MULTIPLE CRITERIA DECISION MAKING APPROACHES FOR CONTAINER SHIPPING LINE SELECTION IN EXPORT SHIPMENTS FROM TURKEY (TÜRKİYE'DEN İHRACAT SEVKİYATLARINDA DENİZYOLU KONTEYNER TAŞIMA HATTI SEÇİMİ İÇİN ÇOK ÖLÇÜTLÜ KARAR VERME YAKLAŞIMLARI)

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LIST OF SYMBOLS

TEU	**:** Twenty-foot Equivalent Unit
MCDM	**:** Multi Criteria Decision Making
QFD	**:** Quality Function Deployment
CNs	: Customer Needs
DRs	**:** Design Requirements
PCs	**:** Part Characteristics
CRs	**:** Customer Requirements
ECs	**:** Engineering Characteristics
AHP	**:** Analytic Hierarchy Process
CAs	**:** Customer Attributes
HOQ	**:** House of Quality
KFY	: Kalite Fonksiyonu Yayılımı
ETA	: Expected Time of Arrival
ETD	: Expected Time of Delivery

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ABSTRACT

With the growth of maritime industry in recent years, managing maritime supply chain activities has become an important for international enterprises to gain a competitive advantage. The performance of the ocean carriers affect the overall performance of the supply chain management system so selecting shipping lines has gained increasing importance all around the world. Turkey also is one of the most significant actors in the sector due to its geographical situation. As it is in the center of Europe, Turkish Republics and Middle East, its economy also relies on maritime shipping.

In Turkey, both shipping companies and authorities try to optimize maritime shipping area with investments because the greater of export and import shipments realize by maritime transportation. Maritime shipping provides lots of advantages in transit time and economic mean to a country about gaining an important role in the world.

The concept of logistics is delivering products and materials in a safest way with reasonable prices in needed time to the delivery points. As it is important to gain competitive advantage against competitors, all companies should give importance to select appropriate shipping lines either directly or by the way of freight forwarders.

This study consists 4 parts, first of all, maritime logistics in Turkey sector is analysed numerically, and then definitions of main concept are given. Next, general literature review is given, after that; the critical factors determined by experts and among direct shippers are defined. Finally, they are ordered by using one of the multi-criteria decision making methods. In this study, Fuzzy QFD (Quality Function Deployment) is chosen as MCDM method. In this QFD application, linguistic variables quantified with fuzzy numbers are used, then total scores for each alternative is calculated, and according to these scores, finally the most suitable shipping line is selected by a fuzzy programming model. Conclusion and future study suggestions are given.

ÖZET

Dünyada ticaret hacmi arttıkça, dünyanın bir ucunda üretilen bir ürünün diğer tarafında tüketilmesi mümkündür. Lojistik talep edilen ürün, hizmet ve bilgiyi üretim noktasından son tüketiciye zamanında ve tam olarak göndererek müşterileri tatmin etmenin bir yoludur.

Denizyolu taşımacılığı demir yolu, kara yoluna göre ve havayoluna göre de daha ucuz olduğundan en çok tercih edilen ulaşım aracıdır. Dünya ticaret hacminde ve Türkiye ithalat – ihracat hacminin büyük çoğunluğu deniz yoluyla yapılmaktadır. Denizyolu taşımacılığı hatları, hammaddeyi üretim noktalarına ve son ürünü müşteriye taşımada büyük bir bağlantı noktasıdır. Denizyolu hatlarında esas olan müşteri ihtiyaçlarının karşılanması için yüksek kalitede hizmet sunmak ve memnuniyeti arttırmaktır.

Bu çalışmanın amacı, müşterilerin ve taşıyıcı firmalarının deniz yolu taşıma hattı seçme kıstaslarını ağırlıklandırmak, önem derecelerine göre sıralamak ve en sonunda ise en iyi deniz yolu hattını seçmektir. Bu kriterler lojistik uzmanları ve daha önce yapılmış akademik çalışmalar baz alınarak belirlenecektir. Çalışmanın temel ülkesi Türkiye olacaktır ve kriterler Türkiye'den yapılan ihracat sevkiyatları için belirlenmiştir.

Kalite Fonksiyon Yayılımı, öncelikle müşteri ihtiyaçlarını belirleyerek, daha sonra bu ihtiyaçları araştırma ve ürün geliştirme, mühendislik, pazarlama, satış ve dağıtıma kadar her süreçte değerlendirip entegre ederek işletme gereksinimlerine dönüştüren bir mühendislik yöntemidir. Tez kapsamında uygulama yöntemi olarak belirlenen bu yöntem, müşteri memnuniyetini güvence altına alan bir kalite sistemidir ve önemli bir planlama, geliştirme ve iletişim yöntemidir.

Kalite Fonksiyon Yayılımı, müşteri memnuniyetinin arttırılması kapsamında, müşteri taleplerinin ve gereksinimlerinin doğru bir şekilde analiz edilerek elde edilmesi ve bu talep ve ihtiyaçları karşılamak üzere ürün ve süreçler üzerinde olumlu yeni değerler yaratılması için kullanılabilen en etkili sistemlerdendir. Bu yöntem uygulandığı süreçlerde müşteri taleplerinin daha iyi anlaşılmasını, tasarımın iyileştirilmesini, ürün kalitesinde ve ürüne / sürece olan güveninin artışını sağlamaktadır. Aynı zamanda, verimlilikte ve gelirlerde artış ve maliyetlerde azalma sağlayarak bir sistem için en uygun düzeyi sağlamaktadır.

Bu terimin Japonca aslı "Hinshitsu KiNo TenKai" olup uluslarası literatürde "Quality Function Deployment" olarak ve Türkçe kaynaklarda ise "Kalite Fonksiyon Yayılımı" olarak yer almaktadır. (Yenginol, 2002).

Bu çalışma kapsamında beyaz eşya sektöründe faaliyet gösteren bir firmanın ihracat lojistik ekibinde çalışan uzmanların görüşleri ve literatür incelemesinde daha önce yapılan çalışmalar değerlendirilerek Türkiye'den yapılan ihracat sevkiyatlarında denizyolu hat seçimi için önemli kriterler belirlenmiştir. Daha sonra kriterler Bulanık Kalite Fonksiyonu Yayılımı yaklaşımı ile incelenmiş olup, deniz yolu hat seçiminde müşteri istekleri ve deniz yolu taşıma hatlarının özellikleri arasındaki ilişkilerin gösteriminde bulanık yaklaşıma başvurulmuştur. KFY uygulamasının ilk aşamasında belirlenen kriterler birden fazla uzman tarafından dilsel ifadeler kullanılarak değerlendirilmiştir. Bu dilsel değişkenler bulanık sayılar ile gösterilmiştir. Bu dilsel ifadelerden yola çıkılarak, deniz yolu hat alternatifleri için toplam skor hesaplanmıştır. Tüm bu uygulamalardan sonra bulanık programlama modeli ile en uygun deniz yolu hattı belirlenmiştir.

1. INTRODUCTION

As the international trade volume increase, it is usual that one product produced on one side of world, can be consumed on the other side. Logistics became the first of important issues for countries success in economic mean.

Logistics is a way of customer satisfying by sending demanded products, services and information into related market from the production place to last consumer on time in full.

Nowadays, logistics is becoming also very important for Turkey as its geographic location on world. As it is located near to Balkans, Middle East, Caucasus and Mediterranean, it is also the center of this logistics center and connection point of Asia and Europe. Therefore, it is important for shipping lines organizing vessel programs.

Container shipping or maritime logistics can be defined as carrying people or things from one point to another by vessels. According to Ministry of Development reports, % 80 of world maritime trade volume and %90 of Turkey's export and import carriers are done by seaways. As seaway transport is 3.5 times cheaper than railway, 7 times cheaper than highway and 22 times cheaper than airway, in sea transport the most volume can be carried in one time in secure and cheaply.

Maritime transportation provides a low-cost way for transferring large volumes of cargo to the delivery points. Majority of export and import shipments realize by maritime transportation as it has many advantages like shorter transit time and lower expense. Ocean carrier's performance has a key role on cost and quality of the logistics activities.

As the transporter's productivity may affect the strength of the whole supply chain, logistics functions performed by ocean freight shipping lines are crucial to the success of a company (Durvasula et al., 2002; Meixell & Norbis, 2008).

The carrier selection is an important decision in purchasing. A company buys the services of a carrier in order to provide transportation of cargo among logistics points, especially from production points to last customer (Bardi, 1973). Due to the competitive and rapidly changing business environment, in the shipping industry, companies' carrier selection decisions are no longer based solely on price (Chung et al, 2011). In addition to cost criteria, satisfying the needs of shippers is becoming an important issue and enhancing service quality is actually more important than lowest price (Chung et al., 2011). With its need to trade-off a large number of criteria, shipping line selection is a very important multiple criteria decision making (MCDM) problem.

Ocean container carriers' customers can be divided into two types: "direct shippers" and "ocean freight forwarders" (Chung et al., 2011). The carrier selection factors of concern to direct shippers and freight forwarders are obviously different: direct shippers select a shipping line according to its overall performance, while freight forwarders consider only a few of critical factors (Lu, 2013). This study considers the shipping selection problem from the "direct shipper" perspective and presents a fuzzy MCDM approach based on QFD for container shipping line selection. For multiple criteria decision making problems, multiple experts are often preferred to prevent the affects and minimize the bias in the decision (Bevilacqua et al., 2006). The group decision making methodology used in this study aggregate the opinions of decision makers to obtain an overall performance score.

The main purpose of this study is determine how customers select shipping lines, weighting and ordering these selection criteria according to their importance degree and select the best shipping line using these criteria's by the help of one of analytic method.

Criteria will be decided by the logistics experts and from the literature review. Turkey was chosen as the main country for representing especially the emerging market in the world export economy. The study is organized in different sections. The sections and what is examined in each section will be as follows.

The following section reviews generally the maritime sector especially by numbers. Section 3 reviews literature from different aspects. Section 4 presents the Fuzzy QFD-based decision making approach which is determined as main method to evaluate the shipping line selection. The application of this method on a shipping line selection problem is provided in Section 5. Conclusions and guidance for future research are expressed in Section 6.

