FUEL SUPPLIER SELECTION IN THE AIRLINE INDUSTRY USING AN INTEGRATED MULTIPLE CRITERIA DECISION MAKING APPROACH

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LIST OF SYMBOLS

AHP **:** Analytic Hierarchy Process
ANP **:** Analytic Network Process
DEMATEL **:** Decision Making Trial and Evaluation Laboratory
ELECTRE **:** Elimination and Choice Translating Reality English
GP **:** Goal Programming
IATA **:** International Air Transport Association
MCDM **:** Multiple Criteria Decision Making
MCOM **:** Multi-Objective Decision Making
PROMETHEE **:** Preference Ranking Organization Method for Enrichment Evaluation
SCM **:** Supply Chain Management
SMART **:** Simple Multi-Attribute Rating Technique
VIKOR **:** Vise Kriterijumska Optimizacija I Kompromisno Resenje

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ABSTRACT

Nowadays the cost of aviation fuel also called as jet fuel or aviation turbine fuel which is petroleum product fuel based on kerosene surpassed the other cost criteria in the airline industry. Formerly, new aircraft purchases and personnel salaries have the greatest percentage in the total operational cost. Since 2016 there is an ongoing increase in the percentage of fuel cost in the total expenditure. One of the reasons is the cost of aviation fuel is directly proportional with the price of crude oil and the price of crude oil continued its' upward trend in the last decades.

This aviation fuel is supplied to airlines at airports by fuel companies or resellers through a jet fuel supply chain. All suppliers have to provide the standards which are determined by International Air Transport Association (IATA) to give a service at airports but suppliers may have different characteristics. The fuel is being provided by fuel suppliers to airlines accordance with the terms and conditions of the fuel agreements and airlines do not make long term agreement with fuel suppliers due to the volatile crude oil prices. The agreements are generally established with refinery prices (Platts), market or government prices and normally only last one year. The specific commercial details such as negotiated price, duration and the quantity take part in these agreements.

The performance of these fuel suppliers affects not only cost effectiveness but also the other performance aspects of airline companies because industry is sensitive to many variables and parameters. For instance, the responsiveness of suppliers has directly effect on on -time flight operation, the accuracy of invoices can provide decrease in man power at management side , the amount of insurance can prevent future problems and the flexibility of suppliers can provide to airlines operate flights in different time schedule.

Accordingly, the fuel supplier selection is becoming a significant decision process for the airline industry because of the increased cost of jet fuel in the airlines` total cost structure and other performance expectations. The contemporary supply chain management requires to involve more qualitative and quantitative criteria for the supplier selection processes which can be combined and solved by Multiple Criteria Decision Making (MCDM) methods.

In the matter of studies regarding supplier selection in the aviation sector, limited amount of studies are available so in this research so it was decided to select a fuel supplier with a MCDM approach which enables to make a decision among many alternatives such as actions and solutions while considering the criteria belong to alternatives. In consideration of different criteria result in useful and better choices.

In this research, firstly Decision Making Trial and Evaluation Laboratory (DEMATEL) method was used which is one of MCDM methods. This method is effective to identify cause-effect relationship between items of a complex system and resolving the complicated, interconnected problem which was developed by Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976. The other applied DEMATEL researches are examined in the literature review section.

Prior to application of DEMATEL Method, the first and foremost step is defining the supplier selection criteria. In this research it is being benefitted from Dickson (1966), Weber et al. (1991) and the other many supplier selection researches. In Dickson (1966)`s research 23 criteria were listed under supplier selection and it was stated that according to the survey done, the most important criteria were quality of product/service, the capability of deliver on time , performance history of supplier and warranties policies. According to Weber et al. (1991)`survey, 10 criteria were defined with the purpose of selecting ideal supplier. The most important factors are net price, delivery, quality and production capabilities factors. Eventually, 14 criteria were determined accordingly with expert views in this research which have an effect on operational excellence of airline and concerning airline industry.

After the application of DEMATEL Method, it is found that the most significant criteria is respectively the cost of fuel , financial condition, the reputation of the fuel company, accuracy of agreements and invoices, warranties and insurance, responsiveness and the product quality. The cost of fuel criterion is being fulfilled by fuel supplier with the most advantageous offer. Some suppliers can offer low cost at some airports in which they have a strong position in the market condition. This criterion is generally accepted to evaluate suppliers during fuel tenders. When considering financial condition of suppliers, it is costly to invest in fuel infrastructure and fuel truck at airports so the suppliers should be financially stable to maintain fueling process. As for the reputation of supplier, the assessment of suppliers is crucial in terms of airlines. Reputation is the overall valuation of a fuel supplier from different airlines in aviation industry. A good reputation of fuel supplier will cause airlines feel more trusting regarding business.

The accuracy of agreements and invoices has a big role after sales. Airlines firstly update their ERP system with the agreement condition and start to make payments regularly according to the agreed conditions after completing the tender .However they can face with wrong priced invoices and can be busy to correct the invoices which cause extra man power on behalf of airlines. In addition, aviation is full of accident and incident risk so fuel suppliers must submit a certificate of insurance which covers the loss, injuries and damage. A huge amount of liability limit is always preferable for airlines. Furthermore, responsiveness can described as the ability to react airlines` needs purposely within an appropriate timeframe. Lastly, suppliers must supply jet fuel which meets the specifications and requirements set for Jet A1 & TS-1. In this research all suppliers are evaluated with an IATA risk score which is used in second phase.

In the second phase, best suitable supplier was selected among 5 suppliers under targeted levels for determined 7 criteria with the usage of Zero-One Goal Programming (GP) which is a mathematical programming.

Keywords: Airline industry, DEMATEL, Supplier Selection, Goal Programming

ÖZET

Bugünlerde havacılık yakıt maliyetleri bilinen diğer adıyla kerosen maddesinden elde edilen jet yakıtı veya uçak turbin yakıtı maliyetleri havayollarındaki diğer maliyet kalemlerini aşmaktadır. Eskiden yeni uçak alımları ve personel maaşları toplam operasyonel giderlerde azami bir yüzde içerisinde yer almaktaydı. 2016 yılından itibaren toplam maliyetler içerisindeki yakıt maliyeti yüzdesinde devam eden bir artış vardır. Sebeplerden biri, havacılık yakıtının maliyeti, ham petrolün fiyatı ile doğrudan orantılı olması ve ham petrolün fiyatı, son 10 yılda yükselme eğilimini sürdürmüştür.

Havacılık yakıtı, havalimanlarındaki havayollarına, yakıt şirketleri veya satıcıları tarafından bir jet yakıt tedarik zinciri aracılığıyla sağlanmaktadır. Tüm tedarikçiler, havaalanlarında hizmet vermek için IATA tarafından belirlenen standartları sağlamak zorundadır ;ancak tedarikçiler farklı uzmanlıklara sahip olabilir. Yakıt, yakıt tedarikçileri tarafından, yakıt anlaşmalarının şart ve koşullarına uygun olarak havayollarına sağlanmaktadır ve havayolları, değişken ham petrol fiyatları nedeniyle, yakıt tedarikçileri ile uzun vadeli bir anlaşma yapmamaktadır. Anlaşmalar genellikle Platts, piyasa veya devlet fiyatları ile oluşturulmaktadır ve normalde sadece bir yıl sürmektedir. Anlaşmalı fiyat, süre ve miktar gibi belirli ticari detaylar bu anlaşmalarda yer alır.

Bu yakıt tedarikçilerinin performansı sadece maliyet etkinliğini değil, havayolu şirketlerinin diğer performans özelliklerini de etkilemektedir;çünkü endüstri birçok değişkene ve parametreye karşı hassastır. Örneğin, tedarikçilerin duyarlılığı zamanında yapılan uçuş operasyonlarını doğrudan etkiliyor, faturaların doğruluğu yönetim tarafındaki insan gücünün azalmasını sağlayabilir, sigorta miktarı gelecekteki sorunları önleyebilir ve tedarikçilerin esnekliği havayollarının farklı zamanlarda uçuş düzenlenmesini sağlayabilir.

Buna bağlı olarak, yakıt tedarikçisi seçimi, havayollarının toplam maliyet yapısındaki artan jet yakıtı maliyeti ve diğer performans yönleri nedeniyle havayolu endüstrisi için kritik bir karar süreci haline gelmektedir. Çağdaş tedarik zinciri yönetimi, tedarikçi seçim süreçlerinde çok kriterli karar verme yöntemleri ile birleştirilip çözülebilen nicel ve nitel kriterler içermeyi gerektirir.

