A FUZZY MULTIPLE CRITERIA DECISION MAKING APPROACH FOR 3PL PROVIDER SELECTION

(Üçüncü Parti Lojistik Hizmet Sağlayıcı Seçimi için bir Bulanık Çok Ölçütlü Karar Verme Yaklaşımı**)**

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Ayşegül TOKSOY

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LIST OF SYMBOLS

MCDM:	:	Multi Criteria Decision Making
DEMATEL	:	Decision Making Trial and Evaluation Laboratory
3PL	:	Third Party Logistics
4PL	:	Fourth Party Logistics
FCM	:	Fuzzy Cognitive Map
FLR	:	Fuzzy Linear Regression
SCRM	:	Supply Chain Risk Management
SCM	:	Supply Chain Management
SS	:	Supplier Selection
TOPSIS	:	Technique for Order Preference by Similarity to Ideal Solution

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ABSTRACT

Nowadays, supply chain management becomes more important day by day as a result of rapid competition and need for cost reduction in supply chain operations that include logistics activities. Supply chain departments of firms have become major elements instead of support elements in the global economy. This situation also leads to more risk-oriented supply chain operations and Supply Chain Risk Management notion is aroused from focusing not only benefits of the suppliers but also risks and uncertainties in the long term.

Supplier selection is one of the most crucial part of supply chain operations in the consequence of increase in outsourcing of supply chain activities. Supplier selection problem is examined as a multi-criteria decision-making problem and many researches about the MCDM methods in supplier selection have conducted since 1960s. These researches are getting more complex day by day with the emerging trends in supply chain.

Third-party logistics (3PL) provider selection problems are classified as supplier selection and outsourcing problems in the literature. The firms outsource their logistics operations that include transportation, inventory management, warehousing, order processing, value-added services and information systems. Firms can prefer to outsource their all logistics operations to one or several 3PL providers or they can outsource some of these operations. Thanks to logistics outsourcing, the firms can have cost reduction and focus on their core businesses. In 3PL selection problems, different multi criteria decision making methods are used so that can be extended by fuzziness depends on uncertainties and the situations in which human influential is essential.

The aim of this study is arranging in order the criteria that are used in 3PL provider selection problems via DEMATEL Method and enhancing a model that assesses the risk of alternatives via applying Fuzzy TOPSIS Method with the help of the criteria that specifies risk. The relationship between the assessment of alternatives according to criteria that is made by experts and risk factors that alternatives have is fuzzy. Fuzzy TOPSIS Method enables to choose the most appropriate 3PL firm in the long run.

In order to demonstrate the effectiveness of proposed methodology, the criteria that are used in the supplier selection problems are risk oriented and criteria are evaluated by the experts in logistics area. These criteria are sorted via DEMATEL Method and after the criteria related risk are determined. A model that specifies the risk values of 3PL service providers is enhanced by applying Fuzzy Regression Analysis. Risk values of the alternatives are calculated by using old data via the equation that is obtained after Fuzzy Regression Analysis. Finally, the alternatives that are the options for future are evaluated via Fuzzy TOPSIS Method and it enables to choose the most appropriate one in the long time.

In the literature, the researches in risk concept of 3PL selection problems is very limited. However, logistics outsourcing should be more risk oriented for more sustainable relationships between the 3PL companies and firms in the long run. This thesis aims to introduce a new approach for risk evaluation in logistics outsourcing.

ÖZET

Günümüzde, lojistik aktivitelerini de kapsayan tedarik zinciri operasyonları hızla artan rekabet ve maliyet azaltmaya duyulan ihtiyaç sonucunda her geçen gün daha da çok önem kazanmaktadır. Firmaların tedarik zinciri departmanları destek birimi olmaktan çıkıp temel birimler olmaya başlamıştır. Bu durum da firmaları daha çok risk odaklı tedarik zinciri yönetim anlayışına yöneltmektedir. Tedarik Zinciri Risk Yönetimi kavramı firmaların tedarikçilerinin, sadece kendilerine sağlayacağı yararlara değil aynı zamanda riskleri ve belirsizliklerine de odaklanmaları gerektiği gerçeği sonucunda ortaya çıkmıştır.

Tedarikçi seçimi, tedarik zinciri yönetiminin en önemli alt başlıklarından biridir ve dış kaynak kullanımının artması sonucunda daha da önemli bir hale gelmektedir. Tedarikçi seçimi problemleri çok ölçütlü karar verme problemleri olarak sınıflandırılır ve bu konuda 1960 yılından beri pek çok akademik çalışma yapılmaktadır. Akademik alandaki çalışmalar tedarik zincirindeki gelişmelere göre gün geçtikçe daha da gelişmiş hale gelmektedir.

Üçüncü parti lojistik sağlayıcı problemleri de literatürde tedarikçi veya dış kaynak kullanımı problemi olarak sınıflandırılır. Firmalar ulaşım, depolama, stok yönetimi, sipariş süreçleri, bilgi sistemleri ve değer katma hizmetlerini içeren lojistik operasyonları için dış kaynaklar kullanabilirler. Bu aktivitelerden bir kaçı için veya hepsi için tek veya farklı üçüncü parti lojistik sağlayıcıları ile çalışmayı tercih edebilirler. Lojistikte dış kullanım sayesinde, firmalar maliyetlerini azaltabilir ve aynı zamanda kendi ana iş alanlarına odaklanabilirler. Üçüncü parti lojistik sağlayıcı seçimi problemlerinde belirsizliklerin ve insan etkisinin önemli olduğu bulanıklık da içeren çok ölçütlü karar verme yöntemlerinin kullanımı önemli ölçüde yaygındır.

Bu çalışmanın amacı üçüncü parti lojistik hizmet sağlayıcı seçimi problemlerinde kullanılan ölçütleri DEMATEL metodu ile sıralamak ve riski belirleyen ölçütler yardımıyla Bulanık Regresyon Analizi kullanılarak alternatiflerin riskini belirleyen bir model geliştirmektir. Uzmanlar tarafından yapılan kriterlere göre alternatiflerin ölçütlere göre değerlendirmesi ve alternatiflerin sahip olduğu risk faktörleri arasındaki ilişki bulanıktır. Bulanık TOPSIS metodu ile uzun vadede en uygun üçüncü parti lojistik firmasının seçiminin sağlanması mümkün kılınmıştır.

Önerilen yaklaşımın verimliliğini kanıtlamak amacıyla, risk odaklı tedarikçi seçimi problemlerinde kullanılan ölçütler incelenmiş ve lojistik alanında uzman kişiler tarafından ölçütler değerlendirilmiştir. DEMATEL metodu ile ölçütler sıralanarak, risk ile ilgili olanlar belirlenmiştir. Bulanık Regresyon Analizi uygulanarak üçüncü parti lojistik hizmet sağlayıcılarının risk değerlerini belirleyen bir model elde edilmiştir. Geçmiş veriler kullanılarak Bulanık Regresyon Analizi sonucu elde edilen risk denklemine göre risk dereceleri hesaplanmıştır. Son olarak, bulanık TOPSIS metodu ile gelecekte birlikte çalışılma ihtimali olan alternatifler değerlendirilerek en uygun olanın seçilmesi sağlanmıştır.

Literatürde, üçüncü parti lojistik hizmet sağlayıcılarının risk faktörlerinin değerlendirmesi için yapılan çalışma sayısı oldukça limitlidir. Ancak, lojistikte dış kaynak kullanımı uzun sürede daha sürdürülebilir ilişkiler kurabilmek için risk odaklı olmalıdır. Bu çalışmanın amacı lojistikte dış kaynak kullanımında uygulanabilecek yeni bir bulanık yaklaşım sunmaktır.

1.INTRODUCTION

Supply chain management has become a significant element in the global economy as a result of competition among the businesses. Supply chain is seen as the area to minimize the cost. Supplier selection is one of the effortful parts of supply chain operations so supplier selection has become more important to have competitive advantage by the cooperation with suppliers in the sustainable long run (Lee, 2009) . The relationship between supplier and buyer make the operations effectively or vice versa. Both positive and negative effects of supplier relationship directly affect the quality of the performance of the company.

Supplier selection process has strategic importance in all supply chain operations that also include logistics operations. Supplier selection problems are considered as MCDM problems and the researches have been conducted since 1960s (Xiao et. al, 2011). 3PL provider selection problem also attracts notice in supplier selection problems. In order to maintain strategic alliance, true 3PL selection is important for the firms. Therefore supplier selection problems attract the notice of both academicians and professionals.

However, the risk concept in both supplier selection and 3PL selection problems are limited in the literature. In the recent years, Supply Chain Risk Management (SCRM) has become more attracting as a result of high competition among the firms. The complexity of the problems and uncertainties lead to difficult and risky 3PL selection process (Yayla et. al, 2015).

In the global economy, the supply chain operations become major elements in the firms instead of support elements. With the increased competition, it can be said that firms want to establish more sustainable and successful relationships with their suppliers.

However, supply chain operations have exposed to different kinds of risks in nowadays as a result of globalization (Xiao et. a, 2011). Micheli et. al (2008) states that the increasing depence on suppliers makes companies more exposed to supply risks.

Tang (2006) classifies the four paradigms to decrease the supply chain risk effect. First of them is demand management. Coordination with the downstream partners has effects on demand in a good way. Product management is also the other apporach to mitigate the supply chain risk because change in product and process design can effect the supply chain risk. Information management is the third of the basic paradigms. With the colloboration and coordination among the suppliers by sharing information help to mitigate the supply chain risk. The last part of basic approaches is supply management, again colloboration plays curicial role. In order to ensure efficient and effective material supply, it is important to have colloboration with upstream partners.

Although there have been researches in the recent years about supplier selection and SCRM, there are limited studies in the literature have focused on risk concept in 3PL selection. On the other hand, many studies evaluated the benefits of the 3PL providers but the negative aspects of the 3PL providers should be evaluated.

