{w}_3 = 0.4$$

$$w_4 = Q(4/5) - Q(3/5) = \frac{\frac{4}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} - \frac{\frac{3}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} = \frac{\frac{5}{10}}{\frac{5}{10}} - \frac{\frac{3}{10}}{\frac{5}{10}} = 0.4, \quad w_4 = 0.4$$

$$w_5 = Q(5/5) - Q(4/5) = 1 - \frac{\frac{4}{5} - \frac{3}{10}}{\frac{8}{10} - \frac{3}{10}} = 1 - 1 = 0, \quad w_5 = 0$$

Using the linguistic quantifier "most" and the Equation (4.2) and (4.3), the OWA weights for five decision-makers are calculated as w = (0, 0.2, 0.4, 0.4, 0). The weights and their results are depicted in Table 4.2.

Table 4.2: Weights obtained from the RIM quantifier "most"

Weights	Values
W_1	0.00
W_2	0.20
W_3	0.40
W_4	0.40
W_5	0.00

The experts graded distributor selection's nine criteria with their significance degrees according to their opinions. As it is indicated previously, the evaluation is conducted by a committee of five decision-makers, two of which are field sales engineers, two of them are business development and technical support engineers, and the fifth person is a general manager in automation industry. The linguistic variables which are ''very low (VL)'', ''low (L)'', ''moderate (M)'', ''high (H)'' and ''very high (VH)'' are used in order to evaluate the importance of the risk criteria by the decision-makers. The evaluations of five experts (Expert 1, Expert 2, Expert 3, Expert 4, and Expert 5) are given in Table 4.3. All the answers of assessments are gathered from each expert separately.

Table 4.3: Importance Degrees of Risk Criteria

Risk Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
RC1	VH	VH	VH	VH	VH
RC2	H	H	M	L	L
RC3	M	M	H	M	L
RC4	H	VH	H	H	M
RC5	M	M	M	L	M
RC6	H	VH	H	M	M
RC7	M	L	M	L	VL
RC8	H	M	M	H	M
RC9	H	H	VH	H	M

After the importance degrees are collected from experts, their evaluations are aggregated using Equation (4.1) to obtain the aggregated fuzzy weights of criteria. The calculations are made according to the algorithm and the calculation steps can be seen below:

The decision-makers' linguistic variable scores are multiplied by the weights in order to find each criteria's aggregated fuzzy weight. The calculations of the each criterion has been made and shown in the following part:

$$RC1_{Aggregated} = \begin{bmatrix} 0.750 & 0.750 & 0.750 & 0.750 & 0.750 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.750 \\ 1.000 \\ 1.000 \end{bmatrix} = (0.750,\ 1.000,\ 1.000)$$

$$RC2_{Aggregated} = \begin{bmatrix} 0.500 & 0.500 & 0.250 & 0.000 & 0.000 \\ 0.750 & 0.750 & 0.500 & 0.250 & 0.250 \\ 1.000 & 1.000 & 0.750 & 0.500 & 0.500 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.200 \\ 0.450 \\ 0.700 \end{bmatrix} = (0.200,\ 0.450,\ 0.700)$$

$$RC3_{Aggregated} = \begin{bmatrix} 0.500 & 0.250 & 0.250 & 0.250 & 0.000 \\ 0.750 & 0.500 & 0.500 & 0.500 & 0.250 \\ 1.000 & 0.750 & 0.750 & 0.750 & 0.500 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.250 \\ 0.500 \\ 0.750 \end{bmatrix} = (0.250,\ 0.500,\ 0.750)$$

$$RC4_{Aggregated} = \begin{bmatrix} 0.750 & 0.500 & 0.500 & 0.500 & 0.250 \\ 1.000 & 0.750 & 0.750 & 0.750 & 0.500 \\ 1.000 & 1.000 & 1.000 & 1.000 & 0.750 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.500 \\ 0.750 \\ 1.000 \end{bmatrix} = (0.500,\ 0.750,\ 1.000)$$

$$RC5_{Aggregated} = \begin{bmatrix} 0.250 & 0.250 & 0.250 & 0.250 & 0.000 \\ 0.500 & 0.500 & 0.500 & 0.500 & 0.250 \\ 0.750 & 0.750 & 0.750 & 0.750 & 0.500 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.250 \\ 0.500 \\ 0.750 \end{bmatrix} = (0.250,\ 0.500,\ 0.750)$$