Havacılık sektöründe tedarikçi seçimi ile ilgili çalışmalara gelince, sınırlı sayıda çalışma bulunmaktadır. Bu yüzden bu araştırmada, birçok alternatif arasından karar vermeyi sağlayan çok kriterli karar verme yaklaşımı ile yakıt tedarikçisi seçilmesine karar verilmiştir. Alternatif tedarikçilere ait kriterleri göz önünde bulundurarak eylemler ve çözümler gibi birçok alternatif arasından karar vermeyi sağlayan çok kriterli karar verme yaklaşımı ile bir yakıt tedarikçisi seçilmesine karar verilmiştir. Farklı kriterler göz önüne alındığında, faydalı ve daha iyi seçimler ortaya çıkar.

Bu araştırmada öncelikle Çok Ölçütlü Karar Verme (ÇÖKV) yöntemlerinden biri olan DEMATEL yöntemi kullanılmıştır. Bu yöntem 1972-1976 yılları arasında Cenevre'nin Battelle Anıt Enstitüsü'nün Bilim ve İnsan İşleri Programı tarafından geliştirilmiş olup karmaşık, birbirine bağlı problemleri çözmek için etkili bir yöntemdir. Bu yöntem, karmaşık bir sistemin bileşenleri arasındaki sebep-sonuç ilişkisini belirlemek için kullanılmaktadır.

DEMATEL Metodunun uygulanmasından önce, ilk ve en önemli adım tedarikçi seçim kriterlerinin tanımlanmasıdır. Bu çalışmada Dickson (1966), Weber ve ark. (1991) ve diğer tedarikçi seçimi çalışmalarından faydalanılmıştır. Dickson (1966) 'nın araştırmasında tedarikçi seçiminde 23 kriter listelenmiş ve yapılan ankete göre, en önemli kriterlerin ürün / hizmet kalitesi, zamanında teslim kabiliyeti, tedarikçinin performans geçmişi ve garanti politikaları olduğu belirtilmiştir. Weber ve ark. (1991) 'nin çalışmasında ideal tedarikçi seçimi için 10 kriter belirlenmiştir. En önemli faktörler net fiyat, teslimat, kalite ve üretim yetenek faktörleridir. Nihayetinde, havayollarının operasyonel mükemmeliğine etkisi olan ve havayolu endüstrisini ilgilendiren 14 kriter uzman görüşleri alınarak belirlenmiştir.

DEMATEL Metodunun uygulanmasından sonra, en önemli kriterlerin sırasıyla yakıt maliyeti, finansal durum, yakıt şirketinin itibarı, anlaşmaların ve faturaların doğruluğu, garantiler ve sigorta, hızlı çözüm oluşturma ve ürün kalitesi olduğu tespit edilmiştir. Yakıt maliyeti kriteri, en avantajlı teklif veren yakıt tedarikçisi tarafından karşılanmaktadır. Bazı tedarikçiler, pazar koşullarında güçlü bir konuma sahip oldukları içim bazı havaalanlarında düşük maliyet sunabilir. Bu kriter genellikle tedarikçileri yakıt ihalesinde değerlendirmek için kabul edilir. Tedarikçilerin mali durumu göz önüne alındığında, hava alanlarındaki yakıt altyapısına ve yakıt kamyonuna yatırım yapmak maliyetlidir, bu nedenle tedarikçilerin yakıt sağlama işlemini sürdürmek için finansal olarak istikrarlı olmaları gerekir. Tedarikçinin itibarına gelince,tedarikçilerin havayolları açısından değerlendirilmesi çok önemlidir. İtibar, bir yakıt tedarikçisinin havacılık endüstrisindeki farklı havayolları tarafından genel değerlendirmesidir. Yakıt tedarikçisinin iyi bir ünü, havayollarının iş konusunda daha güvende hissetmesine neden olacaktır.

Satışlardan sonra anlaşmaların ve faturaların doğruluğunun büyük rolü vardır. İhaleyi tamamladıktan sonra havayolları ilk önce ERP sistemlerini sözleşme koşullarıyla günceller ve sonra kararlaştırılan koşullara göre düzenli olarak ödemeler yapmaya başlarlar. Ancak yanlış fiyatlandırılmış faturalarla karşılaşabilirler ve fazladan insan gücü neden olan faturaları düzeltmekle meşgul olabilirler. Ek olarak, havacılık kaza ve olay riski ile doludur, bu nedenle yakıt tedarikçileri zararı, yaralanmaları ve hasarları kapsayan bir sigorta sertifikası sunmalıdır. Havayolları için her zaman büyük miktarda sorumluluk limiti tercih edilmektedir. Ayrıca, hızlı çözüm oluşturma, havayolu şirketlerinin gereksinimlerine bilerek uygun bir zaman dilimi içerisinde cevap verebilme yeteneği olarak tanımlanabilir. Son olarak, tedarikçiler Jet A1 ve TS-1 için belirlenen teknik özellikleri ve gereksinimleri karşılayan jet yakıtı tedarik etmelidir. Bu araştırmada tüm tedarikçiler ikinci aşamada kullanılan IATA risk skoru ile değerlendirilmiştir..İkinci aşamada ise, matematiksel bir programlama olan 0-1 Hedef Programlama kullanımıyla belirlenen 7 kriter için belirlenen seviyelerdeki 5 tedarikçi arasından en uygun tedarikçi seçildi.

.**Anahtar sözcükler**: DEMATEL, Hava yolu endüstrisi, Hedef programlama Tedarikçi seçimi

1. INTRODUCTION

The modern supply management requires cooperating with the suppliers long term. Instead of working with the large number of suppliers, it aims to use fewer but trustworthy ones. Therefore, selecting the right supplier depends relies on a wide spectrum of quantitative and qualitative variables not only comparing the price (Ho, Xu, & Dey, 2010).

For an airline, fuel cost is the one of the most significant expenditure and it is highly variable within time. For instance, in Table 1.1, in 2017, for the all airlines worldwide, fuel costs take approximately one-fifth of total expense. In 2012, this rate was nearly one third and it decreased rapidly year by year but a remarkable increase up to one quarter of the total expenditure expected in 2019. Aviation fuel, kerosene-based petroleum product is also known as jet fuel or aviation turbine fuel. Therefore, the total cost of the fuel for an airline company is directly commensurate with the price of crude oil. Generally, airlines create a buffer, for the sudden changes of fuel prices, with hedging their fuel purchases. The meaning of hedge is to make an agreement on a constant price within a period of time, in other words, fixing the fuel prices.

Practically, with a long term contract, airlines can reduce the risk of financial loss in the unexpected situations which affect the price of crude oil. (Statista, 2019). In spite of making hedge, the cost of jet fuel is the one of the most important factor affecting the profitability of airlines. For example, in 2015, with the sharp drop in fuel expenditures, airlines' profit showed a significant increase. Also there are some other variable operating expenses which affect airlines' profitability like aircraft maintenance charges, airport utilization fees, navigation and handling costs, marketing…etc(Statista, 2019).

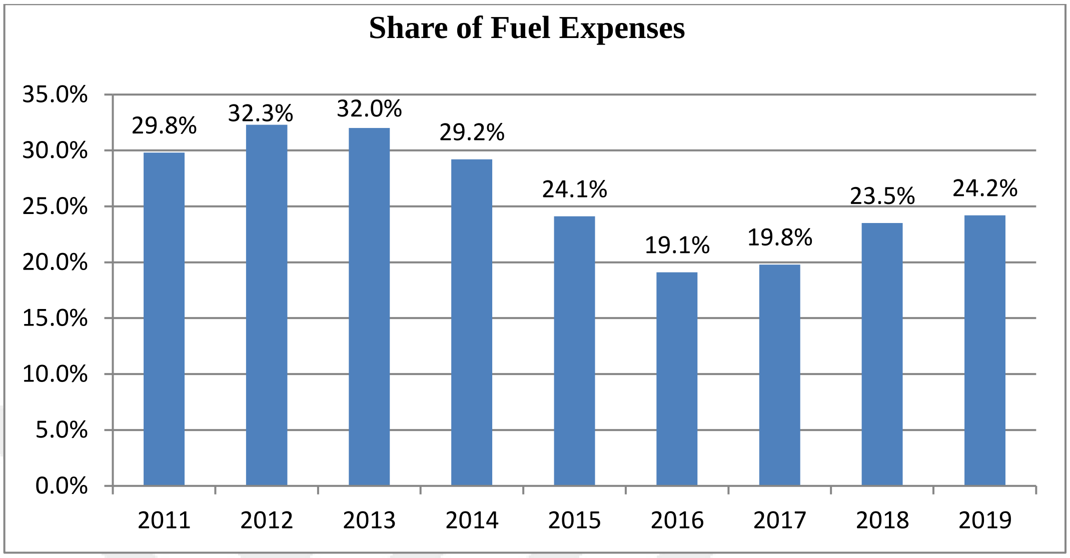

Figure 1.1 Share of Fuel Expenses in Airlines Expenditure
(Statista, 2019)

In recent years, airline industries' cost structure changed with the increasing proportion of jet fuel costs. Formerly, new aircraft purchases, wages, personnel salaries have the greatest percentage; however, as the price of crude oil continued its' upward trend in the last decades, fuel takes the highest percentage in a typical airlines' total expenditure (IATA, 2008).