2. MARITIME SECTOR IN TURKEY

The maritime sector in Turkey, whose coastline is 8.333 km, has a significant development potential due to its proximity to the energy-producing countries, geopolitical position, proximity of international transportation routes, and sufficient land and rail links, The Turkish maritime industry has continued to show consistent growth since the middle of the 1980s reflecting the general liberalization policies of the Turkish economy (Chamber of Shipping, 1996).

Turkey is the bridge between Europe and Asia. Thanks to this geographical location, Turkish ports provide to manage significant amount of cargo between the Western and the Eastern points. Cargo coming from Europe and Americas are managed in transit to CIS Republics, Iran, Iraq, and the Balkans and vice versa. Turkey has great potential in terms of intermodal transportation owing to its geographical position surrounded by European, Central Asia and Middle Eastern countries.

In addition, the ports of Turkey are mostly used by all countries ships; therefore historically as a maritime country, Turkey gives great importance to develop its maritime sector and ports by investments.

Maritime transportation is the most preferred method of transportation both in export and import all around the world. Hence, from east to west or vice versa, Turkey ports have crucial place in the ocean-trade.

The volume of commerce in the world is increasing day by day. The amount of vessel and correspondingly container (including import, export, cabotage and transit) handled in Turkish ports were expanding. According to statistics of international trade and maritime shipping, handled container number was 1.95 million TEU in 2002, whereas it has reached 5.7 million TEU in 2010 with a huge increase. In 2017, from January to the end of April, it has reached 3 million TEU. Export statistics are demonstrated in Table 1.1. (Turkish Statistical Institute Foreign Trade Statistics).

Table 1.1: Export by mode of transport, 2016 – 2017

(Değer: Bin ABD $ / Value**:** Thousand US $)

Yıl Year	**Ay**	**Toplam** Total	**Denizyolu** Sea	**Demiryolu** Rail	**Karayolu** Road	**Havayolu** Air	**Diğer** Other	Month
2017 (r)	**Toplam**	**37 868 666**	**21 982 596**	**214 530**	**11 121 616**	**4 230 434**	**319 490**	Total
	Ocak	**11 259 548**	6 599 337	65 963	3 352 679	1 165 378	76 192	January
	Şubat	**12 113 341**	6 962 452	71 393	3 606 633	1 371 237	101 625	February
	Mart	**14 495 777**	8 420 807	77 174	4 162 304	1 693 819	141 673	March
2016 (r)	**Toplam**	**142 544 457**	**78 408 484**	**641 446**	**44 760 311**	**17 747 066**	**987 150**	Total
	Ocak	**9 546 375**	5 490 342	40 932	3 144 361	815 784	54 957	January
	Şubat	**12 366 524**	6 415 877	50 678	3 686 815	2 131 790	81 364	February
	Mart	**12 759 015**	6 798 466	50 399	3 993 833	1 859 386	56 932	March
	Nisan	**11 950 965**	6 699 476	50 417	3 934 401	1 186 478	80 193	April
	Mayıs	**12 099 196**	6 442 615	42 027	3 663 934	1 892 134	58 486	May
	Haziran	**12 867 694**	7 030 616	47 983	4 069 949	1 661 694	57 453	June
	Temmuz	**9 850 195**	5 323 417	32 896	3 107 265	1 345 774	40 842	July
	Ağustos	**11 831 862**	6 391 189	51 142	3 912 155	1 435 356	42 020	August
	Eylül	**10 902 618**	6 182 983	46 355	3 578 967	1 063 096	31 217	September
	Ekim	**12 797 820**	6 975 424	77 757	4 025 990	1 637 977	80 672	October
	Kasım	**12 789 001**	6 983 787	76 859	3 968 371	1 503 761	256 223	November
	Aralık	**12 783 193**	7 674 294	74 001	3 674 269	1 213 838	146 791	December

Container liner shipping is a study area which has long investment lead times. As service specialization is not so high in container liner shipping services, although there are lots of elements should be taken in consideration, the competition is mainly depends on a cost basis. In time of crisis, for example the financial crisis in 2008, there were recession in economy and trade declined so much. This situations caused to capacity exceed in liner shipping services. In addition, it is visible that the freights rates are so changeable. In this context, this services gained more importance.

In global container supply chain, ocean carrier (shipping lines) and container ports are two main players. There exist both competition and cooperation between carriers, ports and terminals.

Shipping line companies are the links in supply chains since they deliver raw material to manufacturers and finished or value-added goods to other members of the chain especially last consumer. It is indispensable for the firm to provide high-quality service in handling customer requirements, leading to high overall customer satisfaction for any shipping firm.

This study tries to understand how the customers and freight forwarders choose shipping line who is the members of the supply chain, to export their goods in terms of cost, time and features of shipping Line Company and to optimize shipping process.

2.1. BASIC CONCEPTS

Basic concepts of this study can be defined as below:

Cargo: A cargo can be a raw material for a manufacturer or a finished good to be carried from one place to another in a ship for an end user.
Shipper: The shipper is the party who arranges goods to be shipped or it can be identified as the seller who sells the goods.
Liner: Liner is the vessel operator who carries the cargo from one port to another in different locations with scheduled voyages.
Freight Forwarder: Freight Forwarder is the agent of the shipper who makes the deals with the liner on behalf of the shipper and makes the contracts with them for the arrival of the shipper’s cargo to the buyer under optimum conditions.

Freight forwarders are important for three parties: the shipper, the liner and the buyer from different aspects. They work with lots of shippers and several numbers of liners.

In addition every shipper has several numbers of buyers. In this sense, all exporters prefer to work with the best freight forwarder to manage these export process.

Another reason of working with a freight forwarder is the mainly cost. If a single shipper decides to work with a liner directly, the cost of the transportation of the cargo will be more than working with a freight forwarder so they usually prefer the second one. As a result, freight forwarders are very important in the transportation system they create value for all by consolidating cargos in optimum conditions that no other party can do (Murphy, 2004, 2005).

Freight forwarders are the service providers who match the cargos with the liners in optimum conditions under their capabilities. The definitions of these two parties can be done as below:

1) The shipper, who is the cargo owner.
2) The liner who is the ship operator and carries the cargo.

The main purpose of the freight forwarders are selling space and time for the shippers and buying space and time from the liners. Therefore they can be in two business partner roles. They are the sellers for the shippers and buyers for the liners. Cheaper and faster space supply creates competitive advantage for the forwarder against players in the freight market.

Although in all process, either customer or freight forwarders should select the best shipping line, in this study we will built a system like a direct shipper and select best line from the view of direct shipper as carrier selection factors of concern to direct shippers and freight forwarders are obviously different and direct shipper can minimize overall cost by the way of appropriate shipping line.

3. GENERAL BACKGROUND LITERATURE

In this part literature review will be given generally for the following key words carrier selection in seaway, liner shipping selection, third party logistics, third party logistics provider, freight forwarding, freight forwarders, ocean container transporter selection, customer satisfaction of ocean freight shipping lines, shipping companies' critical success factors in maritime logistics, freight rates etc.

Although there are lots of articles found by keywords, actually there is no study about directly choosing the best shipping line.

The main study area of this study, shipping line selection can be seen as third- party logistics service provider selection.

For this study, works published until January 2018 and the key words "shipping line selection" and "Fuzzy QFD" are mainly reviewed.

3.1. FREIGHT FORWARDER SELECTION

Perlman, Y. et al. (2009) studied 18 factors for selecting a freight forwarder. They determined these factors as quality certification, meeting deadlines, high knowledge about sector, personal care, customization according to customer's need, elasticity, extra services reliability, global deployment, knowledge of sector, enterprise size, information availability and reliability, online pricing, reports tools, competitor tariffs, revenue enhancement, and classification retention. Then, for developing four dependent variables, he applied a factor analysis in four factor groups. First group was defined as reliability which is a characteristic of service and information. The other important factor was determined as meeting deadlines. Second group was defined as Business Environment of freight forwarders included firm rate, quality documentation, experience in sector and additional services elements. Third group was defined as Information Management which includes price calculation by using online services, reporting materials, and classification, retention and information availability. Last Group was defined as Service and Prices which include flexibility, revision according to customer needs and personal care to customer, expertise and competitive prices. All groups have different reliabilities. He also determined five characteristics of freight forwarders' company. These attributes can be defined as expert's seniority and training, enterprise size, field of use IFF services, number of destinations. Statistics method was used to evaluate the criteria. At the end of this study, the most important factor to Israeli international dealers for selecting a freight forwarder company found as reliability. Majority of customer prefers a trustworthy company while exporting goods. The second most important factor is meeting deadlines. Deadlines are really important for a company, especially if they are sending raw material for a producer. Competitive prices are found as the third most important element because all companies aim to decrease logistics cost.

Markides (2006) examined the important functions provided by International Freight Forwarder Company. Delivery and distribution services are determined as functions and followed by the factor how the freight forwarders handle with payment contract and support in documentation. In addition, making an organisation which contains local and international shipping to last needed points was examined as one of important factors. Information technologies and also assurance of goods was found critical about selecting a freight forwarder company. Finally managing customs services in shipper and receiver countries, warehousing and integration services are also are identified to analyse in this paper. The study is based on a survey of 100 UK based freight forwarders and empirically tests the firms' respective revenue. The survey is complemented by interviews at a four companies in order to provide additional explanations of the practical findings. He concluded his study customers take into account a company size and diversified asset base while choosing a freight forwarder company.

McGinnis (1989) determined seven categories about the choice of freight Forwarder Company. As first he determined freight rates as critical factor. Secondly he examined reliability and transit time. The over-supply and insufficient-supply and damaged-supply are identified as critical. Then, market and carrier considerations, and product characteristics are analysed by also considering four groups of factors. These factors are ranked as transit time, freight price, safety of deliveries and service. He constructed a model about choice of freight transportation then applied a factor- analytic method to evaluate the factors. He concluded by determining the critical factors including quickness, reliability, freight rates. The rate of loss and damage are also determined important.