This study aims to propose a Fuzzy Linear Regression (FLR) approach in order to assess the risk of the alternatives in 3PL selection problem. For this purpose a case study is demonstrated to measure the effectiveness of the proposed model. Firstly, the criteria that are used in 3PL selection and evaluate the risk of the logistics providers are evaluated according to researches. The causal relationship and strengths of influence between criteria is determined via DEMATEL method after evaluation of the alternatives by experts. After selecting the criteria that have the most impact on risk, FLR is employed to obtain a model that identifies the risk of 3PL alternative.

FLR is firstly introduced by Tanaka et al. (1982) in order to provide an alternative approach for modeling situations where the relationship is fuzzy. FLR is also employed where the data set cannot satisfy the conditions of statistical regression. As statistical regression is based on the probability theory, fuzzy regression depends on possibility and fuzzy set theory (Şener & Karsak, 2007).

When the risk value is predicted, Fuzzy TOPSIS Method is employed to 3PL selection problem where there is an environment of multiple decision makers under uncertainty. The alternatives are evaluated by the experts that have experience in logistics sector.

The rest of this thesis is organized as follows. Section 2 provides basic concepts of supplier selection and 3PL selection processes in the subsequent sections. Also, the criteria and MCDM methods are used in the literature are evaluated in the subsequent sections of the Section 2. Section 3 provides risk concept in supplier and 3PL selection as result of huge literature review. The proposed methodology of FLR is provided in Section 4. The Section 5 provides an case study to demonstrate to efficiency of proposed method. The case study is based on 3PL selection problem in an international cosmetic company. Conclusions and future research directions are proposed in the section 6.

2.BASIC CONCEPT OF SUPPLIER AND 3PL SELECTION

Supply chain management operations have strategic importance for companies in global economy with the increasing competency. Suppliers are also in a competency to perform better. Since 1960s many researches about supplier selection are conducted while they are considering as a Multi Criteria Decision Making problem so the process becomes more complex (Xiao et. al, 2012).

Both success and failure of supply chain operations mainly depends on appropriate suppliers. Many firms work for establishing strategic partnership with their suppliers and involving them in their development as unlike the past. The relationship in the long term is preferred in nowadays for sustainable strategic alliance (Araz & Özkarahan, 2006).

The characteristics such as organizational culture, manufacturing procedure, technology capability and geographic location distribution refer to supplier differentiation (Chang et. al, 2007).

There are many objectives to select the best supplier in different areas so the criteria change according to demand and expectations according to multi criteria decision making problems . The criterion *quality(C_1), service(C_2), flexibility(C_3), price(C_4), delivery(C_5), lead time(C_6), reaction to demand change(C_7), production capability(C_8), technical capability(C_9) and reliability of delivery(C_{10})* are determined as the criterion that grasp the greatest attention in previous literatures until 2011.(Chang et. al, 2011).

Also, increasing globalization makes the supplier selection more important. It leads to complexity in international supplier selection problems. While the market becomes

more globalized as a result of globalized economy, many firms focus on international sourcing instead of or addition to their domestic sourcing (Min,1994).

2.1. Basic Concept of Third Part Logistics (3PL) Providers

Logistics operations are important part of supply chain management processes. Therefore, the operations has strategic importance and third party logistics providers (3PL) have become chosen more typically by the companies to be competitive in their sector as result of both cost and location constraints. 3PL providers are the companies which provide logistics services depends on a contract with a primary vendor or manufacturer. The 3PL companies provide different logistics functions such as transportation, warehousing, inventory management, order processing, information systems and value added services (Aguezzoul, 2009). Thus, these companies focus on differentiating in their functions in this wide range of operations. For example; some of them give forecasting services under inventory management. Some 3PL companies work on recycling issues. Their focus areas can be competitive and different in the market while giving opportunity to firms to reduce the cost and improve their performance (Aguezzoul, 2009).

The continuous growth of 3PL companies means the increasing competition between the companies and more complex selection process. Also, the number of qualified 3PL providers are increasing. It is not the same as the number of them in 1990s. It is good step to work on efficient utilization of 3PL is to reduce the cost. However, reducing the cost is not only consideration. Quality should be regarded in the all operations while reducing cost. The general idea of logistics is based on managing the total flow of goods strategically so the word of "*strategically*" shows the importance of optimization at logistics operations over the long haul (Tezuka, 2011).

In Order to focus on the specialization of 3PL, there are some circumstances to examine. First of them is know-how of the company, it can be also expressed as the experience of 3PL provider. The more experience also brings the more cost efficient operations. Especially, in the case of the new markets for the company wants to outsource its' logistics operations, know how becomes more important for the company.

The alliance between the 3PL and the company leads to information sharing between them. The both sides learn from the other side so experience and know how is a circumstance for the 3PL. IT services can be given for the specialization of know-how. IT services of 3PL is such as milestone for the logistics operations and the success of IT operations comes with specialized skills and it is distinguishing from the other companies. Second specialization of the 3PL is also searching, it means that 3PL should know how to outsource its operations in advantageous way. 3PL providers should search for both sub-contractor and partners. While taking these circumstances into consideration, it is appropriate to say that 3PL selection needs to considerable attention (Marasco, 2007).

2.2 Literature Review on 3PL Supplier Selection

Third party logistics supplier selection process need really to be focused on because it is a strategic co operation that requires trust before handling the all operations. Good 3PL providers help firms to focus on their core business while helps them to reduce investment in fixed assets. Also, good 3PL providers help to reduce logistics costs because they are specialized in logistics and they work on this area much more than firms so they follow up the latest trends. However, the reverse situation is possible. If a bad 3PL provider is chosen, this not only causes to fail in logistics operations but also causes to bad reputation and fail in customer management that need a long time to establish good relationships again (Xiu & Chen, 2012).

There are several criteria and multi criteria methods are used to evaluate of 3PL providers in the literature and business life. Cost, price, quality, lead-time, technical service and delivery reliability are used main criteria in the vendor selection problems (Wadwha & Ravindran, 2006). In addition to that, based on the analysis of 67 articles published between the years 1994-2013, cost is attracted the attention as the widely used criteria, relationship, service and quality follows the cost criteria according the mostly used lists in 3PL selection problems according to literature review was conducted by Aguezzol (2014). It is possible conclude that cost remains its' position as the dominating criteria in 3PL selection when the years are passing. Relationship and service becomes more important in the recent years as a result of competition among the 3PL providers.

Hwang et. al. (2016) reveal that the most important criterion while 3PL selection process is evaluating is performance, this is followed by cost, service, quality assurance, intangible and information technology. In order o ensure more detailed aspect of 3PL provider selection, the sub criteria are document accuracy, problem solving capability, continuous cost reduction, to value-added services and associated cost control capacity are defined as the top five criteria while IC industry in Taiwan is examined. According to this recent research, it is appropriate to say that more complex criteria is used in 3PL selection. Performance is seen as more important than cost criteria as a different aspect for long term relationship according to Hwang. It can be said that cost oriented selection lead companies to wrong decisions.

In order to select the best 3PL transportation provider, developing sustainable relationship, service quality and continuous improvement are evaluated as main criteria with the sub criteria as follows (Araz & Özkarahan, 2006). Cost and quality criteria branches into new sub criteria in more detailed way such as transportation cost under developing sustainable relationship and a more complex service quality criteria with sub criteria that evaluate on time delivery, response in emergency, delivery reliability and quality of dispatch personnel.

As 3PL selection becomes a more important decision, the more detailed criteria is began to use in multi criteria decision making problems. Göl and Çatay (2007) take into consideration general company considerations, capabilities, quality, client relationship and labor relations as main criteria. They take into consideration 27 criteria in 3PL selection process in real case in automotive sector. Some of the sub-criteria criteria are financial consideration, industry experience, location, creative management, cultural fit and HR policies.

Due to complexity of the 3PL selection problems, it could be said that the more detailed criteria with different MCDM methods give a new inside to make better selection for sustainable relationship with 3PL in the long run. In the selection process the first step is determining the criteria that will be used.

The multi criteria decision making methods mainly aim to help decision makers to provide a recommendation among the finite set of alternatives. The set of alternatives are evaluated from multiple criteria.

The basic MCDM methods used in 3PL selection are Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Interpretive Structural Model (ISM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Multi-criteria optimization and compromise solution (VIKOR), Decision-Making Trial and Evaluation Laboratory (DEMATEL), Elimination and Choice Expressing Reality (ELECTRE), Fuzzy Sets Theory (FST), utility theory and Quality Function Deployment(QFD) as a result of examination of 67 articles mainly focus on 3PL selection between the years 1994-2013 (Aguezzoul,2014).

The Table 2.1 presents a literature review on 3PL selection based on the analysis of 11 papers which are published between 1996-2016 May period. This table represents the criteria and MCDM methods that are used in 3PL selection. This literature review is conducted by searching "*3PL selection*" & "*Multi Criteria Decision Making*" and *"Logistics outsourcing"* & *"Multi Criteria Decision Making*" key words combination. In this literature review work, the researches about to reverse logistics is not included.

In the recent ten years AHP under and TOPSIS under fuzziness methods are mostly preferred. It can be also said that criteria is divided into sub-criteria in mostly for more appropriate and complex process. Quality, service and cost criteria are used in most of the papers. The criteria range becomes more wide as a result of high expectations from 3PL providers.