Cost Items	**2015 Percentage**	**2016 Percentage**
Fuel	30.5%	26.4%
Personnel Salaries	16.7%	18.4%
Aircraft Purchase	14.4%	16.2%
Airports&Air Navigation	9.3%	9.4%
Sales&Marketing	9.0%	8.7%
Ground Handling	6.3%	6.4%
Passenger Services&Catering	5.9%	5.7%
Maintenance	5.2%	5.8%
Other	2.7%	3.0%
TOTAL	100%	100%

Figure 1.2 Expenses of an Airline Company

To illustrate, in Table 1.2, both in the years 2015 and 2016, fuel took nearly one quarter of the total expenditure and it doubled the aircraft ownership, previously the biggest expense of an airline, with around $3 billion and $2.7 billion respectively. As a result, this chart specifies that, an airline's profitability can directly change with the fuel expenses and this situation shows the importance of a continuing partnership with a reliable fuel supplier. As the number of passengers increases year by year and airlines expanding their fleet with new aircraft purchases, the importance of the fuel supplier selection becomes very critical. Each year, an airline needs much more fuel than previous years because of the increase in the number of flights.

The performance of fuel suppliers affects not only cost effectiveness, also the other performance aspects of airlines like punctuality, aircraft efficiency, and environment responsibility. Even the aircraft manufacturers spend millions on researches to produce more efficient turbofan engines to cut down expenditures of airlines and contribute the environmental protection with reducing carbon emission.

The fuel SS is becoming a decisive decision process because of the increased cost of jet fuel in the airline's total cost structure. The performance of fuel suppliers affects not only cost effectiveness but also the other performance aspects of airline companies like punctuality, aircraft efficiency, and environment responsibility. The selection of fuel supplier in the airline sector is no longer a single objective problem of minimizing the purchasing cost, but rather a multiple criteria decision making (MCDM) problem involving many interfering criteria.

Moreover, over the decade there has been a significant increase in the growth of the global air traffic. By 2030, the number of passengers transported is projected to achieve 6.4 billion. One of the reasons is the developing liberalization of international air transport regulation since 1990 has played a key part in the growth of the air. The global total annual passenger volume worldwide has increased by 46 percent over the previous ten years from 1,457 billion to 2,128 billion per year (ICAO 2007).

This liberalization has enhanced airline industry`s effectiveness in many ways. Firstly, it enables airlines to optimize its network and pricing. The operating efficiency of airlines and the average load factor are improved. This has led to a steady reduction in average expenses. Secondly, the enhanced competition after liberalization forces airlines to enhance their effectiveness relentlessly. Airlines that are less effective will either merge or bankrupt while fresh business models and innovations are being developed. Accordingly, airlines started to try optimize the input criteria in order to be successful in this competition.

Delbari et al. (2016) described the key performance indicators for airlines such as quality, safety, price, timeliness, profitability, productivity, and the key drivers are bargaining power of suppliers, operations capabilities. It is also stated that profitability is the most crucial key competitiveness indicator. According to this study, airlines should offer services at competitive prices on a consistent basis, ought to have a lower average cost than its rivals and have to perform. Moreover, flights have to be performed on time which can be assessed with block off time and scheduled time. The difference between them should not exceed 15 minutes. As well as, airlines have to successfully eliminate injuries and incidents with safety criteria. These criteria have an impact on customers in terms of selecting an airline for travelling.

The dramatic increase in competition in the aviation industry, it leads to airlines compete with the other airlines by thinking the requirements of being successful in this competition. During the fuel supplier selection process, complicated set of factors have to examined which are related to competitiveness indicator. The selection process is a MCDM problem which includes basically evaluating the diverse fuel provider with a complicated set of variables to satisfy the requirements of the airlines in terms of performance.

On the other hand, there is a general concept which selects the most economic offer but there are some disadvantages of selecting lowest bid during the fuel tenders. One supplier can offer advantageous bid by using cheap labor and low quality fuel but in the long term it can be risky. Also the supplier can reduce the safety standards and with this they can offer advantageous offer. In the long term it can cause many safety problems. Moreover, they can present low cost with minimum margin but little money could be spend on research and development. As a result there would be bad impact on engine systems of aircrafts (Rooyen, 2019). Last but not least, the supplier can leave the market and give up providing fuel due to lack of financial stability and also do not pay attention to the training of fueling operators.

Although supplier selection problem at various industries is addressed in the SCM literature, the airline industry is underrepresented in this area (Rezaei et al., 2014). There are a few studies researching supplier selection in the air transport. Chan et al. (2007) suggested a decision support system employing AHP in order to solve SS problem in the aviation sector. Rezaei et al. (2014) investigated SS in the airline sector. In this study a two-phase methodology using a conjunctive screening method and fuzzy analytic hierarchy process (FAHP) is presented. Garg (2016) used AHP and fuzzy TOPSIS to select a strategic partner in the airline sector.

More specifically, Bassig et al. (2017) applied conjoint analysis to find the key criteria of the aviation fuel. Ogunclu (2017) employed hierarchical fuzzy MCDM approaches for fuel SS in an airline company incorporating agility concept. There are many areas in aviation used DEMATEL method to figure out decision problems. Liou (2012) suggested an integrated model DEMATEL, fuzzy preference programming and analytic network process (ANP) for strategic partner selection in the airline sector. Hsu and Liou (2013) suggested a hybrid MCDM model using DEMATEL and ANP methods for selecting an airline supplier.

2. MULTIPLE CRITERIA DECISION MAKING

The aim of the supplier selection is to define providers with the greatest ability to continuously satisfy the requirements of an organization at acceptable costs (Kahraman et al., 2003). The SS process can be described in four stages (De Boer et al., 2001). It starts with the definition of the problem which includes by choosing a provider, what the purchaser wishes to accomplish precisely. Secondly, finding out the most important criteria and formulate these for selection. Thirdly, suppliers are qualified in accordance with company needs and fourthly it is called as final selection stage. In this stage, decision makers make a last decision among suppliers.

The SS process is very indicate process due to 2 reasons. First of all, it consists of conflicting qualitative and quantitative criteria. Secondly, the increased procurement and procurement possibilities offered by increased globalization of world trade and improved communication techniques that has made the supplier selection method more difficult (Fahim, 2014). On the other hand, it is becoming more complex in agile working area owing to dynamic variables such as competitiveness and conditions of industry which can be seen in aviation sector. There are several decision making techniques being used in recent supplier selection studies which classified as MCDM methods, Mathematical Programming and Artificial Intelligence methods respectively (Chai et al., 2013). In this research, MCDM and Mathematical programming methods are used for SS.

Multiple Criteria Decision Making is a methodological discipline enables to make a decision among many alternatives such as actions and solutions while considering the criteria belong to alternatives. It is shortly known as MCDM in the literature. In consideration of different criteria result in useful and better choices. Generally, the first stage of MCDM is defining the objective of the decision process. Secondly, the criteria are defined related with the objective and thirdly choice of alternatives. After using weighting outranking or compromise methods the best alternative can be selected. There are many MCDM techniques which can solve this type of MCDM problems. The AHP and ANP methods which are popular as Multi attribute utility method provide preference degree to rank or to select any choice. They are generally used in supplier selection problems for selecting ideal supplier taking consideration into selection criteria.

Outranking methods: The ELECTRE technique bases binary superiority comparisons for each evaluation factor between alternative decision points and follow this definition closely. The PROMETHEE techniques are built on the condition where options are compared in pairs. This method developed and applied after facing with existing difficulties in usage of prioritizing techniques.

Compromise methods: Yu (1973) founded both TOPSIS and VIKOR methods. According to these methods it is stated that an optimal solution is the closed to the ideal solution.The distinction that TOPSIS is using linear normalization to remove criteria units while VIKOR is using vector normalization (Opricovic & Tzeng, 2004).

Other MCDM methods:

SMART is a fundamental method of classification which uses a simple additive weight method. This method can handle both quantitative and qualitative criteria but it does not deal with uncertain information about decision making effectively, including linguistic terms, intervals, and diverse fuzzy values. (Vinodh & Kumanan, 2011) proposed a fuzzy SMART fuzzy strategy-aligned simple multi-attributes rating technique (SMART) approach for SS. DEMATEL is a systematic model to analyze the connection between complicated evaluation criteria. This method is researched under literature review section of this research.