Matear and Gray (1993) studied about Irish freight shippers and suppliers. Their study was based on a ranking list which includes service attributes. They obtained that shippers and freight forwarders consider different criteria while choosing a carrier service. They determined the critical factors as promptness of service, availability of space in vessels or trucks, high frequency of sea/air service. The speedy of response to any problems are identified as important and followed by freight rate. They also examined arrival and departure time of vehicles and short time taken for sea crossing/flight. The low freight rate and good relationship with sea/air carrier are also taken into account as a critical factor. The distance between port/airport and destination of goods and port/airport between origin of goods are identified as an element of choice of freight forwarders. The special offers or discounts for sea/air service re highly appreciated by exporters in selecting the freight forwarder. The transport choice of shipper lastly examined and finally the most critical element for a supplier is determined as punctuality. Despite shippers determined the factors as the speedy of coping with the problems and avoidance of loss or damage. The on-time pick-up and delivery are also noticed and it is followed by good relationship with carrier, performance about unexpected urgent deliveries and value for money price. The short transit time but after all low price is seen as one of the crucial factors. The other factors are determined as ability to process shipping with special requirement, arrival time at destination and high frequency of service are considered important. The completion of documents by carrier and departure time, discounts and special offers for transport, transport preference of commercial partner, distance of port/airport to origin of goods and destination, information about which port/airport is used, promptness and the capacity to react rapidly to any issue defined as substantial in this selection decision.

Murphy and Daley (1997) determined the critical by the ranking of American IFF customers. These factors in selecting a forwarder are determined as the following: know-how in sector, company scope, recognize of the customer's products. Finding available service for customer and geographic deployment, company reputation and freight rate are identified as critical. In addition personal care to customers and financial strength are highly demanded from freight forwarders by exporting companies. Finally number of service and the ability to supplied relevant information in time needed, and reliability of service determined crucial. At the end of their study, it is found that the most important factor is reliability and it is followed by expertise but cost is determined as in ranking sixth. This order also seemed as different from the other studies.

Pedersen and Gray (1998) studied about Norwegian exporters. They ranked a lot of factors and grouped in four main groups. These groups were determined as timing which means transit time), price, security which contains frequency of damage, ease of claim settlement, and extent of damage and service which is defined as arrival time, good relationship with the carrier, fast response to problems, ability to handle special requirements, and ability to perform urgent deliveries. Then, they evaluated them according to destination country and sectors. Finally, they assessed the shipment volume by mode of transport for foreign trade (imports + exports). Ship transport was ranked as first. They categorized the factors in three groups: Group 1 is defined as route factors which include frequency, capacity and additionally availability, directness, flexibility. Group 2 is defined as cost which includes freight rate and other costs. Finally the Group 3 is determined as service factors which contain delays, reliability and urgency, damage avoidance, loss and theft, fast response to any problems, co-operation with the carrier, tracing ability. According to this study, it is concluded that cost is the most important factor.

The factors affecting freight forwarder selection according to freight forwarders and their customers in the US in 2001 determined by Premeaux (2002) and they are compared to earlier criteria of 1991. The factors are determined as reliability of delivery and pickups being on-time financial strength of carrier, total duration time for the shipment from the beginning to delivery point. The carrier response in emergency or unexpected situations is also determined as critical factor followed by cargo tracking tools (EDI). The popularity of carrier in sector and handling expedited shipments are identified the selection critical criteria. Offering more flexible rates, online billing and tracking tools, geographic coverage and past performance of carrier, information provided to shippers, loss or damage, carrier collaboration with shipper, carrier representative's knowledge of shipper demand, freight loss experience with the carrier, condition of equipment, discount programs offered by carriers, flexible scheduling, damage experience with the carrier ,carrier assistance in obtaining rate and carrier attitude toward acceptance of small shipments, carrier honours, shipper's routing requests, personal relations with the carrier, carrier transportation equipment designed, easy and fast loading and unloading, overcharge claims service, feedback from the consignee to the shipper about the quality of service given by specific carriers, courtesy of vehicle operators, carrier's ability to handle special products, departure and reload advantage, fabrication in transit privileges, carrier willingness to participate in, freight consolidation practices, regular calls by carrier sales representatives opinions or recommendations of, employees of other firms , gifts offered by carriers. At the end of this study, it is found that IFF customers in 2001 were more concerned with information access, consistent carrier performance, customer relations and availability of desired services comparing to 1991.

Voss et al. (2006) evaluated these selection criteria from three perspectives. These are based on decreasing of costs, need for carrier readiness in case of unexpected situations; and, increased importance of supply chain safety. It is found that carrier security is the most important factors. However, the most of studies conclude that security was the least important among the specified diverse criteria. They concluded their study by showing that the security is the most important.

Özsömer, A. et al. (1993) studied about the changing environment of international freight forwarding and the nature of the forwarding problem is reviewed to demonstrate the appropriateness of ES applications to the problem domain. The article continues with discuss of the freight module which also includes a sample consultation session with freight. The final section addresses other potential users who might find freight helpful. Criteria are determined as: complexity, specificity, lack of knowledge.

According to Altuntaş and Öztürkoğlu (2013) the partner selection of these freight forwarders is evaluated through fuzzy TOPSIS analysis. The forwarders' partner selection criteria and the requirements that they seek are collected through unstructured interviews. The various stages of the fuzzy TOPSIS method are represented and the methodology is introduced for real case problems. Criteria are determined as wide network, trust, interest in Turkish market, no other partners in turkey, the title of representation in meetings, fast response, market knowledge, and good level of English, accessibility, payment performance, stability in membership, reciprocity principle and ethics.

Shin and Pak (2016) used a three level AHP to identify critical factors for successful purchasing negotiation for freight forwarders in Korea. These are information (quality of information), power (expert power), and time (high time pressure) and they concluded that Information is the most important factor.

The main aim of the present work of Kokkinis et al. (2006) are measuring the criteria how production companies decide freight forwarders and showing factors which effects quality and to distinguish services in different types of customer. In addition, this work presents the features of Greek freight forwarders by examining their area of specialization concerning services and the profile of their workforce. And also, this analysis measured the information technologies grade in all shipment period.

Mc. Ginnis (1979) suggested that price of services is less important element comparing to the transportation quality. He also proposed that the enterprise procedure and the receiver affects are unimportant. However, he clarified that for the evaluation of these criteria, the delivering concepts are not taken into consideration in selecting service.

Bell (2000), Lambert et al. (1993) and Bardi et al. (1989) stated the cost is an important factor after determining multiple criteria of choice. At the end of study, fortieth place is assigned for “lower price”. Contrarily, reliability with reference to receiving and delivering times together with information accuracy found as the most important factors.

Murphy and Daley (1991) and Evans and Southard (1974) compared freight forwarders and exporter choice. The freight forwarders determined cost as the most important selection criteria; on the contrary, the exporters determined that the quality is the most significant.

Evans and Southard (1974) showed there is not one extraordinary difference between the freight forwarders and the exporters about choosing. These criteria’s are cost and quality.

In Nikolakopoulos (2002) study which can be defined as the only relevant research in Greece. He interviewed 16 international freight forwarders and exporters to determine factor of selecting. This research concluded that the exporters consider the following criteria when deciding upon employing freight forwarders. These factors are reliability, cost, specialization of products, personal care for customer and covered area.

Table 3.1: Literature Review for Freight Forwarder Selection

Author(s)	Year	Journal	Criteria	Method
M. A. McGinnis	1989	Transp. J., vol. 29, pp.36-46,	freight rates, reliability, transit time ,over-supply, short-supply, damaged market and carrier considerations,	Mathematical model
Ayşegül Özsömer, Michel Mitri, S. Tamer Çavuşgil	1992	International Journal of Physical Distribution & Logistics Management	complexity, specificity, lack of knowledge	Candidate EVALuator
V. Markides, and M. Holweg	1993	Int. J. Physic. Distr. Logist. Manag., vol. 23, pp. 25-36	Service Attributes for Freight Shippers fast response to problems, avoidance of loss or damage, etc., on-time collection and delivery, value for money price, good relationship with carrier, ability to perform unanticipated urgent deliveries, short transit time, low price, ability to handle shipments with special requirement, arrival time at destination, high frequency of service, documents completed by carrier, departure time from origin, special offers or discounts for transport, transport preference of trading partner, proximity of port/airport to destination of goods, proximity of port/airport to origin of goods, knowing which port/airport is used Service Attributes for Freight Suppliers punctuality of sea/air service, availability of freight space, high frequency of sea/air service, fast response to any problems, value for money freight rate, arrival time of sea crossing/flight, departure time of sea crossing/flight short time taken for sea crossing/flight, low freight rate, good relationship with sea/air carrier, proximity of port/airport to destination of goods, proximity of port/airport to origin of goods, special offers or discounts for sea/air service, transport preference of shipper	Statistics
P.R. Murphy and J.M. Daley	1997	Transp. J., vol. 37, pp. 29-36	expertise size, experience with the customer's products, convenience, geographic deployment, company reputation, prices, personal attention, financial stability, number of services, the ability to provide relevant information and reliability of service	Statistics
E.L. Pedersen, and R. Gray	1998	Int. J. Physic. Distr. Logist. Manag., vol. 28,	timing , price, security and service	Statistics

		pp. 108-116		
S.R. Premeaux	2002	Transp. J., vol. 42, pp. 28-38,	access, consistent carrier performance, customer relations and availability of desired services	Statistics
V. Markides, and M. Holweg	2006	Int. J. Physic. Distr. Logist. Manag., vol. 36, pp. 336-359, 2006.)	delivery and distribution services , handling payment arrangements assistance in paperwork required for deliveries , organizing local and international shipping information service, insurance , customs services, warehousing and consolidation services	Statistics
G. Kokkinis , A. Mihiotis., C.P. Pappis .	2006	EuroMed Journal of Business, Vol. 1 Issue: 2, pp.64-81	personal treatment, reliability, total cost of transport , possibility of offering special privileges ,experience/time of operation ,flexibility to possible changes of requirements, safety of transport ,specialization in means of transport ,financial stability of freight forwarder, specialization in type of cargos ,specialization in geographic region, brand name of freight forwarder, relations of freight forwarder with collaborating carriers, information provided by third parties ,size of freight forwarder	AHP
Yael Perlman, Tzvi Raz and Livnat Moshka	2009	The Open Transportation Journal, 2009, 3, 29-34	expertise, personal attention , customization, flexibility, additional logistic services, reliability, meeting deadlines , international deployment , quality certification experience, company size, information availability reliable information ,online pricing, reports tools competitive prices, taxation, classification retention.	Factor Analysis
Ceren Altuntaş, Yücel Öztürkoğlu	2013	XI. International Logistics and Supply Chain Congress	wide network, trust, interest in Turkish market, no other partners in turkey, the title of representation in meetings, fast response, market knowledge, good level of English, accessibility, payment performance, stability in membership, reciprocity principle and ethics.	Fuzzy TOPSIS
Soo Yong Shin, Myong Sop Pak	2016	The Asian Journal of Shipping and Logistics 32(4) pp. 195-201	information, power, time	3-Level AHP

3.2. SHIPPING LINE SELECTION

Saleh and Lalonde (1972) Bardi (1973), Brooks (1984), Brooks (1985), and Meyrick and D'Este (1989), they have focused on transportation type choice rather than competition of ports.