$$RC6_{Aggregated} = \begin{bmatrix} 0.750 & 0.500 & 0.500 & 0.250 & 0.250 \\ 1.000 & 0.750 & 0.750 & 0.500 & 0.500 \\ 1.000 & 1.000 & 1.000 & 0.750 & 0.750 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.400 \\ 0.650 \\ 0.900 \end{bmatrix} = (0.400,\ 0.650,\ 0.900)$$

$$RC7_{Aggregated} = \begin{bmatrix} 0.250 & 0.250 & 0.000 & 0.000 & 0.000 \\ 0.500 & 0.500 & 0.250 & 0.250 & 0.000 \\ 0.750 & 0.750 & 0.500 & 0.500 & 0.250 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.050 \\ 0.300 \\ 0.550 \end{bmatrix} = (0.050,\ 0.300,\ 0.550)$$

$$RC8_{Aggregated} = \begin{bmatrix} 0.500 & 0.500 & 0.250 & 0.250 & 0.250 \\ 0.750 & 0.750 & 0.500 & 0.500 & 0.500 \\ 1.000 & 1.000 & 0.750 & 0.750 & 0.750 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.300 \\ 0.550 \\ 0.800 \end{bmatrix} = (0.300,\ 0.550,\ 0.800)$$

$$RC9_{Aggregated} = \begin{bmatrix} 0.750 & 0.500 & 0.500 & 0.500 & 0.250 \\ 1.000 & 0.750 & 0.750 & 0.750 & 0.500 \\ 1.000 & 1.000 & 1.000 & 1.000 & 0.750 \end{bmatrix} . \begin{bmatrix} 0.000 \\ 0.200 \\ 0.400 \\ 0.400 \\ 0.000 \end{bmatrix} = \begin{bmatrix} 0.500 \\ 0.750 \\ 1.000 \end{bmatrix} = (0.500,\ 0.750,\ 1.000)$$

When the linguistic quantifier “most”, linguistic variables, and the weights obtained from the RIM quantifier “most” are used, the aggregated weights of distributor selection criteria are found. Table 4.4 shows the fuzzy weights of distributor selection criteria which are obtained by aggregation.

Table 4.4: Aggregated Fuzzy Weights of Risk Criteria

Risk Criteria	Aggregated Fuzzy Weight
RC1	(0.750, 1.000, 1.000)
RC2	(0.200, 0.450, 0.700)
RC3	(0.250, 0.500, 0.750)
RC4	(0.500, 0.750, 1.000)
RC5	(0.250, 0.500, 0.750)
RC6	(0.400, 0.650, 0.900)
RC7	(0.050, 0.300, 0.550)
RC8	(0.300, 0.550, 0.800)
RC9	(0.500, 0.750, 1.000)

After the aggregated fuzzy weights of the distributor selection criteria are found, crisp weights can be computed. For that reason, in order to get crisp weight, the method which is explained in the article of Bevilacqua et al. (2006) can be applied. It is basically based on fuzzy number (a,b,c), and their score which is calculated as (a+2b+c)/4.

The crisp weights of nine criteria are calculated and calculation can be shown as follows:

$$RC1_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.750+2.000+1.000}{4}\right) = 0.938$$

$$RC2_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.200+0.900+0.700}{4}\right) = 0.450$$

$$RC3_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.250+1.000+0.750}{4}\right) = 0.500$$

$$RC4_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.500 + 1.500 + 1.000}{4} \right) = 0.750$$

$$RC5_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.250 + 1.000 + 0.750}{4} \right) = 0.500$$

$$RC6_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.400 + 1.300 + 0.900}{4} \right) = 0.650$$

$$RC7_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.050 + 0.600 + 0.550}{4} \right) = 0.300$$

$$RC8_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.300 + 1.100 + 0.800}{4} \right) = 0.550$$

$$RC9_{Crisp} = \left(\frac{a + 2b + c}{4} \right) = \left(\frac{0.500 + 1.500 + 1.000}{4} \right) = 0.750$$

The following Table 4.5 shows the crisp weights of distributor selection criteria. According to the importance degrees, the crisp weights are sorted from greater to smaller. The result can be seen in the Table 4.6.