3. LITERATURE REVIEW

The selection of supplier is a key decision-making process in order to improve quality flexibility, performance and form strategic partnerships with better providers (Vinodh & Kumanan, 2011). The purchasing or procurement departments of companies ensure that the right amount of material is procured at the right time even from the right suppliers where they have a fundamental duty in Supply Chain Management. Consequently, in corporate life these departments can face with difficulties while choosing right suppliers to achieve right goal. The significance of selecting suppliers can be ascribed to their actual contribution to the optimization of products and services quality, quantity, reliability and cost (Sarkis, Talluri, & Gunasekaran, 2007).

These suppliers are categorized companies according to profitability, performance and success in achieving their measurements in the required time compatible with companies' objectives. The decision making process for selecting these suppliers involves a variety of different opinions and different alternatives for the final outcome (Renganath & Suresh, 2016).The success of airlines in competition of today and developing atmosphere is attached to working with reliable fuel suppliers. Necessary independent and dependent requirements have to be fulfilled by fuel suppliers. This requirements can be defined with linguistic and scientific terms but the relationship and the influence between these requirement s can be shown on MCDM model. Consequently, the influence degree can be obtained from DEMATEL method. Supplier selection problem is one of the most common MCDM problem (Yildiz & Yaya, 2015) however majority of the current research on supplier selection focus on manufacturing area and the current literature of supplier selection generally targets different industries namely automotive, pharmaceutical, telecoms, electronics sector (Fahim, 2014). In the airline industry (Chan, Chan, IP, & Lau, 2006) firstly suggested a decision support system on supplier selection problem. Following years MCDM methods are being applied on many airlines and airports as summarized in the below.

3.1 MCDM methods used in the airline industry

Throughout the literature view, generally the quality of airline and airport is examined with MCDM methods.

Table 3.1: A summary of the selected studies on airline industry using MCDM methods

Author(s)	Analytical method(s)	Key feature(s)
(Percin, 2018)	• Fuzzy DEMATEL • Fuzzy AHP • Fuzzy VIKOR	Airline service quality was evaluated with an integrated fuzzy decision-making approach
(Chen I.-S. , 2016)	• DEMATEL • ANP	Selected the airline service quality enhancement criteria
(Deveci, Demirel, & Ahmetoğlu, 2017)	• TOPSIS	Concentrated on the method of selecting the new route that has a significant effect on airline revenue.
(Liou & Chuang, 2009)	• AHP	Evaluated corporate image with fuzzy MCDM approach in airline industry
(Hsu & Liou, 2013)	• DEMATEL • DEMATEL based ANP	Selected the appropriate provider by MCDM
(Torlak et al. ,2011)	• Fuzzy TOPSIS	The main air carriers have been ranked with regard to the key sector success variables
(Sevkli et al., 2012)	• Fuzzy logic • Fuzzy AHP • Fuzzy ANP	A traditional multi-criteria decision-making technique was used to analyze the ranking of variables for SWOT analysis.
(Gupta, 2018)	• Best worst method • VIKOR	Sorted the best airlines in terms of attributes.
(Karaman & Akman, 2018)	• AHP	Assessed and weighted the CSR program criteria for a number of airline alternatives.
(Liou, Hsu, Yeh, & Lin, 2011)	• Grey Relation	The competitiveness of airlines in service quality has been measured.

Table 3.2: A summary of the selected studies on supplier selection in airline industry using MCDM methods

Author(s)	Analytical method(s)	Key feature(s)
(Fu, 2019)	• Analytical hierarchy process • Additive ratio assessment • Multi-choice goal programming	This paper addresses the solution for selecting catering providers.
(Jafar, Fahim, & Tavasszy, 2014)	• Conjunctive screening method • Fuzzy analytic hierarchy process (AHP)	Investigated supplier selection in the airline sector.
(Chan, Chan, IP, & Lau, 2006)	• Analytical hierarchy process	A case study on resolving the problem of SS in the airline sector via a decision support system.
(Rezaei, Fahim, & Tavasszy, 2014)	• Fuzzy analytic hierarchy process (AHP) • Conjunctive screening method	Ranked the most suitable supplier(s) for airline.
(Liou & Chuang, 2010)	• VIKOR • ANP • Decision-Making Trial and Evaluation • Laboratory (DEMATEL)	The proposed model may contribute to an improvement of the decision-making process, particularly if there are many and related criteria.

Table 3.3: A summary of the selected studies on fuel supplier selection and evaluation in airline industry using MCDM methods.

Author(s)	Analytical method(s)	Key feature(s)
(Fang & Wang, 2010)	• Evaluation index systems • Entropy method;	Developed an assessment method on the basis of relational degree analysis for jet fuel suppliers
(Cheng & Fang, 2011)	• Fuzzy evaluation • Analytic hierarchy process	Customer satisfaction of a jet fuel company is evaluated
(Bassig & Silverio, 2016)	• Conjoint Analysis	Identify the key elements of aviation fuel.
(Ogunclu, 2017)	• Hierarchical fuzzy MCDM	Selection of fuel supplier using agility concept.

4. THE DEMATEL METHOD

The DEMATEL method is a MCDM method which was used in researching and resolving the complex and interconnected problem group by (Fontela&Gabus, 1974).This methodology could confirm the interrelationship between variables / attributes a nd limit the relationship between functionality with an essential system and development tr end, based on the specific functionality of objective cases (Hori and Shimizu 1999; Tzeng et al. 2007) which is commonly used to solve complicated many problems in different areas.

Additionally, it is a procedure that uses a direct-influence graph to signify the mutual influence of the examined matter in terms of cause-and-effect relationships (Gabus and Fontela, 1972; Tzeng and Huang, 2011).

DEMATEL method`s steps could be illustrated as following:

Step 1: Creation of initial direct influence matrix(A)

The initial direct influence matrix (A) is created by a group of experts or expert with the usage of binary comparison scale to reveal the relationship between criteria. For a factor i exerts on each factor j is described as a_{ij} and the influence between them can be scaled as integer ranging from 0 to 4 representing 0: No Influence, 1: Low Influence , 2: Medium Influence, 3: High Influence, 4:Very High Influence. In direct influence matrix all diagonal values are 0.As a result of this step, it shows that how i factor affects j factor in terms of influence (Karaoğlan&Şahin, 2016).

Step 2: Creation of normalized influence matrix (M)

The normalized initial direct influence matrix (M) can be obtained by normalizing the initial direct influence matrix (A), with using 3.1 and 3.2 Equations. In this step all values in column and rows is being summing. After finding each total value of column (Scolumn) and row(Srow), max value of Scolumn and Srow is found. Then the inverse value of Scolumn and Srow is found. Then minimum value (k) is selected.

$$\mathrm{M} = \mathrm{k} \times \mathrm{A} \qquad (4.1)$$

$$\mathrm{k}=\min\left(\frac{1}{\max\sum_{j=1}^{n}|aij|}, \quad \frac{1}{\max\sum_{j=1}^{n}|aij|}\right) \qquad (4.2)$$

Step 3: Creation of total influence matrix(S)

In step 3, total influence matrix is created by using Equation 4.3 where the identity matrix is emitted as I.

$$\mathrm{S}\ |= \mathrm{M} + \mathrm{M}^2 + \mathrm{M}^3 \ldots \ldots = \sum_{i=1}^{\infty\leftarrow} \mathrm{M}^{\mathrm{i}} \qquad (4.3)$$

$$= \mathrm{M}(\mathrm{M} - 1)^{-1}$$

Step 4: Setting threshold value and obtaining the impact relation map

The sum of the column (D) and the sum of the row (R) is obtained from Matrix S by using 4.4 and 4.5 equation. D + R and D-R values show the effect level of each criterion on others and the relationship with others. Therefore, if (D+R) is positive, then factor i has effect on factors; and if (D-R) is negative, then other factors have an influence on factor i (Chuang & Liou, 2010).

$$\mathrm{S} = |\ s_{\mathrm{i,j}}|_{\mathrm{nxn}}, \mathrm{i, j} \in (1,2,3, \ldots, \mathrm{n})$$

$$\mathrm{D} = \sum_{\mathrm{i}=0}^{\mathrm{n}} \mathrm{s}_{\mathrm{i,j}} \qquad (4.4)$$

$$\mathrm{R} = \sum_{\mathrm{j}=0}^{\mathrm{n}} \mathrm{s}_{\mathrm{i,j}} \qquad (4.5)$$

Step 5: Finding the criteria weights

Total effect can be found by $D_i + R_i$ and net effect can be found by $D_i - R_i$. Afterwards weights can be calculated with quadratic mean by using 4.6 and 4.7 equation (Battal, 2018).

$$w_i = [(D_i + R_i)^2 + (D_i - R_i)^2]^{\frac{1}{2}} \tag{4.6}$$

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{4.7}$$

4.1 DEMATEL Method Used in Airline Industry

The DEMATEL method has been used to resolve decision problems in the airline industry. This method is used in a range of fields, including sales tactics, distance learning assessments, management systems, quality of system, safety issues and assessment of the causes (Haghighat, 2007).