Brooks (1985), Meyrick and D'Este (1989), Gilmour (1976), McGinnis (1979), Ogden and Rattray (1982), Wilson, Bisson, Kobia (1986) they have worked on three categories of factors. Firstly, they determined "vessel factors" as transit time oftenness, ability, availability, directness and flexibility. Secondly, they identified "cost factors" as freight rate and other costs. Finally, they defined "service factors" such as delays, reliability and urgency, damage prevention, loss and theft, quick response to problems, shipper-carrier collaboration, documentation and tracing capability.

Pearson (1980) analysed the service quality and performance of shipping line from the viewpoint of UK shipper's. He concluded his study by deciding the critical shipping line selection criteria as service aspects which include port schedule, proximity of ports to loading and unloading places, sailing information, expected time of arrival, transit time. In addition, service characteristics are also defined as regularity, reliability, place availability in vessels.

In Brooks (1983) study, east Canadian exporters are selected as the main research area for the factors of a shipper's shipping line selection decision. Generally large shippers and forwarders select the shipping lines according to oftenness of sailings, prestige of shipping line company, duration and directness of sailing and service factors. Large shippers defined these factors more important than cost. On the contrary, smaller shippers, in many situations, choose shipping line according to cost criteria.

Brooks (1989) determined lots of criteria such as cost of services, sailing oftenness, transit times, directness of sailings, on time pickup and delivery, next ship leaving to shippers destination. Moreover he identified shipping line selection criteria as collaboration between carrier and shipper personnel and flexibility to bypass port problems. These are followed by carrier's prestige about reliability and tracking tools provided by carrier. In addition, fast claims response, long term commitment by carriers, sales representative service, past loss and damage experience, pressure from customer, international nature of advertising are examined as key factors. Finally he decided that a service improvement in transit time is the most crucial factor for choosing a shipping line company for exporting.

Jamaluddin (1995) studied about the merchandising of shipping line services in the Far East/Europe from the point-view of shippers and carriers. For both he determined similar criteria's in his study. First of all, these criteria can be defined as freight rate, cargo maintenance and handling. They are followed by knowledgeability, promptness, transit time and service oftenness. Chiu (1996) studied similar as Jamaluddin about the logistics performance of shipping lines in Taiwan. He also studied from the point-view of shippers and carriers. Finally he concluded that the service factor was more significant than the cost factor. His study shows that the preference of shippers and carriers in shipping line selection are not similar. Shippers select shipping lines based on the service attributes. These attributes determined as carrier's quick reaction to problems, transit time, and reliability. Moreover he identified the selection factors as documentation services, notice of delay and assistance about loss or damage situations. However, carrier's selection criteria of shipping lines based on similar but a little bit different from shippers. Transit time, reliability, the carrier's quick response to any problem, knowledge of the shipper's needs, the reputation of the carrier and the knowledge of the sales staff are more important to the carriers.

Collison (1984) studied about how shipping line companies determine the strategies in Central Alaskan trade. He determined these criteria such as average transit time, adherence to the specified shipping schedule, and service capacity for the required departure and arrival ports are the most important factors in choosing the shipping line.

Suthiwartnarueput (1998) evaluated skills of the shipping lines in Thailand. He determined these success factors as the cost of any service, punctuality, transit times, and frequency and directness of sailings. In addition he identified that past experience about loss and damage are crucial for choice of shipping line.

Tuna (1999) concentrated on the administration quality performed by container transportation. Moreover, he examined the relationship between the service quality and behavioural objectives as the characteristics of the customers. The most important criterias were determined as documentation quality and cargo safety and loss and damage performance as security criteria from the perspective of shippers.

Mexiell and Norbis (2008) and Premaux (2002) determined six important criteria from the point view of shippers. These criteria are determined as simplicity of getting data, consistent performance, and good relationship between customer and shipping lines. In addition they concentrated on quality of service, availability of needed services such as remarkable solutions in case of crisis or unexpected situations and flexible freights.

Hong et al. (2004) surveyed among the expert from different category of sector and emphasized on four criteria. These criterias determined as quality, rate level, service reliability, speedy of service and long term relationship with the customer and shipping line. They determined the factors about choosing a line service as rate-level, on time delivery, number of service offerings, logistics information services, responsiveness to customer needs, quality of service personnel, error rate, business coverage and loss and damage performance. They concluded that rate level is the most important whereas loss and damage performance is the least among respondent.

Durvasula et al. (2002) analyzed an example of transportation administrators in Singapore who assessed the administration measurements of sea cargo shipping lines (or organizations). He utilized an investigative technique called decision tree calculus to recognize the mix of interfacing divisions that amplify benefit fulfillment. Results are determined in different categories. First of all, he determined sales and marketing a category to examine. In this category they studied personalized service, product/route knowledge, help in unexpected situations. Secondly he determined booking services as availability of space in vessels, advice on delays, handling of sailing inquiries and documentation. For documentation service he found that speedy release of delivery orders, speedy release of bills of lading, telephone services which include giving needed information on time promptness in answering, politeness/ etiquette are important.. As a third category, he mentioned about operations. These operations are examined as container type availability, condition of container, availability of space at warehouse, personal visits for example to the shipping line office, giving needed information, prompt attention, sensitivity to customers, waiting time. And finally he showed claims as a last category. This category included fairness, speedy action, simple and suitable complaint process.

Poirier and Reiter (1996) contended that the transportation function such as shipping is an area that is ready for change as firms begin to realize the integral role it plays in effective supply chains. They debate that company should use logistics as a primary source for identifying savings that exist in the network from supply to the purchase by the customer. However, knowing the determinants that affect satisfaction and perceived quality of logistical services is not easy to evaluate. Physical distribution service quality is the most important criteria for selection of shipping line selection.

A wide range of studies have chosen the service characteristics as main subject in the shipping context (27, 23, 34, 45, 46, 47, 48, 40, and 49).

Brooks (1985) examined the determinants of shipper’s shipping lines selection decision. These are determined the determinants as tracing capability of carrier, oftenness of sailings and direct vessels. In addition he identified on-time pick-up and delivery, sales representative service, cost of service, fast claims response, loss and damage experience, proximity of carrier's office, information nature of advertising, carrier's reputation, transit time, co-operation between personnel, carrier flexibility, carrier appropriateness and cost of service as critical factors for shipping line selection. As a result of his study, service cost was selected as the most critical selection criteria by shippers. These criteria are followed by oftenness and directness of sailings, reputation, transit time.

Murphy et al. (1997) examined the importance of the shipping line selection factors from the point of view of both shippers and carriers. In this study, it is concluded that shippers give more attention to equipment availability and it means getting needed type of container in needed time to be loaded on desired vessel, transit time, financial strength, and loss and damage situations. In addition they determined that freight rates and rate changes in time, cargo tracking tools, line haul service and claims are critical elements of choosing shipping line.

Lu (2003) firstly noticed service characteristics according to shippers. These characteristics are determined as management of storage, cargo tracking, inland transport service, custom clearance service, and packing and certification service. Maritime firms selected sales personnel’s capability to manage problems as the most important item whereas shippers selected correct documentation as the most important. According to maritime firms, the five most important service attributes were determined as follows: personnel’s capability to manage problems, quick response to shippers' complaints, know-how of sales personnel, and availability of space for cargos in vessels and correct documentation. In contrast, for shippers, some of attributes were determined same as maritime firms. The five most important service attributes were identified as follows: accurate documentation, obeying determined sailing schedules, availability of cargo space in vessels, quick response to shippers' complaints and on-time pickup.

Lu (2004) assessed the logistics service requirements of international distribution centers. He determined the key logistics service dimensions of distribution centers in terms of export shipments. These dimensions are determined as information and transportation, cargo consolidation, value-added services, customer service support, distribution and storage. In addition, logistics services such as customer feedbacks, EDI linkage, service reliability cargo tracking tools and value-added services have been described for having superior performance against the competitors.

Lu (2007) assessed key properties and abilities in terms of a container shipping service. To evaluate these services, he identified three resource dimensions. These are described as corporate image resource, equipment and information; whereas seven capability dimensions are defined as human resource management, purchasing, customer service, operation, pricing, information integration and financial management. Lu (2007) proposed that operation capability is the most critical criteria in shipping line selection. Then it is followed by human resource management, customer service, purchasing, pricing and financial management, information integration from the point view of a shipping executive's and container shipping service providers such as freight forwarders, agencies and enterprises. They are suggested to identify the innovation competencies, resources and logistics in container shipping services.

