GALATASARAY UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

AIRCRAFT SELECTION IN AIRLINE FLEET MANAGEMENT

Murat YİLANLİ

Feb 2020

AIRCRAFT SELECTION IN AIRLINE FLEET MANAGEMENT

(HAVAYOLU FİLO PLANLAMA YÖNETİMİNDE HAVA ARACI SEÇİMİ)

by

Murat YİLANLİ, B. S.

Thesis

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

in

LOGISTICS AND FINANCIAL MANAGEMENT

in the

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

Feb 2020

This is to certify that the thesis entitled

AIRCRAFT SELECTION IN AIRLINE FLEET MANAGEMENT

prepared by **Murat YİLANLİ** in partial fulfillment of the requirements for the degree of **Master of Science in Logistics and Financial Management** at the **Galatasaray University** is approved by the

Examining Committee:

Asist. Prof. Dr. Zeynep ŞENER (Supervisor)
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. Orhan İlker BAŞARAN
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. Melis Almula KARADAYI
Department of Industrial Engineering
Istanbul Medipol University -------------------------

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

ACKNOWLEDGEMENTS

I express sincere appreciation to Assist. Prof. Zeynep Şener for the guidance throughout the research. Her big support and guidance helped me to finish the work successfully

I want to send the special thanks to my wife, mother, father and brother. Their endless support was the biggest motivation to complete this process.

I am grateful to all my executives enabling me to manage to handle both my job and academic researches simultaneously.

The last but not least thank is for my colleagues and friends. Their creative thinking played an important role in my research.

Feb 2020

Murat Yilanli

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The aviation sector has become a sector that has been marked by the 20th century and has been developing continuously with the elements it contains. With the rapid development of technology and the deregulation of aviation in 1978, the competition among airlines, which are the most important element of aviation, has started to increase much faster. This increasing competition forced airlines to make large investments and strategic decisions to analyze the long-term effects and consequences of strategic decisions. Fleet planning, which is interested in how and with which strategy airlines should expand their fleets, is also an area that plans airlines both structurally and financially. The increasing competition has brought the importance of fleet planning to the surface.

Fleet planning makes decisions for airlines to make the right aircraft at the right time and in line with the desired conditions. Fleet planning analyzes the environmental, financial and technological implications of the aircraft to be included in the fleet. The purchase of aircraft, which is the biggest investment of airlines, can lead to the bankruptcy of airlines if it is not done in a very good planning framework. For this reason, aircraft selection and aircraft purchase is one of the most important strategic decisions of airlines.

In this study, a Multiple Criteria Decision Making (MCDM) approach was proposed by using Decision Making Trial and Evaluation Laboratory (DEMATEL) and Weighted Distance Metric based evaluation method. Firstly, the factors affecting the choice of aircraft and the effect of these factors on each other were calculated. DEMATEL method was used to calculate this effectiveness of criteria. The criteria were compared in pairs and the decision makers determined their effects. Firstly these criteria as follows were determined: Purchase cost, fuel efficiency, terms of payment, maintenance cost, insurance cost, handling cost, commonality of the fleet, seat capacity, cabin structure, cargo capacity, noise pollution, delivery time and maximum take-off weight.

Criteria below a determined threshold which was specified by decision makers were eliminated and the criteria that affect the decision makers the most were selected. These criteria are purchase cost, cost effectiveness, seat capacity, flight range, cargo capacity and maximum take-off weight.

Secondly, the decision of which aircraft to buy for the decision maker with the criteria obtained is determined by weighted distance metric model. According to the target that is determined by the decision makers and the distance to the target, the decision makers make choice among alternatives. The resulting MCDM approach will already allow airlines to make more accurate decisions for fleet planning and to make decisions that are more logical in strategic decisions.