Haghighat (2007) introduced a hybrid method for evaluating airline service criteria which uses both fuzzy DEMATEL and ANP methods. DEMATEL Method is firstly used to identify the level of influence and effect of criteria on each other that helped rank criteria based on the degree of interaction. Afterwards the network map was generated with the help of ANP method and fuzzy ANP helped to prioritize the criteria. Waiting time is less important than the others for improving the quality of airline service, as the others need to be improved at the same time the cleanliness is the least important.

Chen (2016)` s aim is to choose quality of service enhancement criteria for the airline sector in order to increase the competitive benefits of airlines. It was stated that most of the selected criteria in previous researches are technical issue and the measurement dimensions are stand alone so the service quality was measured insufficiently. This research includes all interrelations and impacts between evaluation dimensions in order to measure and enhance airline service quality.

Different financing methods are being used in airlines to expand their fleet but sector come across with many problems. Battal (2018) investigated the financing problems and explained the cause-effect relationship, the relationship level and the priority status among the problems by using the DEMATEL Method.

Liou (2012) proposed a combined method with using DEMATEL, fuzzy preference programming and ANP for selection in the airline sector. With the help of relationship map from DEMATEL, the complex relationship between criteria and chosen partners is shown.

Chang et al. (2015) presented a study by establishing a hierarchy of assessment and implementing the (DEMATEL) method. This study established a framework for airlines to analyze the interrelationship between CSR problems and to contribute a clear view of the development of CSR policies for airlines.

Hsu & Liou (2013) proposed a hybrid MCDM model for outsourcing decision problems to the airline industry using DEMATEL and ANP techniques. Multiple criteria and interdependencies between dimensions are taken into account with the DEMATEL and ANP to find the weights of criteria.

Chang & Liou (2010) put forward an integrated MCDM model. With the assistance of DEMATEL, the dependent relationships among criteria is shown. To determine the comparative weight of each criterion, the analytical network process is used. The VIKOR approach is used to prioritize the options. This integrated method can strengthen the decision making process when there are several and interlinked criteria.

Wag et al. (2011) coupled DEMATEL approach and the fuzzy linguistic approach to determine the relationships of causality and impact among different assessment criteria of an optimal airline.

5. DEFINING THE JET FUEL SUPPLIER SELECTION CRITERIA IN AIRLINE INDUSTRY

5.1 Defining General Supplier Selection Criteria

The aim is to lower the risk and enhance the total value for the purchaser and to consider certain strategic variables (Kannan & Haq, 2007). In the literature there are several general supplier selection criteria. In Dickson (1966)`s research 23 criteria were listed under supplier selection (Table 5.1). It was stated that according to the survey, the most important criteria were quality of product/service, the capability of delivering on time , performance history of supplier and warranties policies.

Table 5.1: Dickson`s vendor selection criteria

1. Quality
2. Delivery
3. Performance History
4. Warranties & Claims Policies
5. Production Facilities and Capacity
6. Price
7. Technical Capability
8. Financial Position
9. Procedural Compliance
10. Communication System
11. Reputation and Position in Industry
12. Desire for Business
13. Management and Organization
14. Operating Controls
15. Repair Service
16. Attitude
17. Impression
18. Packaging Ability
19. Labor Relations Record
20. Geographical Location
21. Amount of Past Business
22. Training Aids
23. Reciprocal Arrangements

Weber et al. (1991) `s research was improved with new literature reviews which examined 74 articles since 1966. According to the research the most important factors are net price, delivery, quality and production capabilities factors (Stević, 2017).

Table 5.2: Weber`s vendor selection criteria

1.Net price
2.Delivery
3.Quality
4.Production facilities and capabilities
5.Geographical location
6.Technical capabilities
7.Management and position in the industry
8.Reputation and position in the industry
9.Financial position
10.Performance history

5.2. Defining Jet Fuel Supplier Selection Criteria

The jet fuel suppliers are the origin of the supply chain (Figure 5.2) and the supplier selection makes a impression on the effectiveness of distribution chain which it is one of the greatest distribution chain challenges. In order not to face problems in supply chain an effective multi criteria selection mechanism has to be created on behalf of airlines. An effective selection mechanism needs first to define a clear definition of variety of diverse criteria and secondly most important criteria have to be determined for selection.

The process of jet fuel purchasing is a complicated process that not only just negotiate with fuel suppliers is enough but also need a pay attention to the other criteria of suppliers. A detailed evaluation index system has to be established to evaluate the suppliers. Up to now, not many researchers have discussed the method for evaluating jet fuel suppliers (Fang&Wang, 2010).

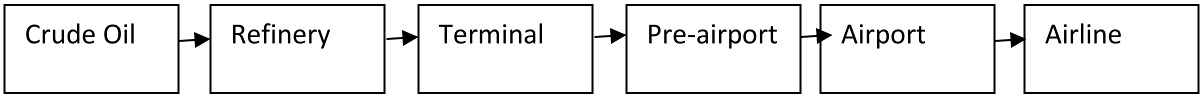

Figure 5.2: Supply Chain of Jet Fuel (IATA Aviation Fuel Management Essential Booklet)

In our research as it is mentioned before, 14 criteria were determined which have an effect on airline operational excellence based on the SS criteria declared in surveys conducted Dickson (1966) and Weber et al. (1991), benefiting from the opinion of purchasing experts and reviewing MCDM studies concerning airline industry presented in literature view section.

Fuel Cost (C1)

There is a concept of lowest bid which is the most advantageous offer to now and it is still one of the most preferable criterion for tendering process. Procurement departments try to complete the tender with minimum cost.

Payment Terms (C2)

This term indicate the period of time allowed to airline by fuel supplier to pay off the fuel invoices. It can be prepayment or in 7, 15, 30 days or other terms (businessdictionary, 2019).

Delivery Speed (C3)

The speed of refueling is important without causing delays on flights. In other words it can described as fueling aircraft on time.

Flexibility (C4)

In general, flexibility is seen as an adaptive response to environmental changeableness (Gosling, Purvis, & Naim, 2010) and the capacity of reaction ability to a system change (Morlok and Chang, 2004; Upton, 1994). For instance, airline`s schedule can be changed season to season and fuel suppliers should adapt and allocate man power accordingly with this change.

Responsiveness-Capacity (C5)

Responsiveness can be described as the capacity to react to airlines` demands at at airports purposefully within a suitable timeframe (Holveg, 2005). At airports airline operational teams call supplier operational team to start the refueling process. Between 5-10 minutes refueling truck can reach nearby the aircraft. This criteria is time value which shows the responsiveness.

Accuracy of Invoices and Agreements (C6)

After completion of tendering process, airlines started to receive agreement and regularly invoices. The accuracy of these documents is so important because it has a directly effect on the man power of airline. More accurate documents prevent extra man power in the airline management side. It's time-consuming to check all of these items for every single invoice and the risks of human error are high. It provides an indirect cost management.

Fuel Quality (C7)

Quality is a key standard for the SS. The aviation fuel supplier has to provide the relevant quality standards which were defined by IATA latest model agreement (IATA, 2017). Fuel quality is the basic survival requirement of airlines in the aviation fuel chain. The jet fuel quality affects engine directly and bad quality jet fuel causes maintenance cost. In this research, all well-qualified and verified suppliers are included to supplier selection problem. Only IATA risk score which is under 5 is acceptable.

Warranties-Insurance (C8)

Aviation is full of accident and incident risk so fuel suppliers must submit a certificate of insurance which covers the loss, injuries and damage. The liability limit of warranty changes supplier to supplier which create an extra cost on behalf of them.

Financial Condition (C9)

Financial position and the stability of condition is always crucial to every business in terms of the sustainability. This is measured through financial statements of fuel suppliers which have a positive cash flow, profit statement ,a balance of assets and owner's equity in the balance sheet (strategiccfo, 2019). Providing refueling fuel is a costly business because of logistics and storage costs so airlines prefer financial stable company in order to receive fueling service sustainably. Otherwise provider can ground any aircraft at any airport due to lack of unstable economic condition.