Table 3.2: Literature Review for Shipping Line Selection

Author(s)	Year	Journal	Criteria
Brooks	1985	Maritime Policy and Management 12: 145–155.	route factors (which include frequency, capacity, convenience, directness, flexibility and transit time), cost factors (freight rate and other costs) and service factors (delays, reliability and urgency, avoidance of damage, loss and theft, fast response to problems, cooperation between shipper and carrier, documentation and tracing capability).
Meyrick and D'Este	1989	Proceedings of the 14th Australian Transportation Research Forum, Perth, Australia, September 1989, pp. 65–81.	
Gilmour	1976	The Logistics and Transportation Review 12: 39–57	
McGinnis	1979	International Journal of Physical Distribution and Materials Management 10: 25–34.	
Rattray	1982	Proceedings of the seventh Australian Transport Research Forum, Hobart, Australia, pp. 249–276.	
Wilson, Bisson, Kobia	1986	Transportation Research Record 1061	
Pearson	1980	Marine Transport Center, University of Liverpool	port itinerary, sailing data, expected arrival data, transit time, port proximity, regularity, reliability, slot availability
Brooks	1983	Ph.D. Dissertation, Department of Maritime Studies, University of Wales College of Cardiff: UK.	Smaller shippers, in many situations, base their choice on cost. For large shippers and forwarders, frequency of sailings, reputation, transit time and directness of sailing, as well as other service factors listed in her paper, are more important than cost.
Brooks	1989	Logistics and Transportation Review 26: 339–356	Service improvements in transit time

Jamaluddin	1995	Ph.D. Dissertation, Department of Maritime Studies and International Transport, University of Wales College of Cardiff: UK.	freight rate, cargo care and handling, knowledgeability, punctuality, transit time and service frequency
Chiu	1996	Ph.D. Dissertation, Department of Maritime Studies and International Transport, University of Wales College of Cardiff: UK	the most important service attributes to shippers were prompt response of carrier to problems, transit time reliability, documentation services, notice of delay and assistance to loss or damage claims. five most important service attributes to carriers were: transit time reliability, prompt response from carrier to any problem, knowing shipper's needs, carrier's reputation and knowledgeability of sales personnel. Chiu found that the service factor was perceived to be more important than the cost factor.
Murphy at al.	1997	Transportation Research—Part E Logistics and Transportation Review 33 (1), 67–72.	availability, transit time, financial stability, loss and damage, freight rates, rate changes, cargo tracing, line haul service and claims were found to be more important for shippers than carriers
Murphy and Daley	1997	Transp. J., 37, pp. 29-36.	storage, cargo tracking, inland transport service, custom clearance service, packing and documentation service
Lu	2004	Transportation Journal 43 (4), 53–66.	value-added services, support services, distribution services, information and transportation services, cargo related services, consolidation services and storage services, logistics services such as EDI linkage, cargo tracking, customer response, service reliability
Lu	2007	Transnational Transdisciplinary Journal, 43, pp. 285- 310	operation capability ,customer service, human resource management, information integration, pricing purchasing and financial management.

3.3. DETERMINATION OF CRITERIA

In this part, literature review and expert's opinions were evaluated. Factors and sub-factors were determined. These experts are from export logistics and purchasing team of Turkey's leader white-good company. Articles which also study each criteria and categories are determined as below.

1. **Cost & Price -** McGinnis (1989) , Matear and Gray (1993) , Murphy and Daley (1997) , Pedersen and Gray (1998)
    1.1. Freight rates
    1.2. Terminal Handling Charges
    1.3. Storage charges
    1.4. Demurrage charges
    1.5. Detention charges

2. **Time -** Shin and Pak (2016), Brooks (1985), Meyrick and D'Este, (1989), Gilmour(1976), McGinnis (1979), Ogden and Rattray (1982), Wilson, Bisson, Kobia (1986)
    2.1. Free time in port
    2.2. Number of storage free gate – in day
    2.3. Transit times

3. **Vessel Schedule**
    3.1. Direct vessel frequency
    3.2. Transshipped vessel frequency
    3.3. Transshipment hub
    3.4. Obeying vessel schedule / Rate of delayed vessel
    3.5. Discharge ports & country
4. **Container supply capability / Container quantity**
5. **Container quality**
6. **Operations after arriving, transport mode choice**

7. **Enterprise reliability -** McGinnis (1989) , Murphy and Daley (1997), Lu (2004)
8. **Carried product type**
9. **Flexibility in times / schedule-** Brooks (1985), Meyrick and D'Este, (1989), Gilmour(1976), McGinnis (1979), Ogden and Rattray (1982), Wilson, Bisson, Kobia
10. **Cargo tracking tools (Friendly user portals)**
11. **Total volume predicted to be shipped**

3.3.1. DEFINITIONS OF CRITICAL FACTORS

Freight rate: is price charged by carrier for carrying goods from starting point to finish point. This rate can be changed based on weight of object being moved, type of commodity being moved, and distance travelled. Nowadays, this term is being used as general for not only maritime sector but also for railway, highway and airway shipments. It can be paid by either sender or receiver according to agreement. Incoterms are being used for this agreement and it is key elements of international contracts of sale. They tell the parties what to do with respect to carriage of the goods from buyer to seller, and customs clearance. They also explain the division of costs and risks between the parties. It can be generally summarized as for incoterms starting with E and F, freight payment is done by receiver and for incoterms starting with C and D.

Terminal Handling Charges: (THC) is the charges collected by terminal authorities at each port against handling and care of equipment. THC varies port to port of each country, as the cost of handling at each port differs one to another port. THC also recovers the unloading of the container from a truck, stacking and transport from the stacking location to just below the crane.

Storage charges: is the charge by the port or the terminal to the shipping line as long as the container is sitting in the port.

Demurrage charges: is the charge by the shipping line on the consignee if the container is not taken from port and returned to the empty depot within the specified time. Each country and shipping line may determine the number of free days and charges according to their port capacity.

Detention charges: is the charge applied to customers in case they hold equipment outside the terminal longer than the agreed Free Time and do not return back in this time.

Free time in port: is the number of days the receiver is allocated after a container is discharged from the vessel for the reasonable clearance from local Customs and the arrangement for pick-up.

Storage free gate – in day: is the number of free day that container can enter the port before the vessel departure.

Vessel schedule: is predetermined schedule of arrival to cut – off, ETA, ETD dates and number of transhipment and arrival points.

Transit time: is the planned travelling time. It begins just after the vessel leaves the loading port and finish when vessel arrives the arrival port. It may be change in case of unexpected situation. The transit time may change, particularly when the destination is not reached directly but via lots of focal points.

Container supply capability: is supplying needed number of container in needed time to customer. For example, customer needs to load a 50*40HC container for a determined vessel The shipping line must supply the needed number of container in respect to vessel schedule and provide them to be in arrival port in intended time.

Container quality: Some containers cannot be preferred by shipper if they are not standard features. For example, inside of container can be dirty, greasy, broken hollow, rusty, and smell bad, size can be different from needed. A good shipping line must provide containers in high quality.

Operations after arriving transport mode choice: Containers can be delivered directly to port and customer can take from port by themselves or to last customer warehouse by railway, truck, barge or different combinations of them after arrival port. Sending needed documents on time to person authorized to deal with official appeals.

Enterprise reliability: is the quality of being trustworthy or of performing consistently well.

Carried product type: It can be varied as carried material or finished goods. Sometimes, high freights can be preferred against lower transit times for material shipments.

Flexibility in times / schedule: There is also specific time called as 'cut-off date & time' Cut off is the latest time that a container can enter the port. This time can be determined according to vessel departure time. All documents must be ready before cut off time.
If they are not ready and container cannot be able to enter the port, shipments can be postponed to the next vessel. Therefore, shippers prefer the carriers and shipping lines that are more flexible in these dates.

Total volume predicted to be shipped: is the number of container will be loaded during determined period between carrier and the shipper. As the volume increase, freight charges can be varied, or according to volume, shipper can distribute shipment between more than one carrier.

Cargo tracking tools (Friendly user portals): For either shipper or receiver, traceability of containers is crucial. In any time, they must be able to check status of vessel, containers, ETA, ATA information for organizing import documents or planning production schedule. In any delay can be seen by this tools, and any need precaution can be taken.

4. METHODOLGY

Background literature review and definition of the method will be given in this section.

4.1. BACKGROUND LITERATURE OF FUZZY QFD

There are a lot of studies which have used the fuzzy set theory to QFD and created different fuzzy QFD approaches. For example, Khoo and Ho (1996) suggested the concept of fuzzy QFD and fuzzified linguistic variables to make them more sensible. In addition they also thought about the correlations among CRs and the correlations among ECs.

Chan et al. (1999) obtain the importance of CRs by using fuzzy number and entrophy method. Then he integrated the results to get the final importance of CRs.

Wang (1999) applied QFD as a multi-criteria decision making problem and developed a new fuzzy outranking method to obtain the importance ranking of ECs.

Shen et al. (2001) made an interpretation of client necessities to determine trends of future examinations. They added a future tendency index to the importance of CRs to have the final importance of CRs.

Shen et al. (2001) specified that the significance positioning of ECs might be influenced by a few elements which includes kinds of fuzzy numbers, defuzzification techniques, and the quantity of fuzzy numbers. It was discovered that defuzzification methods have relatively bigger effects on the ranking result.

Sohn and Choi (2001) used fuzzy QFD to supply chain problems and evaluated reliability in the problems. They used a fuzzy MCDM method to choose a design with an ideal mix of customer satisfaction and reliability.

Venegas and Labib (2001) suggested a fuzzy analytical hierarchy process (AHP) method to calculate the importance of CRs and combined components to get the final importance of ECs. These components can be defined as technical difficulty, customer satisfaction and cost.

Lin (2003) was interested in the troubles of the design of ECs and added these elements to process ECs' importance.

Büyüközkan et al. (2004) built up a system chain of importance in view of the QFD structure and used fuzzy extent analysis to calculate the weight of each pairwise comparison matrix. The results were later combined with a super matrix to process the importance of ECs.

Chen et al. (2005) proposed an integrated fuzzy expected value approach, in which two fuzzy expected value models are built up to decide ECs' importance.

Chen et al. (2006) integrated fuzzy weighted average method and fuzzy expected value method to assess ECs' importance.

Bottani and Rizzi (2006) applied QFD in logistics and supply chain management to convert linguistic values of customer needs into fuzzy numbers and calculate the importance of ECs' using the conventional QFD method.