Table 4.5: The Crisp Weights of Distributor Selection Criteria

Risk Criteria	Crisp Weight
RC1	0,938
RC2	0,450
RC3	0,500
RC4	0,750
RC5	0,500
RC6	0,650
RC7	0,300
RC8	0,550
RC9	0,750

Table 4.6: The Sorted Crisp Weights of Distributor Selection Criteria

Risk Criteria	Crisp Weight
RC1	0,938
RC4	0,750
RC9	0,750
RC6	0,650
RC8	0,550
RC3	0,500
RC5	0,500
RC2	0,450
RC7	0,300

The crisp weights of distributor selection criteria are calculated in order to show the significance levels of criteria. In fact, the distributor has been chosen among the alternatives using the aggregated fuzzy weights of distributor selection criteria which their values are shown on Table 4.4. Before the calculation part, it is beneficial to indicate the risk degrees of distributors. The mutual evaluations of five experts about distributors are given in Table 4.7. In other words, the following Table 4.7 shows risk degrees of distributors in terms of the given criteria.

Table 4.7: The Risk Degrees of Distributors

Alternatives	RC1	RC2	RC3	RC4	RC5	RC6	RC7	RC8	RC9
Alternative 1	L	L	L	M	L	M	M	L	H
Alternative 2	VL	M	VL	L	VL	L	M	L	VL
Alternative 3	M	M	H	L	M	M	H	M	M
Alternative 4	L	VL	M	M	L	M	M	VL	L

The aggregated fuzzy risk scores are calculated with the multiplication of the linguistic variables of the distributors' risk degrees and aggregated fuzzy weights of distributor selection criteria. In the research study, the operations used on triangular fuzzy numbers are:

(1) Let $\tilde{A}_1 = (c_1, a_1, d_1)$ and $\tilde{A}_2 = (c_2, a_2, d_2)$ be two triangular fuzzy numbers: the addition $\tilde{A}_1 \oplus \tilde{A}_2 = (c_1 + c_2, a_1 + a_2, d_1 + d_2)$ where $c_1, a_1, d_1, c_2, a_2, d_2$ are real numbers.

(2) If $c_1, a_1, d_1, c_2, a_2, d_2$ are all positive real numbers, then $\tilde{A}_1 \otimes \tilde{A}_2 = (c_1.c_2, a_1.a_2, d_1.d_2)$. Assuming that $\tilde{A}_i = (c_i, a_i, d_i)$ and $\tilde{B}_i = (q_i, o_i, r_i)$ where $c_i, a_i, d_i, q_i, o_i, r_i$ are all positive real numbers, where $i = 1, ..., n,$ then:

$$\tilde{A}_1 \otimes \tilde{B}_1 \oplus \tilde{A}_2 \otimes \tilde{B}_2 \oplus ... \oplus \tilde{A}_n \otimes \tilde{B}_n = \left(\sum_{i=1}^{n} c_i q_i, \sum_{i=1}^{n} a_i o_i, \sum_{i=1}^{n} d_i r_i \right). \quad (4.4)$$

After the importance degrees are collected from experts, their evaluations are aggregated using Equation (4.4) to obtain the risk scores of alternatives. The results of the aggregated fuzzy risk scores can be seen in the Table 4.8.

$$ALT1_{Aggregated} = (0.488,\ 2.163,\ 4.838)$$

$$ALT2_{Aggregated} = (0.063,\ 0.863,\ 3.163)$$

$$ALT3_{Aggregated} = (0.750,\ 2.738,\ 5.663)$$

$$ALT4_{Aggregated} = (0.300,\ 1.663,\ 4.150)$$

Table 4.8: The Aggregated Fuzzy Risk Scores of the Distributors

Alternatives	Aggregated Fuzzy Risk Score
ALT1	(0.488, 2.163, 4.838)
ALT2	(0.063, 0.863, 3.163)
ALT3	(0.750, 2.738, 5.663)
ALT4	(0.300, 1.663, 4.150)

After the aggregated fuzzy risk scores of the distributor are found, crisp risk scores can be computed. For that reason, in order to get crisp risk scores, the method which is explained in the article of Bevilacqua et al. (2006) can be applied. It is basically based on fuzzy number (a,b,c), and their score which is calculated as (a+2b+c)/4.