Support Service (C10)

A support service is an activity necessary for successful implementation of a product or service.Adequate support services are extremely important to any organization in order to succeed in their business. Currently, support services include phone calls, email, web forms, chat bots, social communications and self-service sites. Airlines generally operate flights 7/24 so should easily communicate with fuel supplier in case of emergency or any charter flights addition to scheduled flights. Also in certain periods, fuel providers invoice the fuel uplifts to airlines. Sometimes these invoices can include mistakes and it is wanted to rearrange again. So suppliers should respond quickly with correct invoices.

Employee Training (C11)

Employee training is a special program to increase specific skills or knowledge of the employees, as per the necessity of the fuel supplier and airline. For example, the airlines own expensive aircrafts and any damages incurred during refueling aircraft will be costly so fuel suppliers have to train their employees regularly according to IATA standards.

Reputation (C12)

Reputation is the overall valuation of a fuel supplier by different airlines in aviation industry. A good reputation of fuel supplier will cause airlines feel more trusting regarding business. Also airlines have an idea of straightforward business model belongs to suppliers.

Environment-Conscious Production (C13)

Environmentally conscious manufacturing (ECM) is a new approach to the production of raw materials and natural resources which concentrates on efficient production, reduces negative impacts on workers and natural environment (IISD, 2019). Fuel suppliers started to ensure compliance with environmental legislation. It includes terms like pollution prevention, energy efficiency, bio-fuel and carbon emission offsetting which are concerning fuel suppliers.

Corporate Social Responsibility (C14)

Corporate Social Responsibility is the general social responsiveness of the fuel supplier (Kumar, Palaniappan, Kannan, & Shankar, 2014) and is a self-acting business model that being ethically answerable to itself, its stakeholders, and the public. CSR score can determined with the number of activities organized by fuel suppliers.

6. PROPOSED SUPPLIER SELECTION METHODOLOGY IN AIRLINE INDUSTRY

The objective of this paper is to define fuel SS criteria which can be used in order to select the most suitable supplier from a number of alternatives. A list of possible criteria is obtained: on the basis of the SS criteria declared in surveys conducted by Dickson (1966) and Weber et al. (1991), benefiting from the opinions of purchasing experts. The fourteen criteria are listed in Table 6.1. The following step aims to identify and prioritize criteria used in the process of selecting a suitable fuel supplier for an airline company among candidate international suppliers.

Table 6. 1: Fuel supplier selection criteria for airline industry

Criteria	**Symbol**
Fuel Cost	c1
Payment terms	c2
Delivery speed	c3
Flexibility	c4
Responsiveness-Capacity	c5
Accuracy of invoices and agreements	c6
Fuel quality	c7
Warranties and insurance	c8
Financial condition	c9
Support service	c10
Company's Training Management	c11
Reputation	c12
Environment-conscious production	c13
Corporate social responsibility	c14

Step 1: The initial direct influence matrix is shown in Table 6.2. The influence degree of is assigned to each criterion and the 0 value is assigned to diagonal matrix. The influence between criteria can be scaled as integer ranging from 0 to 4 representing 0: No Influence, 1: Low Influence, 2: Medium Influence, 3: High Influence, 4: Very High Influence. To illustrate, Cost (C1) has a very high influence (3) on Fuel quality (C7).

Table 6.2: Initial direct influence matrix for fuel supplier selection criteria (A)

Criteria(c)	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14
c1	0	3	1	2	2	2	4	4	3	2	2	1	2	2
c2	4	0	2	0	2	1	0	0	2	1	0	1	0	0
c3	3	0	0	3	4	0	0	0	0	3	1	3	0	0
c4	2	0	2	0	3	0	0	2	1	2	1	1	0	0
c5	4	1	2	3	0	1	1	0	0	0	0	3	0	0
c6	2	2	2	2	2	0	4	4	1	3	3	1	3	0
c7	4	0	0	0	0	0	0	4	2	0	0	4	1	0
c8	4	0	0	0	1	0	4	0	3	0	2	3	0	0
c9	3	3	2	2	1	0	3	2	0	2	3	3	2	4
c10	2	1	2	2	3	0	0	0	1	0	0	1	0	0
c11	0	0	2	2	2	0	0	2	0	3	0	3	1	0
c12	2	2	1	1	1	0	0	0	3	0	0	0	2	2
c13	3	1	0	0	0	0	3	0	2	0	1	3	0	0
c14	1	1	0	0	0	0	0	0	1	0	0	3	0	0

Step 2: All columns and rows are summed. Then normalized direct influence matrix is found represented in Table 6.4 with using Equation 4.1 and 4.2.

Table 6.3: Initial direct influence matrix, Sum of Rows and Columns

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	SRow
c1	0	3	1	2	2	2	4	4	3	2	2	1	2	2	30
c2	4	0	2	0	2	1	0	0	2	1	0	1	0	0	13
c3	3	0	0	3	4	0	0	0	0	3	1	3	0	0	17
c4	2	0	2	0	3	0	0	2	1	2	1	1	0	0	14
c5	4	1	2	3	0	1	1	0	0	0	0	3	0	0	15
c6	2	2	2	2	2	0	4	4	1	3	3	1	3	0	29
c7	4	0	0	0	0	0	0	4	2	0	0	4	1	0	15
c8	4	0	0	0	1	0	4	0	3	0	2	3	0	0	17
c9	3	3	2	2	1	0	3	2	0	2	3	3	2	4	30
c10	2	1	2	2	3	0	0	0	1	0	0	1	0	0	12
c11	0	0	2	2	2	0	0	2	0	3	0	3	1	0	15
c12	2	2	1	1	1	0	0	0	3	0	0	0	2	2	14
c13	3	1	0	0	0	0	3	0	2	0	1	3	0	0	13
c14	1	1	0	0	0	0	0	0	1	0	0	3	0	0	6
SColumn	34	14	16	17	21	4	19	18	19	16	13	30	11	8	

Max(SColumn):	34	Max(SRow):	30
1/ Max(SColumn):	0.0294	1/Max(SRow):	0.033
k:	0.0294		

Table 6.4: Normalized Direct Influence Matrix(M)

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14
c1	0.00	0.09	0.03	0.06	0.06	0.06	0.12	0.12	0.09	0.06	0.06	0.03	0.06	0.06
c2	0.12	0.00	0.06	0.00	0.06	0.03	0.00	0.00	0.06	0.03	0.00	0.03	0.00	0.00
c3	0.09	0.00	0.00	0.09	0.12	0.00	0.00	0.00	0.00	0.09	0.03	0.09	0.00	0.00
c4	0.06	0.00	0.06	0.00	0.09	0.00	0.00	0.06	0.03	0.06	0.03	0.03	0.00	0.00
c5	0.12	0.03	0.06	0.09	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.09	0.00	0.00
c6	0.06	0.06	0.06	0.06	0.06	0.00	0.12	0.12	0.03	0.09	0.09	0.03	0.09	0.00
c7	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.06	0.00	0.00	0.12	0.03	0.00
c8	0.12	0.00	0.00	0.00	0.03	0.00	0.12	0.00	0.09	0.00	0.06	0.09	0.00	0.00
c9	0.09	0.09	0.06	0.06	0.03	0.00	0.09	0.06	0.00	0.06	0.09	0.09	0.06	0.12
c10	0.06	0.03	0.06	0.06	0.09	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00
c11	0.00	0.00	0.06	0.06	0.06	0.00	0.00	0.06	0.00	0.09	0.00	0.09	0.03	0.00
c12	0.06	0.06	0.03	0.03	0.03	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.06	0.06
c13	0.09	0.03	0.00	0.00	0.00	0.00	0.09	0.00	0.06	0.00	0.03	0.09	0.00	0.00
c14	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.09	0.00	0.00

Table 6.5: Identity Matrix(I)

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14
c1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c2	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c3	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c4	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c5	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c6	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
c9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
c10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
c11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
c12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
c13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
c14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Step 3: The Normalized matrix is subsracted from Identity Matrix represented in Table 6.6 and the inverse value of Matrix(I-M) is obtained represented in Table 6.7. Then with using Equation 3.3, the total influence matrix is obtained represented in Table 6.8.