Table 2.1: MCDM techniques and criteria used by 3PL provider selection papers

Author(Year)	Year	MCDM Technique	Main Criteria
William et. al	2012	QFD & Fuzzy AHP	Flexibility Quality Technology Risk Cost Delivery
Göl & Çatay	2007	AHP	General Company Considerations and Capabilities Quality Client Relationship Cultural Fit Labor Relations
Bottani&Rizzi	1996	Fuzzy TOPSIS	Breadth of Service Business Experience Characterization of Service Compatibility Financial Stability Flexibility of Service Performance Price Physical Equipment and Information Quality Strategic Attitude Trust and Fairness
Zhang et. al	2010	AHP	Logistics Capacity Service Quality Information Service Capacity Development Potential
Prakash & Barua	2016	Fuzzy AHP&Fuzzy TOPSIS	Capacity Financial Ability IT System Service Quality RL Activities Geographical Location Partner Image & Experience
Xiu & Chen	2012	AHP	Operational Capability Service Levels Price Level Development Potential Green Level

Author	Year	MCDM Technique	Main Criteria
Al-Khatib et. al	2015	FDEMATEL&Fuzzy TOPSIS	Warehousing & Inventory Facilities Transportation Facilities Production & Packaging Facilities Facilities Improvement & Maintenance Physical IT Communication Tools IS & Internet Based Facilities Knowledge & Experience Education & Training Skills Collaboration Long-term Relationships Information Sharing Database & Software Image & Reputation Firm Culture
Kahraman et.al	2015	AHP under fuziness	Market Leadership Functionality Quality Price Implementation Speed Interface with Other Systems International Orientation
Büyüközkan et.al	2009	MCDM with Choquet Integral	Service Quality Service Cost Service Flexibility Value-Added Services IT Competency IT Capacity IT Flexibility IT Compability Management Quality Management Flexibility Management Sustainability
Soh	2010	Fuzzy AHP	Finance Service Level Relationship Management Infrastructure
Hwang et. al	2016	AHP	Performance Cost Service Quality Assurance Information Technology

According to Table 2.1, it can be seen that there is a wide range of the 3PL selection criteria in the literature. Quality and price are the mostly used criteria in the articles that are mentioned in the Table 2.1. Because, the quality of operations specifies the quality and professionalism of the companies.

The other criteria that are used in the recent researches can be grouped as below:

- Financial Status criteria
- Technology and IT Capability criteria
- Customer Relationship criteria
- Performance criteria
- Management Skills criteria
- Human Relations criteria

These groups show that, there are many consideration in 3PL selection processes so they are assessed with quality and cost.

3.RISK CONCEPT IN SUPPLIER AND 3PL SELECTION

3.1. Basic Concept of Supply Chain Risk Management

In the recent years, the new concepts in supplier selection are developed as a result of complexity in the decisions for a good alliance. Companies demand long term and trustable relationship with their logistics partners. Supply chain management becomes significant for cost reduction and these operations play crucial role in competency. For playing a good role in the competency, companies usually do not want to take the risk in the most of their strategic supply chain operations that include 3PL selection.

Risk can be defined in different ways and there are some criteria that affect risk in the supplier selection process. While outsourcing becomes more important for companies and the companies want to decrease the costs and also decrease the risks at the same time so it creates a new need for risk evaluation in supplier selection . It is important to define criteria that can evaluate risk and it is changing according to sector and operations. For transportation and warehouse, there can be different factors that create risk.

As a result of this competition, need for long term relationship and at the same time cost reduction, supply chain operations become more risk oriented. The evaluation of the key focus area of supply chain management is developed by expanding responsiveness, leanness and agility in addition to main focus of the three of quality, time and cost. Lastly, risk is added to the supply chain focus can be seen in Fig 3.1 (Norrman & Jansson, 2004)

Micheli et. al (2008) builds a correlation between supply chain management and risk issue as a result of dependence on suppliers. While the rate of dependence on suppliers

increases, the exposition to supply risks also becomes higher and this situation leads to focus on supply chain risk management to mitigate the risks of supply chain.

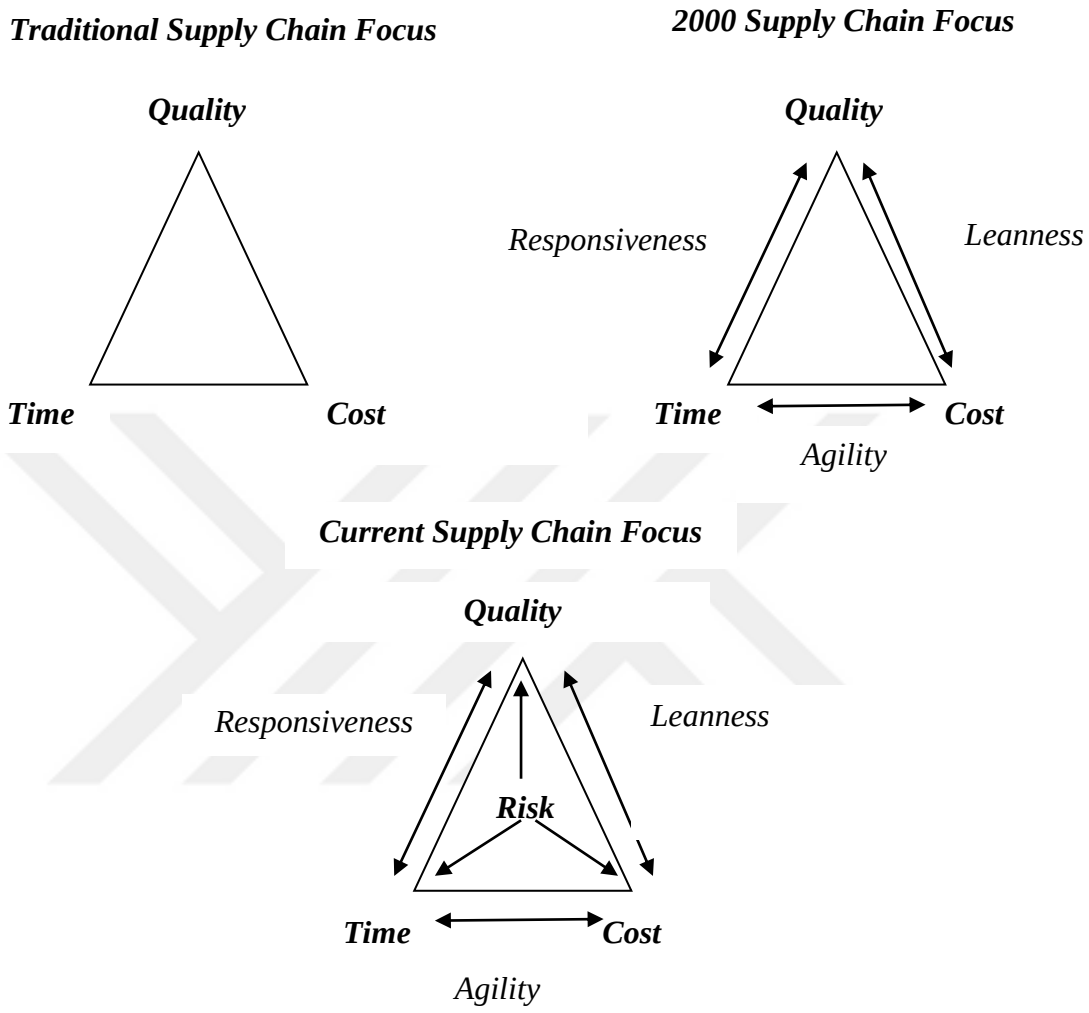

Figure 3.1: The evoluation of supply chain focus (Norrman & Janssson, 2004)

Tang (2006) states that disruptions of supply chain have huge effects on firm's short-term performance. For instance; Ericson lost approximately 400 million Euros as a result of fire in semiconductor plant in 2000. Also, Apple faced a problem of losing many customer orders as a result of supply shortage of DRAM chips after a big earthquake in Taiwan, 1999. These two examples show that it is necessary to decrease the supply chain risks in supplier selection to mitigate the disruptions of supply chain.
Tang (2006) also indicates that SCRM can address two dimensions below:

- ***Supply Chain Risk*** —Operational or disruption risks are mentioned under supply chain risk. Here, operational risk refers to uncertainties such as caused by customer demands or uncertain cost. Disruption risks implies the man made or natural disasters such as Apple and Ericson example as mentioned before.
- ***Mitigation Approach***—Supply management, demand management, product management, or information management. Here, these types or risks are mitigated as a result of improvements, coordination and collobration in supply chain operations.

3.2 Risk Concept in Supplier Selection

At the under of Supply Chain Management, supplier selection also become risk oriented in the last years but there is a still long way on risk issue in supplier selection. Uncertainty in supply and demand, globalization of the market, shorter and shorter product and technology life cycles and increased use of outsourcing makes the risk issue significant in supplier selection (Christopher & Towill, 2001).

Micheli et. al. (2008) focus on the criteria of past performance, willingness to cooperate, technological characteristics and financial statement while considering risk in the supplier selection as SS criterion. Delivery speed, conformity to specifications, technical quality, on time delivery, reputation criteria are examined as the sub group of past performance, flexible payment conditions, risk sharing possibility, customization and after sales service are examined under the willingness to cooperate criteria. And lastly, technological characteristics main criteria has specific technologies and patents processed, innovation capability, co design capability and environmental performance sub criteria. Financial statement of the company is evaluated without sub criteria.

Uncertainties on decision making of supplier selection lead to using risk criteria in supplier selection process. Xiao et. al (2012) have identified the criteria after detailed discussion on every criterion. Supplier selection criteria is identified based on the quality risk of the product, service risk, supplier's profile risk and long term cooperation risk. Under the supplier's profile risk, financial status, customer base, performance history and production facility and capacity are evaluated. In the service risk, response

to changes ,technological and R&D support and ease of communication are identified as sub criteria. Long term relationship criteria focus on management level, supplier's delivery ratio and technological capability sub criteria..

Not only the positive aspects of suppliers both also the negative aspects of the suppliers should be considered simultaneously for the appropriate and sustainable supplier selection. Risks are also evaluated based on financial risk, bad performance history and reputation and inadequate environmental controls and programs under the supplier risk criteria. Benefits, Opportunities, Costs and Risks approach is used in this research (Lee, 2009).

Sustainability is also directly related to risk in supplier selection problems. Having risk management system is used as criteria with the branches of risk analysis, risk evaluation and risk management for sustainable supplier selection. Neo-fuzzy TOPSIS method is preferred to select the best supplier (Chaharsooghi & Ashrafi, 2014).

The risk of supplier can depend on geographical locations and natural events especially these criteria are used in international supplier selection. These type of risks are classified as operational risks. As an old study on risk concept in supplier selection, Min (1994) evaluates the risk under the perceived risk criteria that focuses on political stability, foreign exchange rate, legal claims, labor disputes and local price control while choosing the best supplier in international area. This can be said that for the globalization the risk is adopted to supplier selection process. The another point that this paper shows is risk concept can be changeable according to current period in the country. There can be some topics in the countries' agenda such as political stability.