The crisp risk scores of four distributors are calculated and calculation can be shown as follows:

$$ALT1_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.488+4.325+4.838}{4}\right) = 2.413$$

$$ALT2_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.063+1.725+3.163}{4}\right) = 1.238$$

$$ALT3_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.750+5.475+5.663}{4}\right) = 2.972$$

$$ALT4_{Crisp} = \left(\frac{a+2b+c}{4}\right) = \left(\frac{0.300+3.325+4.150}{4}\right) = 1.944$$

The following Table 4.9 shows the crisp risk scores of the distributors.

Table 4.9: The Crisp Risk Scores of the Distributors

Alternatives	Crisp Risk Score
ALT2	1.238
ALT4	1.944
ALT1	2.413
ALT3	2.972

In contrast to the crisp weights, the distributor which has a minimum risk score should be chosen among the alternatives. At first glance, Alternative 2 seems the best option according to the calculations; however, the constraint should be taken into consideration. At this point, it is crucial to explain the constraint which is defined by experts. The restriction is the minimum margin rate which is acquired from the regular forwarded sales. In other word, it means that margin which will be added to products by distributors. The margin requests of the distributors are shown on Table 4.10.

Table 4.10: Margin Requests of the Distributors

Alternatives	Margin Rate
ALT1	%20
ALT2	%18
ALT3	%12
ALT4	%14

According to the experts' consensus, the margin rate should be smaller than %15. After the constraint is applied, Alternative 2 is eliminated from the list. Finally, it is concluded that the Alternative 4 is the most appropriate distributor among the others.

5. CONCLUSION

It was concluded in the present study that distributor selection and the evaluation of its risk factors had a positive effect on automation sector. Moreover, the distributor selection is also crucial for other sectors' distributor selections. The criteria which are used can support other research studies. Companies can apply these criteria in order to minimize their risk in terms of bankruptcy, sustainability, maturity of payments, etc.

Choosing the most suitable distributor from a wide range of alternatives is a commonly faced problem by the multinational firms. Risk criteria are needed to be evaluated in distributor selection processes in addition to benefit criteria. Globalization makes the firms evaluate all possible risks and to take necessary precautions on time. The rapid changes in economy can also affect the companies' economical structures in many aspects. For that reason, companies should minimize the risk of loss of incomes by choosing the most appropriate partners and distributors.

This study presents a fuzzy approach to evaluate risk factors that should be considered in the distributor selection problem in automation industry. For that reason, related to the risk factors designation, the risk criteria of the supplier selection give an idea to make this research study more comprehensible. Furthermore, in order to solve MCDM problem, the OWA operator is used for aggregating the opinions of decision makers about the importance degrees of risk criteria. This technique is applied on nine criteria which are described.

In this research study, there is a goal which aims the risk minimization, and, in addition to the risk minimization, the constraint is applied to find the most appropriate distributor among the alternatives. The first step of this research study begins with the definitions of criteria. These criteria are described and reinterpreted according to the needs of this topic.

After these definitions are made, the OWA technique is used to specify aggregated fuzzy weights of these criteria. At this point, the significance levels of the each criteria is also calculated according to the inputs of the experts. Therefore, as a result of experts' assessments, the crisp weights of the risk factors are found and sorted respectively. It shows which criteria is more important and which is less important. Through this information, it is aimed to give an idea about criteria that should not be ignored. This calculation can be adapted to other studies in determining the most important or less important criteria among the criteria to be used. After the crisp weights are found, the calculation is continued with the aggregated fuzzy risk scores of the distributors. During the calculation of the fuzzy risk scores, the fuzzy weights of the criteria are used instead of the crisp weights. Then, the crisp risk scores of the distributors are calculated. As a result of this calculation, the Alternative-2 has the minimum risk score among the alternatives. The Alternative-4 has the second minimum risk score.

The constraint represents the margin requests of the distributors. In other words, it refers to the margin which will be added to products by distributors. When the threshold value which is defined by the experts of main company is compared with the request of distributors, Alternative-2 is eliminated from the selection. After the constraint is evaluated properly, it can be concluded that the Alternative-4 is the most appropriate distributor among the other alternatives.

In brief, the present study contributed to the existing literature by investigating the impact of distributor selection and risk factors on automation sector's development. Future research will focus on applying fuzzy group decision making approaches to distributor selection problems by using the obtained ranking of risk criteria. In addition, it can be evaluated whether the selected distributor is compatible with the actual received theoretical data or not. The assessments can be reviewed and new criteria can be added to current system.

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BIOGRAPHICAL SKETCH

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