Kahraman et al. (2006) used the analytic network process (ANP) method to define the importance of each EC and integrated resource constraints. These constraints are determined as cost budget. This cost constraint was used to build a multi-objective programming problem and derived important ECs.

Bevilacqua et al. (2006) applied fuzzy QFD to select suitable supplier without allocating an order.

Kwong et al. (2007) calculated the importance degree of ECs and the correlations among ECs by using a fuzzy expert system approach These two measures were consolidated to show the total importance of ECs, etc.

Recently, Abdolshah et al. (2013) published a literature review about fuzzy QFD models.

Karsak and Dursun (2015) explained how the relationship between the suppliers needs and the products purchased can be expressed using House of Quality (HOQ). In addition, they showed how the success of the supplier characteristics can be determined based on inner dependencies. They computed the rating and the weights of the supplier by constructing two HOQ matrices, and fuzzy data.

Scott et al. (2015) introduced a novel solution approach by combining AHP, QFD, and chance constraint optimization algorithm that can be used for supplier selection and order allocation.

Francisco and Carpinetti (2016) weighted the criteria for the supplier selection using fuzzy QFD which was derived using linguistic terms to determine the importance of the given requirements. They applied this approach in automotive industry.

Yazdani et al. (2017) developed a relationship matrix between some criteria and customer requirements to find the connections between them using a QFD model.

In addition, in the literature, there is not a study related to shipping line selection by Fuzzy QFD Method.

4.2. FUZZY MCDM METHODOLOGY BASED ON QFD

QFD is a strategic method to developing improved products and services according to customer needs. The basis of QFD is to get and convert client requirements into engineering characteristics, and subsequently into part properties, process design and production needs. In order to create these relationships, QFD usually requires four matrices: product planning, part deployment, process planning, and production/operation planning matrices, respectively (Shillito, 1994). The product planning matrix, also called the house of quality, translates subjective and qualitative customer needs (WHATs), into technical engineering attributes (HOWs). The relationships between customer needs and engineering attributes are placed in each cell in the body part of the house of quality. The weights of HOWs, which are one of the main outputs of the house of quality, are determined by (Bevilacqua et al., 2006):

$$Weight\ (HOW)_i = V(HOW)_{i1}\ x\ imp(WHAT_1) + \ldots + V(HOW)_{in}\ x\ imp(WHAT_n) \quad (4.1)$$

where $V(HOW)_{in}$ is the correlation value of HOW_i with $WHAT_n$, and $imp(WHAT_n)$ represents the importance of $WHAT_n$.

In multiple criteria decision making problems, the values of certain option related with a given attribute often cannot be accurately determined; so experts are not able to demonstrate their choices precisely, so the comments are given in linguistic terms (Bevilacqua et al., 2006).

Fuzzy set theory is frequently employed in the house of quality to deal with the imprecision and unclearness in deciding the importance of customer needs and building the relationships between client requirements and engineering characteristics (Karsak, & Ozogul, 2009). Linguistic variables expressed by fuzzy numbers can be used the input data in QFD (Bevilacqua et al., 2006).

Step 1: Identifying process of the WHATs: This process covers determining exporter company's needs and the assignment of priorities to customer attributes (CAs), and the assessment of the customer's perception are needed (Temponi et al., 1999). The wanted advantages in a service and product in the client's own words are exporter needs and frequently known as (CAs).

Step 2: Determination process of the HOWs: Technical characteristics (TCs), which are also called measurable necessities, are stated as the "HOWs" of the HOQ.

Step 3: Preparation of the relationship matrix: TCs, which impact on which CAs, are evaluated by experts. Similarly, it is really significant to identify the influence degree of TCs.

Step 4: Preparation process of the correlation matrix: This matrix shows relationships among the technical requirements. These are shown on an array which is also known as "the roof matrix"

Step 5: Action plan: The weights of the TCs, are shown at the base of the quality matrix.

The weights are one of the primary results of the HOQ, and are calculated by:

$$Weight(TC)_i = V(TC)_{i1} \times Im(CA_1) + \ldots + V(TC)_{in} \times Im(CA_n), \qquad (4.2)$$

where V(TC) in is the correlation value of TC_i with CA_n, and $Im(CA_n)$ shows the importance or priority of each CA_n. (Bevilacqua et al., 2006).

4.2.1. PROPOSED INTEGRATED FUZZY QFD APPROACH

The steps of the proposed approach are described in these steps (Bevilacqua et al., 2006)

Step 1: Identifying shipper company needs ''WHATs''.

Step2: Identifying shipping line selection criteria ''HOWs''.

Step 3: Determining the relative importance of the ''WHATs''.

Let $w_{it} = (a_{it}, b_{it}, c_{it})$, i = 1,..., k, t = 1,..., n be the weights assigned by decision makers D_t to ''WHATs'' criteria C_i.

The average weight $w_i = (a_i, b_i, c_i)$ of criterion C_i assessed by the committee of n decision makers can be evaluated as:

$$w_i = \left(1/n\right) \otimes (w_{i1} \oplus w_{i2} \oplus \ldots \oplus w_{in}) \tag{4.3}$$

Where $a_i = \left(1/n\right) \sum_{t=1}^{n} a_{it}$, $b_i = \left(1/n\right) \sum_{t=1}^{n} b_{it}$, $c_i = \left(1/n\right) \sum_{t=1}^{n} c_{it}$

Step 4: Determining the ''WHATs''–''HOWs'' correlation scores.

Let $r_{ijt} = (d_{ijt}, e_{ijt}, f_{ijt})$, i = 1,…, k, j=1,…, m, t=1,…, n be the suitability rating assigned by decision maker Dt, for''WHATs'' criteria C_i and ''HOWs'' criteria C_j. The averaged suitability rating $r_{ij} = (d_{ij}, e_{ij}, f_{ij})$ can be evaluated as :

$$r_{ij} = \left(1/n\right) \otimes (r_{ij1} \oplus r_{ij2} \oplus \ldots \oplus r_{ijn}) \tag{4.4}$$

Where $d_{ij} = \left(1/n\right) \sum_{t=1}^{n} d_{ijt}$, $e_{ij} = \left(1/n\right) \sum_{t=1}^{n} e_{ijt}$ and $f_{ij} = \left(1/n\right) \sum_{t=1}^{n} f_{ijt}$

Step 5: Determining the weight of the ''HOWs''.

The weights of the ''HOWs'' are calculated by averaging the aggregate weighted rij correlation scores with the aggregate weights of the ''WHATs'' w_i as follows.

$$w_k = \left(1/k\right) \otimes [(r_{i1} \otimes w_i) \oplus \ldots \oplus (r_{jk} \otimes w_k)] \tag{4.5}$$

Step 6: Determining shipper company needs' impact on the attributes considered ''HOWs''.

Let $SR_{hjt} = (g_{hjt}, h_{hjt}, k_{hjt})$, h=1,…, s, j=1,…, m, t=1,…, n be the suitability rating assigned to shipper company needs A_h, by decision maker D_t, for ''HOWs'' criteria C_j.

$$SR_{hjt} = \left(1/n\right) \otimes (sr_{hj1} \oplus sr_{hj2} \oplus \ldots \oplus sr_{hjn}) \tag{4.6}$$

Where $g_{hj} = (1/n) \sum_{t=1}^{n} g_{hjt}$, $h_{hj} = (1/n) \sum_{t=1}^{n} h_{hjt}$ and $k_{hj} = (1/n) \sum_{t=1}^{n} k_{hjt}$

Step 8: Determining the normalized weighted rating.

The normalized weighted ratings G_h are calculated by multiplying the normalized averaged suitability rating SR_{hj} with its associated weights W_j as follows.

$$G_h = (1/m) \otimes (SR_{h1} \otimes W_1) \oplus .. \oplus (SR_{hm} \otimes W_m)$$

$$h=1, \ldots, s \text{ and } j=1, \ldots, m \qquad (4.7)$$

The shipping line selection problem can be considered as a logistics service supplier problem. The weights of shipping line selection criteria (HOWs) for satisfying the shipper company needs (WHATs) are calculated using Equation (4.1). Then, the fuzzy index expressing the degree, to which each shipping line alternative satisfies a given requirement, is obtained from the aggregated ratings (performance assessments of each alternative) multiplied by the weights of each selection criteria. The most suitable alternative is selected by the result of a fuzzy mathematical programming which maximize the overall score of each alternative subject to company’s constraints.

4.3. FUZZY LINEAR PROGRAMMING

In conventional mathematical programming models, the coefficients of the objective function and constrains are assumed to be deterministic, represented by crisp values. But in real world problems, when uncertainty exists, fuzzy methods can be employed (Ishibuchi & Tanaka, 1990).

The fuzzy mathematical programming can be divided into 3 categories related to the uncertainties treated in the method (Inuiguchi & Ramík, 2000): flexible programming, i.e. fuzzy mathematical programming with vagueness, treats decision making problem under fuzzy goals and constraints, possibilistic programming, i.e. fuzzy mathematical programming with ambiguity, treats ambiguous coefficients of objective functions and constraints but does not treat fuzzy goals and constraints, and finally robust programming, i.e. fuzzy mathematical programming with vagueness and ambiguity, treats ambiguous coefficients as well as vague decision-maker's preference (Inuiguchi & Ramík, 2000). Numerous methods have been proposed in order to solve mathematical programming models involving fuzziness.

According to Karsak and Kuzgunkaya (2002), consider the linear programming formulation given below:

$$Min\ z = cx \tag{4.8}$$

Subject to

$$AX \leq b$$

$$X \geq 0$$

where c is an n-dimensional row vector, b is an m-dimensional column vector, x and 0 are n-dimensional column vectors, and A is an mn matrix.