Chan & Kumar (2007) also considers the risk factors as related to geographical location, political stability, economic conditions and terrorism while evaluating global supplier selection criteria. The fuzzy extended AHP method is used in the scenario of global supplier selection problem and it is aimed to give a capability to employ the firm's strategy to suppliers.

The risk also can be expressed as vulnerability of suppliers due to risks such as natural/man-made disaster which can depend on the history of the supplier or location. Uncertainty is seen as one of the most important problems in supplier selection. Therefore fuzzy and grey theories are used to deal with the uncertainties (Memon et. al, 2015). Memon et.al (2015) preffered to use qualitative criteria as quality, delivery, logistics service, sustainability factor and risk factor in addition the quantitative criteria as cost and lead time. Grey theory is used for this study because it helps to study on uncertainty problems in small sample with poor info.

Mohaghar et. al. (2013) has indicated that risk factors of economic environment of suppliers should be taken into consideration in the supplier selection process because evaluation of suppliers leads to an important strategic decision for the company. Fuzzy- AHP method is used for calculation of criteria weights' and VIKOR method is used to rank the alternatives.

Fang et. al. (2016) state that usually cost factors are examined in supplier selection and this traditional attitude in supplier selection leads a vulnerable supply chain with various risks so they introduced two models as value-at-risk (VaR) and conditional value-at-risk (CVaR) for operational risks and disruption risks. Also a multi optimization model is proposed with total cost, operational and disruption risks. The level of operation risks are mainly based production capacity and flexibility of the selected supplier portfolio. The magnitude of disruption risk is evaluated by the probability of disruption events and the impact to the buyers. TOPSIS-based model, the max–min fuzzy model and the GRA-based models are presented to hand different results.

In order to enhance supply chain risk management in outsourcing under the presence of both random and fuzzy uncertainty, it is aimed to treat stochastic data by utility theory and fuzzy set theory is developed to handle fuzzy data. Reliability/risk criteria is used to evaluate the risk. The other criteria used in the paper is price/cost, acceptance/quality, on time response/quality, R&D in technology/innovation/design, production facilities/assets, flexibility/agility, service, management and organization (Wu et. al, 2013).

Chen & Wu (2013) propose a model failure mode and effects analysis (MFMEA) method for selection of new suppliers according to supply chain risk's perspective. AHP method is also employed to determine the weight of each criterion and sub criterion. It is aimed to develop a model for both effective and low-risk supplier selection process. In this paper, cost, quality, deliverability, technology, productivity and service criteria are represented to have effects on risk of the supplier.

While the papers on the risk concept in supplier selection after 2000, it is seen that many different MCDM methods are integrated to fuziness such as fuzzy extented AHP, neo-fuzzy TOPSIS, FCM methods are employed to supplier selection from supply chain risk perspective. When the risk of the suppliers is aimed to evaluate, fuzziness takes role in these selection processes. Also, the other methods such as BOCR, stochastic approaches to fuzzy sets, Grey theory, and VIKOR are employed to supplier selection problems in the situation of uncertainties. The criteria that are used to mitigate the risk can be about to both operational or disruption risks.

3.3 Risk Concept in 3PL Selection

Even there are many researches on supplier selection and risk concept especially in the previous years as a result of importance of SCRM, the researches on 3PL selection and risk concept is very limited and inadequate to develop to mitigate in risk of 3PL selection .

Lam & Dai (2015) states that SC security is recognized as some of the significant part of managing business risks therefore a model is developed to security design of logistics service provider to customer demands. ANP-QFD is employed in order to develope to supply chain security of LSPs. The criteria is about to security of the LSPs. Cargo safety and security, timely delivery and time and track are used as the criteria that evaluate service factor. Also, documented emergency plans, workforce security culture and training, IT capability and RFID tags, security standards certification, secured package and seal and rigorous screening of suppliers and carriers are used to evaluate the strategic action of the LSPs.

It can be said that mostly 3PL selection problems are still based on traditional selection criteria which do not evaluate risk of the alternatives. However, logistics outsourcing is one of the most important parts in supply chain management.

4.PROPOSED METHODOLOGY

4.1 DEMATEL METHOD

DEMATEL method is originally developed by the Science and Human Affairs Program of the Batelle Memorial Institute of Geneva between the years 1972 and 1976 (Dey et. al, 2012).

DEMATEL method identifies the possible interaction between the criteria in a system by developing diagraphs to show the causal relationships and the strengths of influence among the criteria .

The steps of DEMATEL method is expressed below:

Step 1: Calculation of the Average Matrix

In the first step, H experts are asked to evaluate the suppliers in the study and there is *n* factors to be evaluated. Each decision maker (expert) are asked to determine the degree if he or she believes that factor *i* has an effect on factor *j*.

This pairwise influence are denoted by x^k_{ij} and the influence is expressed in the terms of an integer scale of 0,1,2,3 and 4 (Chang & Ishikii, 2013).

The influence scale can be seen at the Table 4. 1 .For example: if factor *i* has no effect on factor *j*, the score is 0.

Table 4.1: Pair wise Comparison Scale of DEMATEL Method

(adapted fromChang & Ishikii, 2013).

Influence Rate	***Score***
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

The score are handled after the evaluation of the each decision maker and it helps to construct the nxn nonnegative matrix $X^k=[x_{ij}^k]_{nxn}$, where k=1,2,...,H. Here,The diagonal elements are each answer matrix should be equal to 0.

The *n*x*n* average matrix A from all experts is found by computing the average of scores are obtaining from the experts and the average matrix A=[aij] is developed with the formula below (Chang & Ishikii, 2013).

$$a_{ij}=\frac{1}{H}\sum_{k=1}^{H} x_{ij}^{k} \quad (4.1)$$

Step 2: Calculation of the Normalized Initial Direct Influence Matrix

D matrix is indicated by the normalized initial direct influence matrix and it is obtained by normalizing the A matrix with the formula below (Kuo et. al, 2015):

$$D=sxA \quad (4.2)$$

where *s* is calculated with the formula below:

$$s=\min\left[\frac{1}{\max 1\le i\le n \sum_{j=1}^{n}[aij]}, \frac{1}{\max 1\le i\le n \sum_{i=1}^{n}[aij]}\right] \quad (4.3)$$

As the sum of each row j of matrix A shows the direct effect of each criterion on others, $\max_{1\le i\le n}\sum_{j=1}^{n} aij$ represents the maximum direct influence. Also, the sum of each column i of matrix A represent the direct effect on criterion i, $\max_{1\le i\le n}\sum_{j=1}^{n} aij$ represents the most influenced by the other factors. The positive integer s is the maximum of the two extreme sums (Kuo et. al, 2015).

Step 3: Computation of the total relation matrix

T represents the Total Relation Matrix where the identity matrix is represented by I. Here r and c are *nx1* and *1xn* vectors that show the sum of rows and sum of columns of the total relation matrix T, respectively. r_i represents the sum of i^{th} row in the matrix T, then r_i summarizes both direct and indirect effects given by criterion *i* to the other criterion.

Also c_i shows the sum of j^{th} column in matrix T, then c_{ij} shows the both direct and indirect effects by criterion j from the other criteria. When j equals to i, the sum of (r_i+c_i) represents the total effect of given and received by criterion i. Therefore, (r_i+c_i) also means the degree of importance of criterion *i* in the entire system. In contrast, (r_i-c_i) represents the net effect that criterion *i* contributes the system.

It can be said that if the difference (r_i-c_i) is positive, *I* is a net cause, while the criterion *i* is a net receiver or result (Kuo et. al, 2015).

$$T=DX(I-D)^{-1} \quad (4.4)$$

Step 4: Setting up a threshold value to obtain the diagraph

Matrix T gives information on how a criteria affects another, it is necessary for a decision maker to set up a threshold value to seperate out some negligible effects. The effects can be greater than the threshold value can be chosen. The diagraph can be obtained by mapping the dataset of (r_i+c_i,r_i-c_i) (Kuo et. al, 2015).

4.2. Fuzzy Regression

4.2.1 Basic Notions of Fuzzy Logic

Zadeh (1965) firstly introduced the fuzzy logic to deal with the situation that the decision decision-maker is unable or unwilling to express his or her preferences precisely and the evaluations are expressed in linguistic terms.

In order to deal with strategic and significant decision process, problems, uncertainties and doubts make the decision process more complex and difficult. Probability theory usually are used to cope with these uncertainties that is governed by the random law. However probability theory is sometimes not adequate to deal with different types of uncertainties and inaccurate so there is a need for specific tools (Bevilacqua et al, 2006). Fuzzy sets are suitable for enhancing mathematical way to show the vagueness and fuziness in the systems (Ross, 2010).

Tanaka (1982) also states that fuzziness is considered in the systems where the human estimation is influential. In the situation of influential estimation such as determination of water level of a river, there is need for fuzzy sets because the water level of a river cannot be measured appropriately in the exact way as a result of the fluctuation. The fuzzy sets theory is used for modeling the statistical models when the fuzzy sets theory is observed. In the water level of river example, the level is expressed such as a number of around 30 meters. This phrase can be thought as a fuzzy number.

Fuzzy logic is based on fuzzy sets. A fuzzy set defines a degree of belonging by a membership function that is not similar to traditional Boolean logic which defines an

element belongs to a crisp set (1 or 0). For example; all people over 180 cm can be classified as tall and persons under 180 cm are not in a binary set. However, the fuzzy set theory defines degrees for membership in the tall set. A person who is 173 may be assigned a 0.96 degree of membership. This example explains that there is more meaningful way to assign membership in a fuzzy set (Mc. Neil & Freiberger, 1993)
There are many types of fuzzy numbers in the literature, triangular fuzzy numbers are often chosen for linguistic data (Karsak, 2004).