Key Words: Investment Management in Aviation, Fleet Planning, Multiple Criteria Decision Making

ÖZET

Havacılık sektörü içinde bulundurduğu elementlerle beraber 20. Yüzyıla damgasını vuran ve sürekli gelişim gösteren bir sektör olagelmiştir. Teknolojinin hızla gelişmesi ve 1978 yılında havacılıkta deregülasyonun gerçekleşmesiyle beraber havacılığın en önemli elementi olan havayolları için rekabet çok daha hızlı bir şekilde artmaya başlamıştır. Artan bu rekabet büyük yatırımların yapıldığı ve stratejik kararların alındığı havayolları firmalarını aldıkları stratejik kararların uzun vadeli etkilerini ve sonuçlarını çok iyi analiz etmek zorunda bırakmıştır. Havayollarının filolarını hangi stratejiyle büyütmesi gerektiği ve ne yönede geliştirmesiyle ilgilenen filo planlama da, havayollarını hem yapısal hem de finansal açıdan planlayan bir alandır. Rekabetin artması filo planlamının önemini çok daha gün yüzüne çıkarmıştır.

Filo planlama, havayolu firmaları için doğru hava aracının doğru zamanda ve istenilen şartlar doğrultusunda havayoluna kazandırılması için kararlar almaktadır. Filoya dahil edilcek hava aracının firmaya olan çevresel, finansal ve teknolojik etilerini analiz eder. Havayollarının en büyük yatırımları olan hava aracı satın alımı çok iyi bir planlama çerçevesinde yapılmazsa havayollarının iflasına bile sebep olabilmektedir. Bu sebepe hava aracı seçimi ve satın alınması hava yollarının en önemli stratejik kararlarından biridir.

Bu çalışmada, DEMATEL ve Ağırlıklı Uzaklık Metriği temelli değerlendirme yöntemi kullanılarak bir Çok Ölçütlü Karar Verme (ÇÖKV) yaklaşımı önerilmiştir. İlk olarak hava aracı seçimini etkileyen faktörler ve bu faktörlerin biribirini ne derece etkilediği hesaplanmış olup bu faktörlerin oluşturulacak olan modelde hava aracı seçiminin kararını ne derece etkilediği işlenmiştir. Bu etkinliğin hesaplanması için DEMATEL yöntemi kullanılmıştır. İlk aşamada karar vericiler tarafından ölçütler belirlenmiştir. Bu ölçütler şu şekildedir: Satın alma maliyeti, yakıt etkinliği, ödeme koşulları, bakım maliyetleri, sigorta maliyetleri, yer hizmetleri maliyetleri, filo benzerliği, koltuk kapasitesi, kabin yapısı, kargo kapasitesi, ses kirliliği düzeyi, teslim süresi ve maksimum kalkış ağırlığıdır. Kullanılan yöntem ile ölçütler ikili olarak karşılaştırılıp etki dereceleri karar vericiler tarafından belirlenmiştir. Belirli bir eşik değerinin altında kalan ölçütler elenmiş olup karar vericiyi en çok etkileyen ölçütler seçilmiştir. Bunlar satın alma maliyeti, maliyet etkinliği, koltuk kapasitesi menzil, kargo kapasitesi ve maksimum kalkış ağırlığıdır.

İkinci adım olarak elde edilen ölçütler ile beraber karar verici için hangi hava aracının satın alınacağı kararı ağırlıklı uzaklık yöntemiyle belirlenmiştir. Karar verici tarafından belirlenen hedef ve bu hedefe olan yakınlığa göre alternatifler arasından seçim yapılmıştır. Ortaya çıkan ÇÖKV yaklaşımı hali hazırda tarifeli sefer havayollarının filo planlaması için daha doğru kararlar verip alacakları stratejik kararlarda daha mantıksal hareket etmelerine imkan sağlayacaktır.

Anahtar Sözcükler: Havacılıkta Yatırım Yönetimi, Filo Planlama, Çok Ölçütlü Karar Verme

1. INTRODUCTION

Investment management enables enterprises to take strategic decisions within the framework of growth in line with the determined objectives and targets in line with the appropriate resources and conditions. The analysis of these decisions, their financial and corporate feasibility, their contribution to the company and determination of the possible outcomes in possible scenarios are under the responsibility of investment management. Investment management is also a very important place in the aviation sector.

Airlines, aircraft manufacturers and airports, which make up the elements of the aviation industry, have initial investment and operating costs much higher than other agents, GSA operators and distributors. For this reason, the decisions taken by these three major employees as investment management are as important and critical as the first investment capital of the company. The decision for new market, a new tender offer for an airport authority or planning of the cutting of production of a product which has been already on the market due to scarce resources are strategic decisions and these decisions are analyzed and concluded within the framework of investment management.