When the objective function and the constraints are fuzzy, the corresponding fuzzy linear programming model is expressed as follows:

Find x such that

$$cx \lesssim Z_0 \qquad (4.9)$$
$$Ax \lesssim b,$$
$$x \geq 0$$

where Z_0 defines the level to be achieved by the objective, and $\lesssim$ implies the fuzziness of the objective function and the constraints. In other words, achievement levels are determined for the objective function and the constraints, and the decision maker allows for a certain degree of violation of these levels. The following membership function is used to introduce the fuzziness of the constraints into the formulation.

$$\mu_i(x) = \begin{cases} 1 & if\ A_i\, x < b_i \\ 1 - (A_i\, x - b_i)\,/\,d_i & if\ b_i \leq A_i\, x \leq b_i + d_i \\ 0 & if\ A_i\, x > b_i + d_i \end{cases} \qquad (4.10)$$

Here, A_i corresponds to the ith row (I = 1, 2, m) of A, $d_i$denotes subjectively chosen constants of admissible violations, and $\mu_i(x)$ can be interpreted as the degree to which x satisfies the fuzzy inequality $A_i \lesssim x\, b_i$. The membership function tha presents the degree to which x fulfills the fuzzy inequality $cx \lesssim Z_0$ corresponding to the objective function is denoted by $\mu_0(x)$ and can be modeled in analogy to $\mu_i(x)$ Employing the Bellman and Zadeh principle of maximizing the decision in fuzzy space, we obtain

$$\mu_D(x^*) = \max_{x \geq 0} \min\ [\,\mu_0(x), \mu_1(x), \dots,\ \mu_m(x)\,]\,, \qquad (4.11)$$

where $\mu_D(x^*)$ is the membership function of the fuzzy set decision of (4.9). We can note that, in contrast to conventional mathematical programs, the objective is treated in the same manner as the constraints. A fuzzy linear program can be transformed to a classical linear programming formulation as follows (Karsak and Kuzgunkaya, 2002):

$$
\begin{gathered}
\max \lambda \\
\text{subject to} \\
\lambda \leq (1 - (cx - Z_0)) \ / \ d_0 \\
\lambda \leq (1 - (A_i x - b_i)) \ / \ d_i, \ i=1,2,\dots, m \\
0 \leq \lambda \leq 1
\end{gathered}
\tag{4.12}
$$

As a result of fuzzy QFD approach presented in previous section, this study considers fuzzy mathematical programming with fuzzy coefficients.

Let X be the set of alternatives defined as follows:

$$
x_j = \begin{cases} 1 & \text{if the jth alternative is selected,} \\ 0 & \text{otherwise} \end{cases}
\tag{4.13}
$$

C denotes the set of objectives that has to be satisfied by X. There exist objectives to be maximized denoted by Z_k and the ones to be minimized represented by W_S. Employing these definitions, the model formulation is as follows:

$$
\begin{gathered}
Max\ \tilde{Z}(x) = (\widetilde{c_1}\ x,\ \widetilde{c_2}\ x, \dots, \widetilde{c_l}\ x) \\
Min\ \tilde{W}(x) = (\widetilde{c_1}'\ x,\ \widetilde{c_2}'\ x, \dots, \widetilde{c_l}'\ x) \\
s.t.\ x \in X = \{ x \in \{0,1\} \mid \widetilde{A}\, x * \widetilde{b}
\end{gathered}
\tag{4.14}
$$

where $\widetilde{c_k}$ (k=1,.., l) and $\widetilde{c_s}'$ (s=1,…, r) are n – dimesional vectors, $\widetilde{b}$ is an m – dimensional vectors. $\widetilde{A}$ is an m x n matrix, $\widetilde{c_k}$, $\widetilde{c_s}'$ $\widetilde{A}$ and $\widetilde{b}$ are fuzzy numbers, $*$ indicates $\leq, \geq$ and $=$ operations.

Triangular fuzzy numbers appear as useful means of quantifying the uncertainty in decision making due to their intuitive appeal and computational –efficient representation. In this study, we assume that all of the fuzzy coefficients in the model are triangular fuzzy numbers represented by $\tilde{Q}$ = (q_1, q_2, q_3) with the membership function given below:

$$\begin{cases} 0 & x < q_1 \\ (x - q_1)/(q_2 - q_1) & q_1 \leq x < q_2 \\ (q_3 - x)/(q_3 - q_2) & q_2 \leq x < q_3 \\ 0 & x > q_3 \end{cases} \tag{4.15}$$

An α – cut of Q̃ is a crisp set that contains all the elements of the universal set U that have membership grade in Q̃ greater than or equal to the specified value of α such that

$$(\tilde{Q})_\alpha = \{ x \in U \mid \mu_Q(x) \geq \alpha \} \tag{4.16}$$

Let $(\tilde{Q})^L_\alpha$ and $(\tilde{Q})^U_\alpha$ be the lower and upper bound of the α – cut of Q̃, respectively. Then α – cut of Q̃ can be expressed

$$(\tilde{Q})_\alpha = [(\tilde{Q})^L_\alpha, (\tilde{Q})^U_\alpha] = [q_1 + (q_2 - q_1)\alpha, q_3 - (q_3 - q_2)\alpha] \tag{4.17}$$

Thus, for a given value of α, objectives to be maximized and to be minimized can be replaced by the upper bound and the lower bound of their respective α – cuts as follows:

$$\begin{aligned} (\widetilde{Z_k})^U_\alpha &= \sum_{j=1}^{n} (\tilde{C}_{kj})^U_\alpha \, x_j, \quad k = 1, \ldots, l \\ (\widetilde{W_s})^L_\alpha &= \sum_{j=1}^{n} (\tilde{C}'_{sj})^L_\alpha \, x_j, \quad s = 1, \ldots, r \end{aligned} \tag{4.18}$$

Further, the constraints i= 1,..., m_1 , of type " ≤ " and the constraints I= m_1 + 1,..., m_2 of type " ≥ " can be replaced with the following ones :

$$\sum_{j=1}^{n} (\tilde{a}_{ij})_{\alpha}^{L} \; x_j \leq (\tilde{b}_i)_{\alpha}^{U} \, x_j \;\; i = 1, \ldots, m_1$$
$$\sum_{j=1}^{n} (\tilde{a}_{ij})_{\alpha}^{U} \; x_j \geq (\tilde{b}_i)_{\alpha}^{L} \, x_j \;\; i = m_1 + 1, \ldots, m_2 \qquad (4.19)$$

For the equality constraints in the constraint set (i= m_2 + 1, …, m), a fuzzy equality $\sum_{j=1}^{n} (\tilde{a}_{ij}) \; x_j = \widetilde{b}_i$ can be treated as equivalent to inequality constraints (Lee & Li, 1993):

$$\sum_{j=1}^{n} (\tilde{a}_{ij})_{\alpha}^{L} \; x_j \leq (\tilde{b}_i)_{\alpha}^{U} \, x_j \text{ and } \sum_{j=1}^{n} (\tilde{a}_{ij})_{\alpha}^{U} \; x_j \geq (\tilde{b}_i)_{\alpha}^{L} \, x_j. \qquad (4.20)$$

5. ILLUSTRATIVE SHIPPING LINE SELECTION PROBLEM AND APPLICATION ANALYTIC METHOD TO PROBLEM

In this section, problem will be defined and selected method will be applied to our problem.

5.1. PROBLEM DEFINITION

The problem considered in here consists selecting the most appropriate shipping line from a set of 3 alternatives. Hypothetical data is used to illustrate the application of the proposed fuzzy MCDM framework. Problem will be evaluated as direct shipper view. Benefiting from the opinions of four supply chain managers and earlier studies given in the literature review section;

- reliability, security, capability and availability are determined as the shipper (customer) needs;

Table 5.1: Company Needs (WHAT'S)

Company needs	**Definitions (and references)**
Reliability	The ability to be relied on or depended on, as for accuracy, honesty, or achievement of freight forwarders and shipping lines (Perlman et al., 2009), (Bardi, 1973), (McGinnis, 1989), (Murphy and Daley , 1997), (Bardi et al. 1989), (Bell, 2000) , (Lambert et al. 1993), (Nikolakopoulos,2002), (Brooks ,1985), (Meyrick and D'Este, 1989), (Gilmour,1976), (McGinnis, 1979), (Ogden and Rattray ,1982), (Wilson, Bisson, Kobia ,1986), (Pearson, 1980) (Chiu, 1996), (Collison, 1984), (Hong et al. ,2004), (Lu , 2004)
Security	Delivering products without problem (damage), safety. (McGinnis, 1989), (Pedersen and Gray, 1998) (Voss et al. ,2006)
Capability	Provide needed service on time (Brooks, 1985), (Meyrick and D'Este, 1989), (Gilmour, 1976), (McGinnis, 1979), (Ogden and Rattray, 1982), (Wilson, Bisson, Kobia , 1986), (Lu, 2004), (Lu, 2007)
Availability	Suitable or ready for use of shipping (Perlman et al., 2009), (Matear and Gray, 1993), (Premeaux, 2002), (Markides and Holweg , 1993), (Pearson, 1980), (Mexiell and Norbis, 2008), (Durvasula et al., 2002), (Murphy at al., 1997)

- fleet size, expertise in sector, container condition, loss & damage performance, information management system's performance are determined as the shipping line selection criteria (SLSC).

Table 5.2: Shipping Line Selection Criteria (HOW'S)

Shipping line selection criteria	**References**
Fleet size (FS)	(Bardi,1973), (Ding, 2013),
Expertise in sector (EF)	(Murphy and Daley, 1997) (Perlman, Y. et al. ,2009)
Container condition (CC)	(Durvasula et al., 2002)
Loss & damage performance (LD)	(Chiu ,1996), (Suthiwartnarueput , 1998)
Information management system's performance (IM)	(Perlman, Y. et al., 2009) (Markides, 2006), (Premeaux (2002), (Murphy and Daley, 1997), (Shin, S.Y., Pak M.S., 2016), (Kokkinis et al. ,2006), (Bardi et al. ,1989), (Bell, 2000) and (Lambert et al., 1993)

5.2. CASE STUDY

Each of decision makers expresses the opinions by using a linguistic variable.
Linguistic variables are employed are instead of numerical values when solving problems which involve qualitative aspects (Herrera, & Martinez, 2000). The linguistic term set employed in this study is given in Table 5.3. As in Bevilacqua et al. (2006), this paper uses the average operator to aggregate decision makers' assessments.