For example; let U={VL,L, M,H,VH} are linguistic data that define VL=very low, L=low, M=medium, H=high and VH=very high. U can be expressed by using triangular fuzzy numbers as follows VL- >(0, 1, 2); L- >(2, 3, 4); M- >(4, 5, 6); H- >(6, 7, 8); VH->(8, 9, 10). For example; medium in linguistic data means from 4 to 6 with the maximum degree of 5. (Bevilacqua et. al, 2006).

4.2.2 Fuzzy Linear Regression Methodology

Regression analysis aims to establish a model relationship between variables and it is commonly used in severe fields of science. Statistical Regression mainly describes the correlation between dependent and independent variables in a non-fuzzy environment. In the case of a phenomenon under consideration does not have stochastic variability but it is also uncertain, the fuzzy functional relationship for the given data can be fuzzy or crisp. It can be said that fuzzy phenomenon can be modeled by a fuzzy functional relationship. The prime motivation is this for the FLR. The fuzzy linear relationship is as follows in the Fig 4.1. It is represented by a band with a center line (Şener & Karsak, 2007).

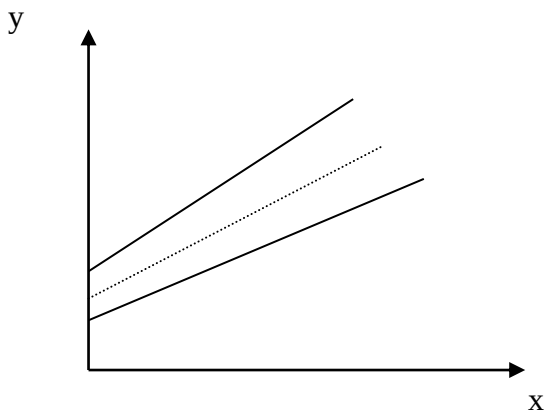

Figure 4.1 : Fuzzy Linear Relationship

FLR was firstly developed by Tanaka, et. al, 1982 to introduce an different approach for making easy to model situations where the relationships are seen as not precisely defined or the data set do not satisfy the requirements of approaches of statistical regression that is based on probability theory. Therefore, it can be concluded that fuzzy regression is mainly dependent on possibility theory and fuzzy set theory (Şener & Karsak, 2007).

A regression model is mainly focus on the two aspects. One of them is finding the most suitable mathematical model and the second one is determining the best fitting model for the data can be seen at Table 4.1. In the table, *y* denotes the output of the observation obtained from the i^{th} sample. Here, *x* represents the a_j^{th} input or a_j^{th} independent variable for the i^{th} sample (Tanaka et. al. , 1982).

Table 4.2: Input-Output Data

Sample Number	Output y	Inputs x
1	y_1	x_{11},.....,x_{1n}
.	.	.
.	.	.
.	.	.
n	y_n	x_{n1},.....,x_{nn}

Tanaka et. al (1982) figured the FLR function as follows.

$$\tilde{y}_i^* = \tilde{A}_1 * x_{i1} + \ldots\ldots\ldots\ldots\ldots + \tilde{A}_n ** x_{in} \quad (4.5)$$

where he parameter A_j is denoted as fuzzy parameter that can be defined by

$$\mu_{\tilde{A}j}(a_j) = L((a_j - m_j)/s_j) \quad (4.6)$$

Here the explanations of the denotations are as follows, m_j and s_j represent the center and spread of fuzzy number $\tilde{A}_j$. and $\mu_{\tilde{A}j}$ denotes the membership of a_j in the fuzzy number $\tilde{A}_{j..}$

The reference function *L(x)* satisfies as follows (Tanaka & Watada, 1988).

- *L(x)=L(-x)*
- *L(0)=1*
- *L(x)* is decreasing on $[0, \infty)$

The H level set of $\tilde{y}_i^*$ is developed as follows (Tanaka & Guo, 1999)

$$H = L\left(\left(y - \sum_{j=0}^{N} mijxij \,/\, \sum_{j=0}^{N} sj\,|xij|\right)\right) \quad (4.7)$$

The H value is usually an ad hoc value and H values in the previous researches lies between 0 from to 0.9. The problem that leads to fuzzy linear regression model is to decide on fuzzy parameter estimates $\tilde{A}_j = \{(\propto_0, \propto_1, \ldots\ldots, \propto_n), (c_0, c_1, \ldots\ldots\ldots, c_{n)}\}$ to determine the membership value of y to its fuzzy estimate $\tilde{y}_i^*$ at least $H \in [0,1)$, that expresses the measure of goodness and it is selected by decision maker. (Kim et.al, 1996).

The main aim of FLR is to minimize the total fuzziness of the values of the dependent variables after prediction. Following linear programming model is employed (Tanaka & Watada, 1988).

$$\text{Min } Z = \sum_{J=0}^{N}(s_j \sum_{i=1}^{M}|x_{ij})|) \quad (4.8)$$

subject to:

$$\sum_{j=0}^{N} m_j\, x_{ij} \; + \; |L^{-1}(H)| \sum_{J=0}^{N} s_j \; |x_{ij}| \geq y_i, \; i = 1,2, \ldots\ldots, M,$$

$$\sum_{j=0}^{N} m_j\, x_{ij} \; - \; |L^{-1}(H)| \sum_{J=0}^{N} s_j \; |x_{ij}| \geq y_i, \; i = 1,2, \ldots\ldots, M,$$

where

$x_{i0} = 1$, $\quad i=1,2, \ldots\ldots, M,$

$s_j \geq 0$ $\quad j= 0,1, \ldots\ldots, N$

where

$L(x)=\max(0,1 - |x|) \rightarrow |L^{-1}(H)| = (1 - H)$.

In order to summarize, it can be said that H value determines the resulting possibility of fuzzy parameters so determination of H value plays crucial role in fuzzy regression that varies between 0 and 0.9. The higher H value results in a wider spread, it also means that predicted intervals owns a higher fuzziness (Kim et. al, 1996).

4.3. Fuzzy TOPSIS Methodology

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of the MCDM methods. This model is developed by Hwang and Yoon in 1981 (Chen , 2000). TOPSIS Method finds the distance that is nearest to Fuzzy Positive Ideal Solution (FPIS) and farthest from the Fuzzy Negative Solution (FNIS). The optimal alternative is chosen according to these distances while comparing them .

It is necessary to evaluate the alternatives via linguistic variables, determining their weights and deciding on the best solution in fuzzy MCDM method.

A fuzzy triangular number is denoted as *"n" (n_1,n_2,n_3)* and $\mu_n(x)$ membership function is expressed as follows (Chen, 2000).

$$\mu_n(x) = \begin{cases} 0, x < n_1 \\ \frac{x-n_1}{n_2-n_1}, \ n_1 \leq x \leq n_2 \\ \frac{x-n_3}{n_2-n_3}, n_3 \leq x \leq n_2 \\ 0, x > n_3 \end{cases} \quad (4.9)$$

The figure denotes the triangular fuzzy number, $\mu_n(x)$ is shown as below:

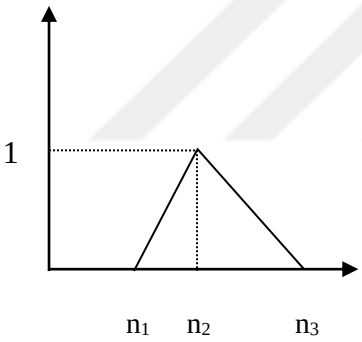

Figure 4.3 : n Triangular Fuzzy Number (adapted from Chen, 2000)

The distance between two fuzzy numbers are calculated via the vertex method, where *m= (m_1,m_2,m_3)* and *n=(n_1,n_2,n_3)* (Chen, 2000).

$$d(m,n) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right.} \quad (4.10)$$

Linguistic and changeable variables are like the variables in the sentences in vernacular language (Zadeh, 1987). For instance; beauty is a linguistic variable and the variables

are like low, medium and very beautiful. Linguistic variables can be expressed via fuzzy numbers.

Fuzzy TOPSIS Method enables to make evaluation considering both quantitative and qualitative criterion so the method has flexible construction (Chen et al, 2006). Fuzzy TOPSIS Method is also suitable for the situation that needs group decision. The weights of the different criterion and criterion values are expressed via linguistic variables. Decision makers use linguistic variables to determine the weight of criteria and alternatives' criterion value. These linguistic variables are seen at Table 4.3 and 4.4 (Chen, 1997).

Table 4.3 : Linguistic Variables for weight of each criterion (Chen,1997)

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)

Table 4.4: Linguistic Variables for Rating

(Chen, 1997)

Very Low	VL	(0,0,0.1)
Low	L	(0,0.1,0.3)
Medium Low	ML	(0.1,0.3,0.5)
Medium	M	(0.3,0.5,0.7)
Medium High	MH	(0.5,0.7,0.9)
High	H	(0.7,0.9,1)
Very High	VH	(0,9,1,1)

The Fuzzy TOPSIS Method follows the steps below:

(i) The aggregate the weights of criterion and ratings of the alternatives given by K decision makers are calculated via the formulas (4.11) and (4.12) respectively where x^k_{ij} represents the rating of the *ith* alternative, A_i (i = 1, ..., n), with respect to criterion j, given by the *kth* decision maker and w^k_j shows the rating of the jth criteria given by the *kth* decision maker (Rodrigues et. al, 2014).

$$x_{ij} = \frac{1}{K} [x^1_{ij} + x^2_{ij} + ... + x^k_{ij}] \quad (4.11)$$

$$w_j = \frac{1}{K} [w^1_j + w^2_j + ... + w^k_j] \quad (4.12)$$

(ii) The Fuzzy Decision Matrix of Alternative ($\tilde{D}$) and criteria ($\tilde{W}$) are expressed via the equations (4.13) and (4.14) (Rodrigues et. al, 2014).

$$D = \begin{array}{c} \\ A_1 \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & & C_n \end{array} \\ \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (4.13)$$

$$W=(w_1, w_2, w_3) \quad (4.14)$$

(iii) Here, x_{ij} and w_{ij} are linguistic variables and these can be defined as $x_{ij}=(a_{ij},b_{ij},c_{ij})$ and $w_j=(w_{j1},w_{j2},w_{j3})$ (Rodrigues et. al, 2014).