Table 6.6: Initial Matrix-Normalized Matrix(I-M)

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14
c1	1.00	-0.09	-0.03	-0.06	-0.06	-0.06	-0.12	-0.12	-0.09	-0.06	-0.06	-0.03	-0.06	-0.06
c2	-0.12	1.00	-0.06	0.00	-0.06	-0.03	0.00	0.00	-0.06	-0.03	0.00	-0.03	0.00	0.00
c3	-0.09	0.00	1.00	-0.09	-0.12	0.00	0.00	0.00	0.00	-0.09	-0.03	-0.09	0.00	0.00
c4	-0.06	0.00	-0.06	1.00	-0.09	0.00	0.00	-0.06	-0.03	-0.06	-0.03	-0.03	0.00	0.00
c5	-0.12	-0.03	-0.06	-0.09	1.00	-0.03	-0.03	0.00	0.00	0.00	0.00	-0.09	0.00	0.00
c6	-0.06	-0.06	-0.06	-0.06	-0.06	1.00	-0.12	-0.12	-0.03	-0.09	-0.09	-0.03	-0.09	0.00
c7	-0.12	0.00	0.00	0.00	0.00	0.00	1.00	-0.12	-0.06	0.00	0.00	-0.12	-0.03	0.00
c8	-0.12	0.00	0.00	0.00	-0.03	0.00	-0.12	1.00	-0.09	0.00	-0.06	-0.09	0.00	0.00
c9	-0.09	-0.09	-0.06	-0.06	-0.03	0.00	-0.09	-0.06	1.00	-0.06	-0.09	-0.09	-0.06	-0.12
c10	-0.06	-0.03	-0.06	-0.06	-0.09	0.00	0.00	0.00	-0.03	1.00	0.00	-0.03	0.00	0.00
c11	0.00	0.00	-0.06	-0.06	-0.06	0.00	0.00	-0.06	0.00	-0.09	1.00	-0.09	-0.03	0.00
c12	-0.06	-0.06	-0.03	-0.03	-0.03	0.00	0.00	0.00	-0.09	0.00	0.00	1.00	-0.06	-0.06
c13	-0.09	-0.03	0.00	0.00	0.00	0.00	-0.09	0.00	-0.06	0.00	-0.03	-0.09	1.00	0.00
c14	-0.03	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	-0.09	0.00	1.00

Table 6.7: Matrix (I-M)^-1

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14
c1	1.14	0.14	0.09	0.12	0.13	0.07	0.19	0.19	0.17	0.11	0.11	0.15	0.10	0.10
c2	0.178	1.04	0.09	0.04	0.10	0.04	0.04	0.04	0.10	0.06	0.03	0.08	0.03	0.03
c3	0.15	0.04	1.04	0.13	0.17	0.02	0.04	0.04	0.04	0.12	0.05	0.14	0.02	0.02
c4	0.12	0.03	0.09	1.04	0.13	0.01	0.04	0.09	0.07	0.09	0.05	0.08	0.02	0.02
c5	0.18	0.06	0.09	0.12	1.05	0.04	0.07	0.05	0.05	0.04	0.03	0.14	0.03	0.02
c6	0.19	0.11	0.11	0.12	0.13	1.02	0.19	0.19	0.11	0.14	0.13	0.14	0.12	0.03
c7	0.19	0.04	0.03	0.03	0.04	0.01	1.06	0.16	0.12	0.03	0.04	0.18	0.06	0.04
c8	0.19	0.05	0.04	0.04	0.07	0.01	0.17	1.06	0.14	0.04	0.09	0.16	0.04	0.04
c9	0.20	0.14	0.11	0.11	0.10	0.02	0.15	0.12	1.08	0.11	0.13	0.19	0.10	0.15
c10	0.11	0.06	0.09	0.09	0.13	0.01	0.03	0.03	0.06	1.03	0.02	0.07	0.02	0.02
c11	0.06	0.03	0.09	0.09	0.10	0.01	0.03	0.08	0.04	0.11	1.02	0.13	0.05	0.02
c12	0.12	0.09	0.06	0.06	0.07	0.01	0.04	0.03	0.12	0.03	0.03	1.06	0.08	0.08
c13	0.15	0.06	0.03	0.03	0.03	0.01	0.12	0.04	0.10	0.03	0.05	0.14	1.03	0.03
c14	0.06	0.05	0.01	0.01	0.02	0.01	0.01	0.01	0.05	0.01	0.01	0.11	0.01	1.02

Table 6.8: Total Influence Matrix (Matrix (M) * Matrix (I-M)^-1

c	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	D
c1	0.14	0.14	0.09	0.12	0.13	0.07	0.19	0.19	0.17	0.11	0.11	0.15	0.10	0.10	1.80
c2	0.18	0.04	0.09	0.04	0.10	0.04	0.04	0.04	0.10	0.06	0.03	0.08	0.03	0.03	0.91
c3	0.15	0.04	0.04	0.13	0.17	0.02	0.04	0.04	0.04	0.12	0.05	0.14	0.02	0.02	1.02
c4	0.12	0.03	0.09	0.04	0.13	0.01	0.04	0.09	0.07	0.09	0.05	0.08	0.02	0.02	0.88
c5	0.18	0.06	0.09	0.12	0.05	0.04	0.07	0.05	0.05	0.04	0.03	0.14	0.03	0.02	0.98
c6	0.19	0.11	0.11	0.12	0.13	0.02	0.19	0.19	0.11	0.14	0.13	0.14	0.12	0.03	1.73
c7	0.19	0.04	0.03	0.03	0.04	0.01	0.06	0.16	0.12	0.03	0.04	0.18	0.06	0.04	1.02
c8	0.19	0.05	0.04	0.04	0.07	0.01	0.17	0.06	0.14	0.04	0.09	0.16	0.04	0.04	1.14
c9	0.20	0.14	0.11	0.11	0.10	0.02	0.15	0.12	0.08	0.11	0.13	0.19	0.10	0.15	1.71
c10	0.11	0.06	0.09	0.09	0.13	0.01	0.03	0.03	0.06	0.03	0.02	0.07	0.02	0.02	0.76
c11	0.06	0.03	0.09	0.09	0.10	0.01	0.03	0.08	0.04	0.11	0.02	0.13	0.05	0.02	0.85
c12	0.12	0.09	0.06	0.06	0.07	0.01	0.04	0.03	0.12	0.03	0.03	0.06	0.08	0.08	0.88
c13	0.15	0.06	0.03	0.03	0.03	0.01	0.12	0.04	0.10	0.03	0.05	0.14	0.03	0.03	0.86
c14	0.06	0.05	0.01	0.01	0.02	0.01	0.01	0.01	0.05	0.01	0.01	0.11	0.01	0.02	0.38
R	2.04	0.93	0.97	1.06	1.27	0.30	1.18	1.13	1.25	0.94	0.79	1.77	0.71	0.61	

Step 4: Total effect is obtained by $D_i + R_i$ and net effect is obtained by $D_i - R_i$. Then with the usage of Equation 4.6 and 4.7, weights is obtained represented in Table 6.9.

Table 6.9: Weights of fuel supplier selection criteria

Criteria	D	R	D+R	D-R	w	W
c1	1.80	2.04	3.85	-0.24	3.85	0.126
c2	0.91	0.93	1.84	-0.02	1.84	0.060
c3	1.02	0.97	1.99	0.05	1.99	0.065
c4	0.88	1.06	1.94	-0.18	1.95	0.064
c5	0.98	1.27	2.24	-0.29	2.26	0.074
c6	1.73	0.30	2.03	1.43	2.48	0.081
c7	1.02	1.18	2.19	-0.16	2.20	0.072
c8	1.14	1.13	2.26	0.01	2.26	0.074
c9	1.71	1.25	2.96	0.47	2.99	0.098
c10	0.76	0.94	1.69	-0.18	1.70	0.056
c11	0.85	0.79	1.63	0.06	1.63	0.053
c12	0.88	1.77	2.65	-0.89	2.79	0.091
c13	0.86	0.71	1.57	0.16	1.57	0.052
c14	0.38	0.61	0.99	-0.22	1.01	0.033
				Total	30.55	1

Tablo 6.10: Ranking criteria

Criteria	D	R	D+R	D-R	w	W	Names
c1	1.80	2.04	3.85	-0.24	3.85	0.126	Fuel Cost
c9	1.71	1.25	2.96	0.47	2.99	0.098	Financial condition
c12	0.88	1.77	2.65	-0.89	2.79	0.091	Reputation
c6	1.73	0.30	2.03	1.43	2.48	0.081	Accuracy of invoices and agreements
c8	1.14	1.13	2.26	0.01	2.26	0.074	Warranties and insurance
c5	0.98	1.27	2.24	-0.29	2.26	0.074	Responsiveness
c7	1.02	1.18	2.19	-0.16	2.20	0.072	Fuel quality
c3	1.02	0.97	1.99	0.05	1.99	0.065	Delivery speed
c4	0.88	1.06	1.94	-0.18	1.95	0.064	Flexibility
c2	0.91	0.93	1.84	-0.02	1.84	0.060	Payment terms
c10	0.76	0.94	1.69	-0.18	1.70	0.056	Support service
c11	0.85	0.79	1.63	0.06	1.63	0.053	Company's Training Management
c13	0.86	0.71	1.57	0.16	1.57	0.052	Environment-conscious production
c14	0.38	0.61	0.99	-0.22	1.01	0.033	Corporate social responsibility

In light with the Table 9, the most important criterion is the cost of fuel (C1), financial condition (C9), reputation of the fuel company (C12), accuracy of agreements and invoices (C6), warranties and insurance (C8), responsiveness (C5) and the product quality (C7) which has a normalized weight over 0.070. The average value is 2.18 for 14 weights so the threshold value was agreed as 2.00 and 7 criteria are over the threshold value.