For instance, let *U= {VL; L;M;H;VH}* be a linguistic set used to express opinions on a group of attributes (VL = very low, L= low, M = medium, H = high, VH = very high). The linguistic variables of U can be quantified 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)

Table 5.3: Linguistic term set (Bevilacqua et al., 2006)

	symmetric triangular fuzzy number
Very Low (VL)	(0, 1, 2)
Low (L)	(2, 3, 4)
Medium (M)	(4, 5, 6)
High (H)	(6, 7, 8)
Very High (VH)	(8, 9, 10)

1. Identifying the "WHATs"
2. Identifying the principle shipping line selection criteria's "HOWs"
3. Weighting the "WHATs"
4. Determining the "HOW"-"WHAT" correlation scores
5. Developing the matrix of correlations between the "HOWs"
6. Determining the impact of each potential shipping line on the attributes considered

7. Shipping line ranking

The importance levels of shipper company needs determined by each of supply chain managers depicted in Table 5.4 , and the data of the relationship matrix between company needs (WHATs) and shipping line selection criteria (HOWs) given in Table 5.5 are aggregated using the average operator. The obtained fuzzy values are shown in Table 5.6.

Table 5.4: Relative Importance degrees of WHATs

	decision maker 1	**decision maker 2**	**decision maker 3**	**decision maker 4**
Reliability	H	VH	M	H
Security	VH	VH	H	H
Capability	M	VH	M	H
Availability	VL	M	H	M

Table 5.5: Relationships between WHATs and HOWs

	Information management system's performance				Loss & damage performance				Container condition				Expertise in sector				Fleet size			
	SLSC5				SLSC4				SLSC3				SLSC2				SLSC1			
Reliability	M	H	H	VH	VH	VH	H	H	VL	M	VL	L	M	H	VH	VH	VL	M	M	L
Security	H	VH	VH	H	VH	H	VH	VH	H	M	M	L	L	L	M	M	L	L	VL	VL
Capability	VL	VL	L	L	M	M	H	H	H	H	H	VH	M	M	VH	VH	H	H	VH	VH
Availability	VL	L	M	M	L	L	H	H	VH	H	L	M	VL	L	H	VH	H	M	M	H

Table 5.6: The house of quality with aggregated values

importance degree		SLSC1	SLSC2	SLSC3	SLSC4	SLSC5
(6,7,8)	**CN1**	(2.5, 3.5, 4.5)	(6.5, 7.5, 8,5)	(1.5, 2.5, 3,5)	(7,8,9)	(6,7,8)
(7, 8, 9)	**CN2**	(1,2,3)	(3,4,5)	(4,5,6)	(7.5, 8.5, 9.5)	(7,8,9)
(5.5, 6.5, 7.5)	**CN3**	(7,8,9)	(6,7,8)	(6.5,7.5, 8.5)	(5,6,7)	(1,2,3)
(3.5, 4.5, 5.5)	**CN4**	(5,6,7)	(4,5,6)	(5,6,7)	(4,5,6)	(2.5,3.5, 4.5)

The weights of shipping line selection criteria, which are given in 5.7, are calculated using Equation (4.1). The reader can be referred to Bevilacqua et al. (2006) for a detailed explanation of the algebraic operations with fuzzy numbers.

Table 5.7: Weights of HOWs

	Fuzzy Weight
SLSC1	(19.5, 29.88, 42.25)
SLSC2	(26.75, 38.13, 52.88)
SLSC3	(22.70, 33.31, 46.06)
SLSC4	(34.00, 46.38, 60.75)
SLSC5	(24.81, 35.44, 48.06)

The rating scores of the alternatives with respect to shipping line selection criteria which are given in Table 5.8 are aggregated using the average operator.

Table 5.8: Rating of alternatives with respect to SLSC

	Fleet size				Expertise in sector				Container condition				Loss & damage performance				Information management system's performance			
	SLSC1				SLSC2				SLSC3				SLSC4				SLSC5			
	DM1	DM2	DM3	DM4	DM1	DM2	DM3	DM4	DM1	DM2	DM3	DM4	DM1	DM2	DM3	DM4	DM1	DM2	DM3	DM4
Alternative 1	VH	VH	VH	H	VH	VH	VH	H	H	VH	H	H	VL	L	L	L	VH	H	VH	VH
Alternative 2	H	H	H	VH	H	M	H	VH	M	H	L	M	M	M	M	M	H	H	H	VH
Alternative 3	H	M	M	H	M	H	H	H	M	M	VH	H	H	H	M	L	H	H	H	M
Alternative 4	L	VL	M	L	M	H	L	M	H	M	L	L	M	M	H	VH	M	M	L	L

The fuzzy index expressing the degree, to which each shipping line alternative satisfies a given requirement, is obtained from the aggregated ratings multiplied by the weights of each selection criteria (Bevilacqua et al., 2006). Table 5.9 presents fuzzy performance scores of alternatives.

Table 5.9: Fuzzy scores of alternatives

	Fuzzy Scores
Alternative 1	(146.60 , 247.16, 392.89)
Alternative 2	(135.06, 229.55, 366.31)
Alternative 3	(131.79, 224.62, 358.63)
Alternative 4	(97.38, 174.08, 287.11)

5.2.1. PROBLEM FORMULATION

Suppose that,

The total costs of transport (per container) of the four alternatives are

$$C_1 = \$1280,\ C_2 = \$1220,\ C_3 = \$1400,\ C_4 = \$1510;$$

and the transit times of each alternatives are

TT1= 37-2 days, 37+2 days -> (35, 37, 39)
TT2= 32-3 days, 32+3 days -> (29, 32, 35)
TT3=30-4 days, 30+4 days -> (26, 30, 34)
TT4= 35-3 days, 35+3 days -> (32, 35, 38)

A fuzzy mathematical programming model maximizing the overall fuzzy scores of alternatives subject to the budget ($1400) and expected transit time (30 -2 days, 30+2 days) -> (28, 30, 32) constraints is built.

$$Max\ (146.60,\ 247.16,\ 392.89)\ x_1 + (135.06,\ 229.55,\ 366.31)\ x_2 + (131.79,\ 224.62,\ 358.63)\ x_3 + (97.38,\ 174.08,\ 287.11)\ x_4 \quad (4.20)$$

subject to

$$1510x_1 + 1220\ x_2 + 1400\ x_3 + 1280\ x_4 \leq 1400$$

$$37\ x_1 + 32\ x_2 + 30\ x_3 + 35\ x_4 \leq 30$$

$$x_1 + x_2 + x_3 + x_4 \leq 1$$

$$x_1\ ,x_2,\ x_3\ ,x_4 \in \{0, 1\}$$

$$Max\ [392.89 - (392.89 - 247.16)\alpha]\ x_1 + [366.31 - (366.31 - 229.55)\alpha]\ x_2 + [358.63 - (358.63 - 224.62)\alpha]\ x_3 + [287.11 - (287.11 - 174.08)\alpha]\ x_4$$

subject to

$$1280\ x_1 + 1220\ x_2 + 1400\ x_3 + 1510\ x_4 \leq 1400$$

$$[35 + (37-35)\ \alpha]\ x_1 + [29 + (32-29)\ \alpha]\ x_2 + [26 + (30-26)\ \alpha]\ x_3 + [32 + (35-32)\ \alpha]\ x_4 \leq 32 - (32-30)\ \alpha$$

$$x_1 + x_2 + x_3 + x_4 \leq 1$$

$$x_1\ ,x_2,\ x_3\ ,x_4 \in \{0, 1\}$$

In order to solve the fuzzy mathematical programming model fuzzy ranking methods can be used to obtain a crisp objective function (Herrera, & Verdegay, 1996). To obtain crisp values of the fuzzy scores of alternatives, the method used in Bevilacqua et al. (2006) (for a fuzzy number (a,b,c) the score is equals to (a+2b+c)/4) can be employed.

If this model is solved for α value of 0, 0.3, 0.5, 0.7, 1, five optimal solutions can be found for each. These solutions are showed in the table 5.10.

Table 5.10: Final table of selected alternative

α	Z	Selected Alternative
0	366.31	Alternative 2
0,3	325.282	Alternative 2
0,5	297.930	Alternative 2
0,7	264.823	Alternative 3
1	224.620	Alternative 3

6. CONCLUSION

Changing economic environment in companies, they all try to maximize their profit by decreasing their cost. The logistics activities are generated the biggest part of expenses of the companies. On the other hand it is easy to decrease cost especially in exporting. The most important way of this decrease is selecting the best shipping line in exporting the goods.

The QFD is a multi-attribute decision making method designed to select the most suitable alternative conforming to customer needs and requirements. This study presents a decision making approach based on fuzzy quality function deployment (QFD) for shipping line selection in export shipments. A literature review was done and expert opinions were taken into consideration for determining the criteria and customer needs. These shipping line selection criterias are defined as Fleet size (FS), Expertise in sector (EF), Container condition (CC), Loss & damage performance (LD), Information management system's performance (IM). In addition customer needs are identified as reliability, security, capability, availability. After determining these criteria, experts also evaluated them by linguistic variables as VL (Very Low), L (Low), M (Medium), H (High), and VH (Very High). These linguistic variables, expressed by triangular fuzzy numbers, were employed in the system to deal with the imprecision and vagueness in determining the importance of company needs and addressing the relationships between company needs and shipping line selection criteria. According to the ratings of shipping line alternatives with respect to the criteria, the score of each alternative was calculated, and a fuzzy mathematical programming model was built to determine the most suitable shipping line.

For different α values, each value of objective function has been calculated and values also have been demonstrated in Table 5.10. For α=0, α=0.3 and α =0.5 the most suitable shipping line has been determined as Alternative 2. For α=0.7 and α=1, the most suitable shipping line has been determined as Alternative 3. In solve of thissystem, it can be said that for crisp value of α, Alternative 3 has been selected. In contrast, when vagueness is increased this means that, the constraints are being stretched, Alternative 2 has been selected. In summary, it can be concluded that vagueness affected this model a lot and the choice of shipping line alternative.

This study, being the first example of integrating Fuzzy QFD for shipping line selection. Future research will focus on implementing group decision making approaches based on Fuzzy QFD that consider the interrelationships among selection criteria for real-world shipping line selection problem.

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