The matrix is normalized and expressed as Normalized Fuzzy Decision Matrix and denoted by R.

$$R= [r_{ij}]_{mxn} \quad (4.15)$$

$$r_{ij} = \left(\frac{a_{ij}}{c^*_j}, \frac{b_{ij}}{c^*_j}, \frac{c_{ij}}{c^*_j}\right) \quad \text{where } c^*_j \text{ denotes the } \max_i c_{ij} \text{ and criterion is benefit type} \quad (4.16)$$

Here, the normalized fuzzy matrix keeps the property of the fuzzy numbers should be in the range [0,1].

(iv) Weighted normalized decision matrix, V, is obtained via the formulas 4.13 and 4.14.

$v_{ij}=r_{ij}*w_j$ (4.17)

$V=[v_{ij}]_{mxn}$ (4.18)

(v) Weighted normalized fuzzy decision matrix, v_{ij} components are the normalized triangular fuzzy numbers that are between [0,1]. Fuzzy Positive Ideal Solution (FPIS, A^*) and Fuzzy Negative Ideal Solution (FNIS, A^-) are as follows (Dündar et al., 2007).

$A^*= (v_1^*, v_2^* ,....,v_n^*)$

$A^- = (v_1^-,v_2^-, ...,v_n^-)$

Here, $v_j^*=(1,1,1)$ and $v_j^-=(0,0,0)$.

So, the distance of each criterion from A^* and A^- are as below respectively (Dündar et al., 2007).

$d_i^* = \sum_{j=1}^{n} d(v_{ij,}v^*_j)$, i=1,2,....,m (4.19)

$d_i^- = \sum_{j=1}^{n} d(v_{ij,}v^-_j)$, i=1,2,....,m (4.20)

Here d denotes the distance between two fuzzy numbers.

(vi) The closeness coefficient is calculated as the formula (4.17) below:

$CC_i= d_i^- / (d_i^- + d_i^*)$, where i =1,2,....,m (4.21)

(vii) The alternatives are ranked according to $CC_{i,}$ in the decreasing order. The best alternative is the closest to FPIS and farthest to the FNIS (Rodrigues et. al, 2014).

5.APPLICATION AND DISCUSSION OF 3PL SELECTION PROBLEM

5.1. General Knowledge about the company and problem definition

In order to demonstrate the robustness of the proposed methodologies, it is employed to 3PL selection problem of the international cosmetic company. The company firstly established its' warehouse however, after the growth in Turkey decided to outsource its' both warehouse and transport operations to a 3PL provider to benefit from low cost and good specialized service in the logistics area.

In the warehouse the main operations are handling, receiving, labeling, order picking and providing value added services. From a warehouse, all goods are supplied to different cities in Turkey to many different customers. The value added services are mainly bundling the different products for severe promotion activities. The products also come to warehouse from abroad and these products are labeled in Turkey in the warehouse. The return of the products to the warehouse are also in the responsibility of 3PL provider. The products are taken from the customers and transmitted to main warehouse. Some of the products are recycled here according to health and qualification standards, some of them are destroyed by burning.

The company believes that it is a good way to work with a good 3PL provider to minimize the logistics cost . Supply chain operations are seen as the competitive operations in the market. It means that the improvements in the supply chain operations make the company more successful when they are compared to the other competitors in the market because cosmetic sector is the so fast and open to big competition. Service level is important in all logistics activities. It should be both on time and also qualified. Product quality is in the foreground. No mistake in value added service is accepted.

It is also important to express the company's product range before visualizing the solution for the 3PL selection problem. The company both produces and imports the products from abroad and distributes these products in Turkey to about 60 cities from one warehouse.

The company wants to select best 3PL provider while considering their service level and qualified business culture. The another important point is that, the company wants to minimize the risk in the operations in the long run. The international company wants to take into all the possible criteria which may affect risk in 3PL selection process.

The following steps are considered to select the best 3PL provider:

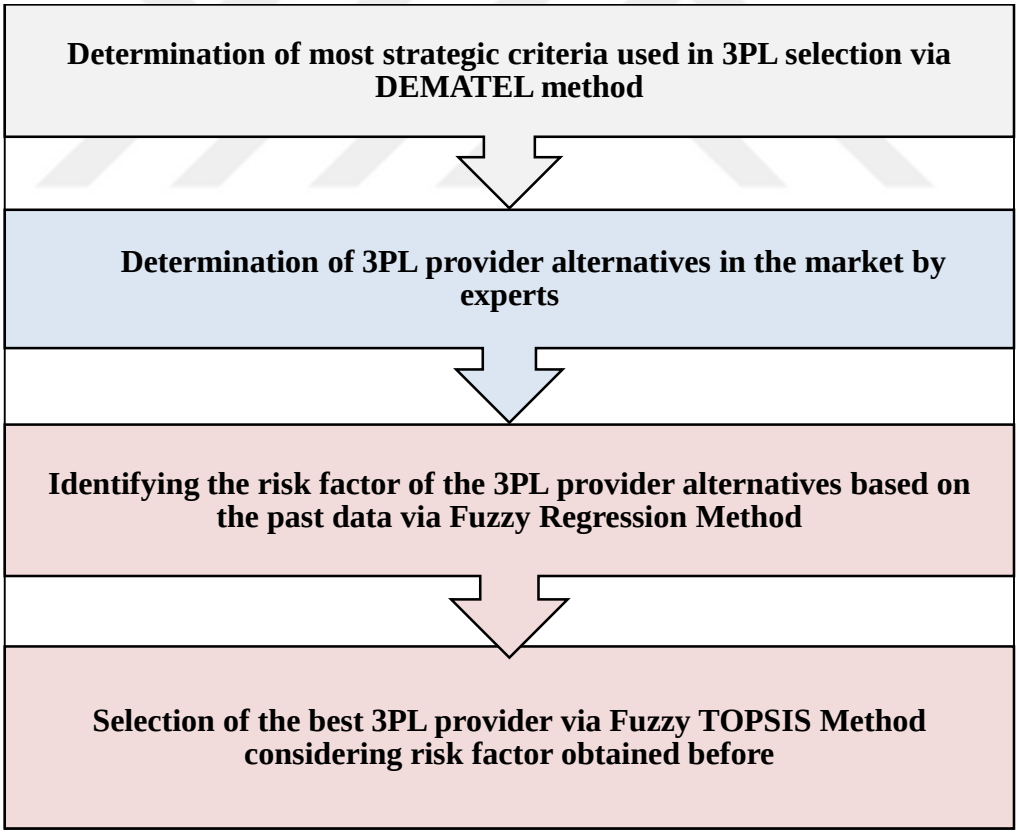

Figure 5.1: 3PL selection process steps

5.2 Determination of the most strategic criteria via DEMATEL method

5.2.1. Criteria Selection according to literature review and experts' opinions

In this part, most appropriate for 3PL selection problem of the company , 10 criterion is selected from literature review on 3PL Selection while concerning the operations of the company and objectives of the firm culture.

The 3PL selection criterion can be seen at the Table 5.1.

Table 5.1: 3PL Selection Criteria

Criteria	**Label**
Financial Position	C_1
Cost	C_2
Conformity to Specifications	C_3
Technological Capability	C_4
Past Performance and Experience	C_5
Social and Environmental Considerations	C_6
Lead Time	C_7
Delivery Quality	C_8
Client Relationship	C_9
Location	C_{10}

The explanations for the criteria are as below:

- ***Financial position* (C_1):** It represents the financial stability of the company by considering its' turnover, growth and forecasts (Bottani & Rizzi, 1996).
- ***Cost* (C_2):** It denotes the cost of the operations that the company offers (Wadwha & Ravindran, 2006 & Aguezzol 2014).
- ***Conformity to Specifications* (C_3):** It refers to if the company has both quality and environmental certificates (William et. al, 2012 & Xiu & Chen, 2012).

- ***Technological Capability*** **(C_4)**: It represents the technological systems that enables more efficient operations (Prakash & Barua, 2016)
- ***Past Performance and Experience (C_5)***: It denotes the relevant industry experience, reputation and years in business of the company (Bottani&Rizzi, 1996).
- ***Social and Environmental Considerations (C_6):*** It evaluates the attitude of the company towards to child labor issue, social responsibility projects, working hours, energy usage control and labor's benefits. (Büyüközkan et.al 2010).
- ***Lead Time (C_7)***: It evaluates the length of lead time and on time delivery of both warehouse and transportation processes (Wadwha & Ravindran, 2006).
- ***Delivery Condition (C_8)*** : It evaluates the damages on the products while handling and transportation processes. (William et. al, 2012)
- ***Client Relationship (C_9)***: It evaluates if the company has works on client relationship issue (Göl&Çatay, 2007).
- ***Location (C_{10})***: : It evaluates the location of the warehouses that 3PL provides (Göl&Çatay,2007).

5.2.2 Selecting the most strategic criteria in 3PL provider selection via DEMATEL Method

In order to determine the most strategic criteria in 3PL selection, three experts from the company were asked individually to determine the influence between these ten chosen criteria.

The DEMATEL Method evaluates supplier performance to find main criteria to improve performance and provide decision-making information in supply chain supplier selection. It helps to reduce number of criteria and focus on most important criteria (Chang et. al, 2011).

The average matrix is obtained by calculating the average of evaluations of three decision makers as can be seen in Table 5.2 and Table 5.3. Formula 4.1 is employed, and A matrix is obtained after three experts' evaluations.

Table 5.2: Average Matrix (I)

Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
C_1	0	3	2,7	4	4
C_2	3	0	2,3	2,3	1
C_3	2,7	3	0	1,3	3
C_4	2,7	3,7	1,3	0	3,3
C_5	4	3	1,3	2	0
C_6	0,7	2,3	3,3	1,3	2
C_7	0,3	3	0,3	1,3	2,7
C_8	0,3	1	1,3	0,7	1
C_9	0	1,7	0	0	0,7
C_{10}	0	3	0	0	0,7

Table 5.3: The Average Matrix (II)

Criteria	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**
C_1	3	1,3	1,0	3	2,3
C_2	3	1,3	0,7	2	2,3
C_3	4	2,3	1,7	2,7	0,3
C_4	1,3	4	4	1,3	0,7
C_5	1,3	2	2,3	2,3	0,3
C_6	0	1,3	1,3	1,7	2,3
C_7	0,7	0	3	1,3	2,3
C_8	0	3,7	0	0	2
C_9	0	0	0	0	0
C_{10}	1,7	3	3	0	0

After the average matrix is normalized according formula 4.2 and relation matrix T is calculated via formula 4.4.