After finding the most important criteria, 0-1 GP is being used to select the most preferable fuel supplier among alternatives.

GP is usually a multi-objective programming method which can be also regarded as a mathematical programming and MCDM method. In the GP model, target levels are assigned to all of the objectives for achievement and importance weights are assigned for objective function.

Table 6.11 Selected Criteria with Units

Symbol	**Criteria**	**Unit**
c1	Cost	Million $
c9	Financial condition	1 to 5
c12	Reputation	0 to 100
c6	Accuracy of agreements and invoices	1 to 5
c8	Warranties and insurance	Billion $
c5	Responsiveness	1 to 5
c7	Product quality	0 to 5 (IATA risk score: 0 risk is the best)

Cost criteria value is obtained with the help of received offers for one airport which are offered by fuel suppliers. Financial condition, reputation and responsiveness criterion is obtained by observation. The accuracy of agreements and invoices is measured with the number of wrong documents. Additionally, the insurance value is taken from the insurance certificates and IATA risk score for product quality is found from IATA quality pool.

Table 6.12: Assigned Values to Fuel Supplier According to the Criteria

Fuel Supplier	C1	C9	C12	C6	C8	C5	C7
Supplier alternative 1	1.5	4	80	4	0.8	3	0.1
Supplier alternative 2	1.55	5	85	3	1	5	0.1
Supplier alternative 3	1.56	3	75	5	0.8	4	0.5
Supplier alternative 4	1.56	5	85	4	1	5	1.1
Supplier alternative 5	1.62	5	90	5	1	5	1.97

The actual values are assigned to 5 supplier alternatives for 7 seven criteria.

Table 6.13: Normalized Assigned Values to Fuel Supplier

Fuel Supplier	C1	C9	C12	C6	C8	C5	C7
Supplier alternative 1	1	0.8	0.889	0.8	0.8	0.6	1
Supplier alternative 2	0.968	1	0.944	0.6	1	1	1
Supplier alternative 3	0.962	0,6	0.833	1	0.8	0.8	0.2
Supplier alternative 4	0.962	1	0.944	0.8	1	1	0.091
Supplier alternative 5	0.926	1	1	1	1	1	0.051

The assigned values for criteria are normalized.

Table 6.14: Target Value for Criteria

Criteria	C1	C9	C12	C6	C8	C5	C7
	1.6	4	80	4	0.8	4	0.1

The target values are assigned to 7 criteria.

Table 6.15: Normalized Target Value for Criteria

Criteria	C1	C9	C12	C6	C8	C5	C7
	0.938	0.8	0.889	0.8	0.8	0.8	1

Table 6.16: Normalized Weights for Criteria

C1	0.204
C9	0.159
C12	0.148
C6	0.132
C8	0.120
C5	0.120
C7	0.117

The normalized target value for criteria which are the right-hand side values for the constraints, are given in the Table 6.15. The weights used in the weighted 0-1 goal programming model are shown I Table 6.16. The 0-1 goal programming is employed to determine the supplier alternative which minimizes the weighted sum of deviation from the target.

0-1 Goal Programming Model:

Min Z= $0.204* d_1^- + 0.159* d_2^- + 0.148* d_3^- + 0.132* d_4^- + 0.120* d_5^- + 0.120* d_6^- + 0.117 d_7^-$

s.t.

$1 x_1 + 0.968 x_2 + 0.962 x_3 + 0.962 x_4 + 0.926 x_5 + d_1^- - d_1^+ = 0.938$

$0.8 x_1 + 1 x_2 + 0.6 x_3 + 1 x_4 + 1 x_5 + d_2^- - d_2^+ = 0.8$

$0.889 x_1 + 0.944 x_2 + 0.833 x_3 + 0.944 x_4 + 1 x_5 + d_3^- - d_3^+ = 0.889$

$0.8 x_1 + 0.6 x_2 + 1 x_3 + 0.8 x_4 + 1 x_5 + d_4^- - d_4^+ = 0.8$

$0.8 x_1 +1 x_2 +0.8 x_3 +1 x_4 +1 x_5 + d_5^- - d_5^+ =0.8$

$0.6 x_1 + 1 x_2 + 0.8 x_3 + 1 x_4 + 1 x_5 + d_6^- - d_6^+ = 0.8$

$1 x_1 + 1 x_2 + 0.2 \ x_3 + 0.091 x_4 + 0.051 x_5 + d_7^- - d_7^+ = 1$

$\sum_1^5 Xi =1 \ \ x_i$ € (0.1),

$d_1^-, d_1^+, d_2^- - d_2^+, d_3^- \ d_3^+, d_4^-, d_4^+, d_5^-, d_5^+, d_6^-, d_6^+, d_7^-, d_7^+ \geq 0$

The goal programming model is solved by using “GAMS” software. At the end of the goal GP phase, supplier alternative 1 is selected. This supplier`s fuel offer cost 1.55 Million USD for an airport and it is the minimum. When it comes to comparing the other criteria, its risk score is minimum.

7. CONCLUSION

In terms of cost and performance management, supplier selection in the airline sector plays a major role because the cost of aviation fuel for airlines reach almost one-quarter of their total cost. In the past, the highest proportion of the operating costs was in aircraft acquisitions and staff wages. The fuel cost proportion of the total expenditure has been increasing steadily since 2016. Contemporary supply chain management requires combining more qualitative and quantitative criteria and solved by MCDM. Consequently, airline companies can integrate MCDM methods into their selection processes to gain greater levels of success. Decision makers must use the best approach and exact tangible, intangible criteria for analysis and resolution of selection issues for fuel suppliers.

As it is mentioned earlier, with regard to studies about supplier selection in the aviation industry, there are limited numbers of studies available so it was decided to choose a fuel supplier with a MCDM approach. Also in the aviation industry, the fuel suppliers can win the tender with the best bid but without considering the other attributes of suppliers can lead to many problems. The procurement or purchasing of aviation fuel is a complicated process so it is more than negotiating and bargaining with suppliers. To assess suppliers thoroughly, a full, scientific and detailed assessment system should be established.

The most appropriate fuel supplier is aimed to select from 5 alternatives for an airport evaluating under applicable criteria. Two phased integrated MCDM Approach is applied. Firstly, the DEMATEL method is employed for determining the influence level of fuel supplier selection criteria and secondly 0-1 Goal Programming method is employed for deciding the most appropriate supplier.

DEMATEL is useful for addressing complicated and interconnected problem group and it can check the interaction between the selection criteria and provide a particular diagram . Furthermore, it decrease the numbers of criteria to be checked. Accordingly, it is applied while ranking the criteria for fuel supplier selection. 0-1 Goal Programming is advantageous if there are many targets under different criteria and unit instead of Linear Programming so this programming method was chose for finding the suitable supplier.

Prior to applying DEMATEL Method, all criteria that will be used for selection were defined clearly and generated compatibly with airlines` objectives. Eventually, 14 criteria were determined in this research which have an effect on operational excellence of airline gaining from earlier studies. After applying this method, it is found that the most crucial criteria are the cost of fuel, financial condition, the reputation of the fuel companies, accuracy of agreements and invoices, warranties and insurance, responsiveness and the product quality.

In the application of Zero-One Goal Programming (GP) step, target values are assigned for each 5 alternative suppliers which is represented in the Table 6.13. After solving the model under the targets, supplier alternative 1 is selected.

To sum up, with this integrated method which includes MCDM and Mathematical Programming methods, airline can reduce the risk of supply chain, minimize the cost, increase the total value and decrease the man power after making an agreement with supplier. In other words, airlines may handle expected and unexpected supply chain occurrences if evaluate suppliers with this method. As a result, they have a domination in the competitive airline sector. Also suppliers start to enhance the features of goods/service and define the priorities accordingly which are demanded by airlines.

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BIOGRAPHICAL SKETCH

Eren Erol was born in Ankara in 1991. After graduation from TED Ankara College Private High School, he received a Bachelor of Science with a major in Industrial Engineering in 2013. Following year he was employed as credit analyst. Currently, he is working as an engineer at fuel management department of an airline company. He is the co-author of the paper entitled "Evaluating Supplier Selection Criteria in the Airline Industry using DEMATEL Method" which was published in the proceedings of the International Academic Conference on Management, Economics and Marketing in Budapest 2019 (IAC-MEM 2019).