The sum of rows and sum of the columns of the T can be seen at Table 5.5.

The sum (r_i+c_i) denotes the degree of importance for criterion i in the system and the difference (r_i-c_i) represents the net effect i contributes to net system. The sum (r_i+c_i) and normalized importance degrees of criteria obtained by the sums can be seen at Table 5.4 and 5.5.

Table 5.4: Sum of the rows and columns for criterion

	r_i	c_i
C_1	2,8981	1,6964
C_2	2,1983	2,7136
C_3	2,4936	1,5542
C_4	2,6514	1,6052
C_5	2,2779	2,1155
C_6	1,9396	1,7882
C_7	1,6987	2,2008
C_8	1,2059	1,9803
C_9	0,3089	1,7254
C_{10}	1,2901	1,5829

Table 5.5: Sum (r_i+c_i) and importance degree of each criteria

	r_i+c_i	importance degree
C_1	4,59459	0,12115
C_2	4,91191	0,12952
C_3	4,04776	0,10673
C_4	4,25655	0,11224
C_5	4,39342	0,11584
C_6	3,72776	0,09829
C_7	3,89947	0,10282
C_8	3,18623	0,08401
C_9	2,0343	0,05364
C_{10}	2,87308	0,07576

In order to obtain most important and strategic criteria, the importance degree is sorted from largest to smallest. The threshold value is determined as 0.10 and based on this value the four criteria below the threshold value are eliminated:

- Social and Environmental Considerations (C_6)
- Delivery Condition (C_8)
- Client Relationship (C_9)
- Location (C_{10})

While the criteria that are eliminated are examined it is seen that Conformity to Specifications is more strategic than Social and Environmental Considerations and it is also possible to conclude that Conformity to Specifications involves social and environmental considerations in a strict way.

According to importance degree, client relationship is seen as the least important criteria however it can be said that past performance and experience criteria helps to understand the client relationship management of the company. Delivery quality and location are also eliminated according to threshold value, here cost criteria plays a role to decrease

the effect of location so cost is more dominant. For the delivery of quality, conformity to specifications helps the understand the quality procedures of the 3PL.

Six criteria below are determined the most strategic criteria because they have importance degree higher than 0.10:

Table 5.6: Selected Criteria according to threshold value

Criteria	***Abbr.***
Financial position	C_1
Cost	C_2
Conformity to Specifications	C_3
Technological Capability	C_4
Past Performance and Experience	C_5
Lead time	C_7

5.3 Determination of the alternative 3PL providers in the market by experts

In the market, there are many logistics providers. Some of them are local companies and some of them are international companies that operate in Turkey. Their business sizes also change. Big, medium and small 3PL providers are alternative for the company to outsource their logistics operations in the long run.

There is also process to decide on the less number of candidate 3PL company to make the selection process more focused and simple.

The company wants to determine on the four company that meets its' requirements instructionally while considering the previous experiences and global best practices.

The five candidate 3PL providers as denoted by A, B, C and D 3PL companies are specified according to their cost feasibility, international background and company size. Therefore it can be said that all four candidates meet the requirements of cost feasibility

that is the most dominant criteria in supplier selection as both specified by DEMATEL method and experts' opinions.

The selected alternatives provide the operations below:

- warehousing
- transportation
- value added services (labelling)
- reverse logistics activities

5.4 Application of Fuzzy Linear Regression to obtain the risk factor

The criteria that are obtained via DEMATEL method are as follows :

- Financial position
- Cost
- Conformity to specifications
- Technological capability
- Past performance and experience
- Lead time

According to literature review about risk in supply chain with regarding trends in supply chain, the most important 3 criteria below is selected to evaluate the risk of the alternatives:

- Cr_1: Financial Position (Xiao et. al, 2012)
- Cr_2: Past Experience and Performance (Micheli et. al, 2008)
- Cr_3: Technological Capacity (Lam&Dai, 2015)

All criteria are benefit type and decision makers give scalar factors between 0 and 10 for the each 3PL providers that were worked together and the average of 3 decision makers' evaluation as follows in the Table 5.8. The risk of the alternatives are evaluated by also scalar factors between 0 and 10. 10 indicates the most risky alternative.

In the application, the risk is defined as the failure risk of the 3PL as result of the aggressive growth of the international cosmetic company. The risk is related to sustainability of the operations and 3PL's response to changes. The main objective is to establish the relationship in the long run. To obtain an equation that shows the relationship between selected criteria and risk, the last experiences of the company are evaluated. For this purpose, 3 experts in the company hypothetically evaluate five 3PL companies that were before chosen to work together were evaluated according to selected criteria and also their risk factor are determined by scalar factors between 0 and 10. The main purpose of this study is help decision makers to select suppliers regarding risk factor.

The relationship between criteria and risk is vague in the case so it makes fuzzy regression more appealing then classical statistical tools. This imprecise and vague relationship also means influential human estimation therefore it is also leads to fuzzy regression model.

The evaluation of the alternatives can be seen as follows. In the matrix, the average of the evaluation of 3 experts is calculated in both alternative evaluation and risk assessment for the 3PL companies.

Table 5.7: Evaluation of alternatives

	Cr_1	Cr_2	Cr_3	Risk
Company A	3,33	7,66	4,33	6
Company B	4,33	5	2,33	7,66
Company C	9	7,66	5,33	3
Company D	2	5,33	6,66	8
Company E	7,66	4	2,33	5

The risk value is associated with the four criteria Cr_1,Cr_2 and Cr_3 thus the linear programming model for H=0.5 is given as:

$\text{Min } Z=5c_0+26.32c_1+29.65c_2+20.98c_3$

subject to

$\alpha_0+3.33\alpha_1+7.66\alpha_2+4.33\alpha_3+0.500c_0+1.66c_1+3.83c_2+2.16c_3\geq 6$

$\alpha_0+3.33\alpha_1+7.66\alpha_2+4.33\alpha_3-0.500c_0-1.66c_1-3.83c_2-2.16c_3\leq 6$

$\alpha_0+4.33\alpha_1+5\alpha_2+2.33\alpha_3+0.500c_0+2.16c_1+2.5c_2+1.16c_3\geq 7.66$

$\alpha_0+4.33\alpha_1+5\alpha_2+2.33\alpha_3-0.500c_0-2.16c_1-2.5c_2-1.16c\leq 7.66$

$\alpha_0+9.\alpha_1+7.66\alpha_2+5.33\alpha_3+0.500c_0+4.5c_1+3.83c_2+2.66c_3\geq 3$

$\alpha_0+9.\alpha_1+7.66\alpha_2+5.33\alpha_3-0.500c_0-4.5c_1-3.83c_2-2.66c_3\leq 3$

$\alpha_0+2\alpha_1+5.33\alpha_2+6.66\alpha_3+0.500c_0+c_1+2.66c_2+3.33c_3\geq 8$

$\alpha_0+2\alpha_1+5.33\alpha_2+6.66\alpha_3-0.500c_0-c_1-2.66c_2-3.33c_3\leq 8$

$\alpha_0+7.66\alpha_1+4\alpha_2+2.33\alpha_3+0.500c_0+3.83c_1+2c_2+1.16c_3\geq 5$

$\alpha_0+7.66\alpha_1+4\alpha_2+2.33\alpha_3-0.500c_0-3.83c_1-2c_2-1.16c_3\leq 5$

$c_1,c_2,c_3,c_4\geq 0$

The solution for this linear program is :

α_0*=13,152, α_1*= - 0.665, α_2*= - 0,498, α_3 *= - 0.199 and c_1*=0.157.

Fuzzy linear regression is as follows:

$y = 13{,}152 + [-0{,}665, 0.157]*x_1-0{,}498*x_2-0{,}199*x_3$

The fuzzy regression-based optimization model helps to consider all interactions between financial situation, past performance and experience and technology capacity. This equation expresses the relation of the risk of the company with the three criterion financial position, past experience and performance and technological capability. Here, while the scalar factor for the criteria gets bigger, the risk factor is decreased. The y value is negatively correlated with x_1, x_2 and x_3. Technological capacity has less effect on decreasing risk comparing to financial situation and past performance and experience.

5.5 Selection of the best 3PL Provider by using Fuzzy TOPSIS Method

The company wants to select a new 3PL provider to work together in the long run. There are 4 alternatives and four criteria are determined by DEMATEL Method in the previous section 5.2. The 4 criteria will be evaluated by Fuzzy TOPSIS Method. In this supplier selection problem, risk is a criteria and it is obtained via FLR equation.

Criteria that are used in the supplier selection problem:

- Criteria 1: Cost Advantage
- Criteria 2: Lead time of warehouse and transportation operations
- Criteria 3: Conformity to specifications
- Criteria 4: Risk

The four candidate 3PL providers are evaluated through Fuzzy TOPSIS Method as follows:

Step 1: Three decision makers are asked individually to define the importance of the criteria (C_1, C_2, C_3, C_4) via using the linguistic variables can be seen at Table 5.10. Here, the evaluation is based on linguistic variables and the experts have different ideas about the weight of criteria. Fuzzy TOPSIS Method gives opportunity to define the importance of criteria in group decision making process. The four criteria weights evaluation according to DM's are shown at Table 5.10:

Table 5.8: Linguistic Variables for weight of each criterion (Chen,1997)

Very Low	VL	(0,0,0.1)
Low	L	(0,0.1,0.3)
Medium Low	ML	(0.1,0.3,0.5)
Medium	M	(0.3,0.5,0.7)
Medium High	MH	(0.5,0.7,0.9)
High	H	(0.7,0.9,1)
Very High	VH	(0,9,1,1)

Table 5.9: Criteria Importance Weights

	DM_1	DM_2	DM_3	DM_4
C_1	H	VH	VH	VH
C_2	H	H	MH	H
C_3	MH	H	MH	MH
C_4	H	VH	H	VH

Step 2: Decision makers use also linguistic variables individually in the table to calculate the ratings of each of four alternatives (A_1,A_2,A_3,A_4). Linguistic variables for rating are indicated in Table 5.11 and hypothetical assessment of alternatives are shown at Table 5.12.

Table 5.10: Linguistic Variables for Rating (Chen,1997)

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)

,

Table 5.11: 3PL Alternatives Evaluation by Decision Makers

Criteria	Alternatives	Decision Makers			
		DM_1	DM_2	DM_3	DM_4
C_1	A1	MG	F	MG	G
	A2	G	G	MG	G
	A3	MG	MG	VG	G
	A4	F	MG	F	MG
C_2	A1	G	G	MG	G
	A2	G	MG	VG	MG
	A3	G	MG	M G	G
	A4	G	MG	MG	VG
C_3	A1	F	P	G	G
	A2	G	MG	MG	G
	A3	G	G	MG	F
	A4	VG	G	G	G

Step 3: The linguistic variables are transformed to fuzzy triangular numbers to construct a fuzzy decision matrix via Table 5.9 and Table 5.10. First three criterion are evaluated via linguistic variables and risk will be calculated via the formula obtained from FLR.

Table 5.12: Criteria Importance Weight in Fuzzy Triangular Numbers

	DM_1	DM_2	DM_3	DM_4
C_1	(0.7,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
C_2	(0.7,0.9,1)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.7,0.9,1)
C_3	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
C_4	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)

Table 5.13: 3PL Evaluation by Decision Makers in Fuzzy Triangular Numbers

Criteria	Alternatives	Decision Makers			
		DM_1	DM_2	DM_3	DM_4
C_1	A1	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,10)
	A2	(7,9,10)	(7,9,10)	(5,7,9)	(7,9,10)
	A3	(5,7,9)	(5,7,9)	(9,10,10)	(7,9,10)
	A4	(3,5,7)	(5,7,9)	(3,5,7)	(5,7,9)
C_2	A1	(7,9,10)	(7,9,10)	(5,7,9)	(7,9,10)
	A2	(7,9,10)	(5,7,9)	(9,10,10)	(5,7,9)
	A3	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,10)
	A4	(7,9,10)	(5,7,9)	(5,7,9)	(9,10,10)
C_3	A1	(3,5,7)	(0,1,3)	(7,9,10)	(7,9,10)
	A2	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)
	A3	(7,9,10)	(7,9,10)	(5,7,9)	(3,5,7)
	A4	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)

To construct the fuzzy decision matrix, firstly the risk values are obtained by the formula:

$y = 13{,}152 + [-0{,}665, 0.157]*x_1 - 0{,}498*x_2 - 0{,}199*x_3$

Risk is mainly dependent on three criteria as follows:

- Cr_1: Financial Situation
- Cr_2: Past Experience and Performance
- Cr_3: Technological Capacity

The four alternatives are evaluated by the experts and the below matrix is obtained. The ranking scale is between 3 and 10 to assess the alternatives. All of the criteria are benefit type, here 10 means the best one.

Table 5.14: Identification of Risk

	Cr_1	Cr_2	Cr_3
A_1	5.33	6	8
A_2	4	7	5.66
A_3	8	5	6.66
A_4	7	5.66	5

The results for the four alternatives as follows:

y_1= (4.20, 5.04, 5.88)

y_2= (5.25, 5.88, 6.50)

y_3= (2.77 ,4.02, 5.27)

y_4= (3.59 ,4.69, 5.78)

Here it can be seen that Alternative 2 has the biggest risk factor because it has the smaller rating of financial situation and financial situation has big effect on decreasing the risk of the alternative. Also, it can be also seen that Alternative 3 has the smallest risk factor with a good financial situation rating.

The aggregate weights of criteria and rating of alternatives given by the decision makers are obtained via equations 4.11 and 4.12. The Fuzzy Decision Matrix of Alternatives (D) and Criteria Fuzzy weights are expressed via equation (4.13).

Table 5.15: Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4
A_1	(5,7,8.8)	(6.5,8.5,9.75)	(4.25, 6,7.5)	(4.20,5.04,5.88)
A_2	(6.5,8,9.8)	(6.5,8.25,9.5)	(6,8,9.5)	(5.25,5.88,6.50)
A_3	(6.5,8.25,9.5)	(5.5,7.5,9.25)	(5.5,7.5,9)	(2.77,4.02,5.27)
A_4	(4,6,8)	(6.5,8.25,9.5)	(7.5,9.5,10)	(3.59,4.69,5.78)

Table 5.16 : Criteria Fuzzy Weights

	C_1	C_2	C_3	C_4
Weights	(0.85,0.98,1)	(0.65,0.85,0.98)	(0.55,0.75,0.92)	(0.8,0.95,1)

Here the most important criteria are cost and risk. After lead time and conformity to specifications follow them. Cost advantage is usually dominant criteria in supplier and 3PL selection problems, however risk is not taken into consideration at the most of the times. The near weights make the 3PL selection problem more risk oriented while regarding the cost as one of the dominant criteria. It helps to bring a new perspective to selection problem. Also lead time and conformity to specification have nearest weights, it shows that the final four criteria has strategic importance in 3PL selection of the company according to their objectives and also past experiences in the sector.

Step 4: The Normalized Fuzzy Decision Matrix is constructed. Here risk is cost type criteria, the other criteria are benefit type so the equation 4.16 is employed and R matrix is found according to equation 4.15.

Table 5.17: Normalized Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4
A_1	(0.52, 0.71, 0.89)	(0.66, 0.87,1)	(0.42,0.6,0.75)	(0.47,0.55,0.66)
A_2	(0.66,0.81,1)	(0.66, 0.85,0.97)	(0.6,0.8,0.95)	(0,43,0.47,0.53)
A_3	(0.66,0.84,0.97)	(0.56, 0.76, 0.95)	(0.55,0.75,0.90)	(0.52,0.68,1)
A_4	(0.4,0.61,0.81)	(0.66,0.85,0.97)	(0.75,0.95,1)	(0,48,0.59,0.77)

Step 5: Weighted normalized matrix is obtained via equation 4.17 and 4.18.

Table 5.18: Weighted Normalized Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4
A_1	(0.44,0.70,0.89)	(0.43,0.74,0.98)	(0.23,0.45,0.69)	(0.38,0.52,0.66)
A_2	(0.56,0.79,1)	(0.43,0.72,0.96)	(0.33,0.6,0.87)	(0.35,0.45,0.53)
A_3	(0.56,0.82,0.97)	(0.36,0.65,0.93)	(0.30,0.56,0.82)	(0.42,0.65,1)
A_4	(0.34,0.60,0.81)	(0.43,0.72,0.96)	(0.41,0.71,0.92)	(0.38,0.56,0.77)

Step 6: Determination of FPIS (Fuzzy Positive Ideal Solution) and FNIS (Fuzzy Negative Ideal Solution).

$A^*=[(1,1,1),(1,1,1),(1,1,1),(1,1,1)]$

$A^- =[(0,0,0),(0,0,0),(0,0,0),(0,0,0)]$

Step 7: The distance to FPIS and FNIS of each alternative is calculated via the formula 4.19 and 4.20 .In the Table 6.8, the results are shown.

Table 5.19: The Distance Measurement

	di*	di-
A1	1,808	2,448
A2	1,671	2,610
A3	1,547	2,752
A4	1,614	2,612

Step 8: Calculation of closeness coefficent.

$CC_1 = \frac{2.448}{2.448+1.808} = 0{,}575$

$CC_2 = \frac{2{,}610}{2.610+1.671} = 0{,}609$

$CC_3 = \frac{2.752}{2.752+1.547} = 0{,}640$

$CC_4 = \frac{2.612}{2.612+1.614} = 0{,}618$

Here, the ranking of the alternatives in decreasing order as below:

$A_3 > A_4 > A_2 > A_1$

The alternative 3 is selected according to Fuzzy TOPSIS Method. It is the also least risky alternative.

6. CONCLUSION

This thesis introduces FLR methodology to evaluate the risks of 3PL alternatives. In order to enhance SCRM in logistics operations, the proposed methods is an appropriate way to evaluate the risk of the alternative in the long run. The firms want to establish sustainable relationships with their logistic providers. Therefore, it is a necessity to calculate the risk of alternatives.

Application of Fuzzy TOPSIS Method helps decision makers to decide on the best alternative according the criterion that depend both their opinions and literature review. In 3PL selection, there are many competitors and they can give similar services so the appropriate selection plays crucial role especially in the long run. Fuzzy TOPSIS Method is also suitable for group decision making processes so it is useful in management and big organizations. The risk is taken into consideration as a criteria in the application.

For further research, globalization effect could be added to criterion and another case could be examined in global environment. Many firms develop their factories at Far East and it enables to examine their 3PL selection process. Cost and risk also play crucial role in global 3PL selection.

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BIOGRAPHICAL SKETCH

Ayşegül Toksoy is an industrial engineer. After graduating from one of the reputable universities in Turkey, Bilkent University, she decided to start Masters Degree in Logistics and Financial Management in Galatasaray University to become more specialized in supply chain area.

During her academic life, she had an internships in automotive, telecommunication and cosmetic sectors. She had chance to observe manufacturing and spare parts of different automotive companies in her internships. She also worked as a long term logistics intern at an international cosmetic company. This internship helped her to focus on logistics area while observing 3PL processes directly.

She currently works as a Sales and Demand Planner at Şişecam A.Ş and learns key notions of the sales and demand planning processes of the company that both manufactures and exports to many countries all over the world. She is the author of a research paper entitled ‘‘A DEMATEL Approach for 3PL Selection" which was accepted to be presented in the 6th International Conference on Communication and Management in Technological Innovation and Academic Globalization (COMATIA'16) at Ischia, Italy.