Although airlines, aircraft manufacturers and airport operators have high initial investment costs, airlines have the lowest profit margin and return on capital compared to the other elements of aviation (Yılmaz, 2006). The competition has progressed very rapidly due to the fact that airlines are in the service sector and the technology required to provide this service can be easily purchased. It is estimated that the number of aircraft operating in the aviation industry in 2029 will be twice that of 2009, which is one of the peak periods of aviation (Airbus, 2009). Due to this strict competition, some airlines went bankrupt or came to the brink of bankruptcy and the profits of airlines in the world fluctuated constantly.

Decisions such as launching flights to a new market for an airline, deciding to leave the market in which it currently operates, or including new aircraft in its fleet are also decisions taken and implemented within the framework of investment management of an airline company. Major airlines also establish fleet management within their own organization to manage the decision-making process of the aircraft to be included in the fleet.

Fleet planning is concerned with the type and model of the aircraft that the airlines want to include in their fleet and the period in which it should enter the fleet. Although the fleet management of each airline company does not proceed under the same conditions, there are generally two criteria on which it is based. The first is which aircraft they will buy; second is when they will be involved in the fleet. While airline companies evaluated the aircraft that would be included in the fleet from their own perspective in the previous years, when the competition was not intense, customer satisfaction and security were included in this perspective in the 21st century (Wu et al., 2012). Fleet planners have to decide under more difficult conditions for airlines with increased competition. During the decision stages the unit cost of the aircraft to be purchased must be very low; the service quality in terms of passengers must also be high (Dožić et al., 2018).

The airline companies take into account the criteria such as the performance and cost of aircraft and its financial burden on airline. Using a combination of all these, a decision model is formed and the decision is made for the most suitable aircraft (Dožić et al., 2018).

Since fleet planning includes both aircraft purchase and aircraft rental, aircraft purchase is a sub-topic of fleet planning. Purchase of aircraft has advantages and disadvantages compared to aircraft rental. While easy inventory control, providing tax ease and being cheaper in the long term are the advantages of purchasing an aircraft, high capital requirements and low fleet flexibility are also disadvantages. Major 5-star airlines in the world generally prefer to expand their fleet by purchasing aircraft.

In this master thesis, the criteria that affect fleet planners' decisions from the purchase of aircraft for the fleet planning department of an airline company are determined and the effect weights of these criteria on the fleet planners' decisions are calculated by DEMATEL method. These criteria are as follows. Purchasing cost, Fuel effectiveness, payment terms, maintenance cost, insurance cost, ground handling cost, commonality, seat capacity, cabin structure, flight range, cargo capacity, noise pollution, delivery time and take-off weight. These criteria were determined based on the literature review and fleet management experts' opinions. The reason for the application of DEMATEL method is the effect of these criteria on each other and it is important for the decision makers. A threshold value has been determined and the number of criteria has been reduced according to this threshold value.

After the determination of the weights, the new generation 4 aircrafts were chosen as alternatives. The decision was made among these 4 aircrafts. In order to choose best alternative, the distance of each alternative was calculated from target values by using weighted distance metric method.

The rest of the thesis is organized as follows;

Chapter 2 involves a literature review about investment management, fleet management, the problem definition that airlines companies face during aircraft purchasing, criteria. Chapter 3 presents a multiple criteria decision making framework using DEMATEL and weighted distance method for aircraft selection. Chapter 4 includes the application of the proposed approach in Turkish aviation industry. Chapter 5 concludes the thesis and discusses the further works, which can be done in the future.

2. LITERATURE REVIEW

2.1. Investment Management

Companies, government agencies and foundations are constantly working to carry out the mission of their organizations and to realize their targeted visions. Organizations make decisions in order to continue their work and achieve their goals in their management at all levels. The total of these decisions is tried to reach the target growth of the organization.

The decisions taken by the organizations are divided into 3 in terms of risk, maturity and scope.

- Strategic Decisions
- Tactical Decisions
- Operational Decisions

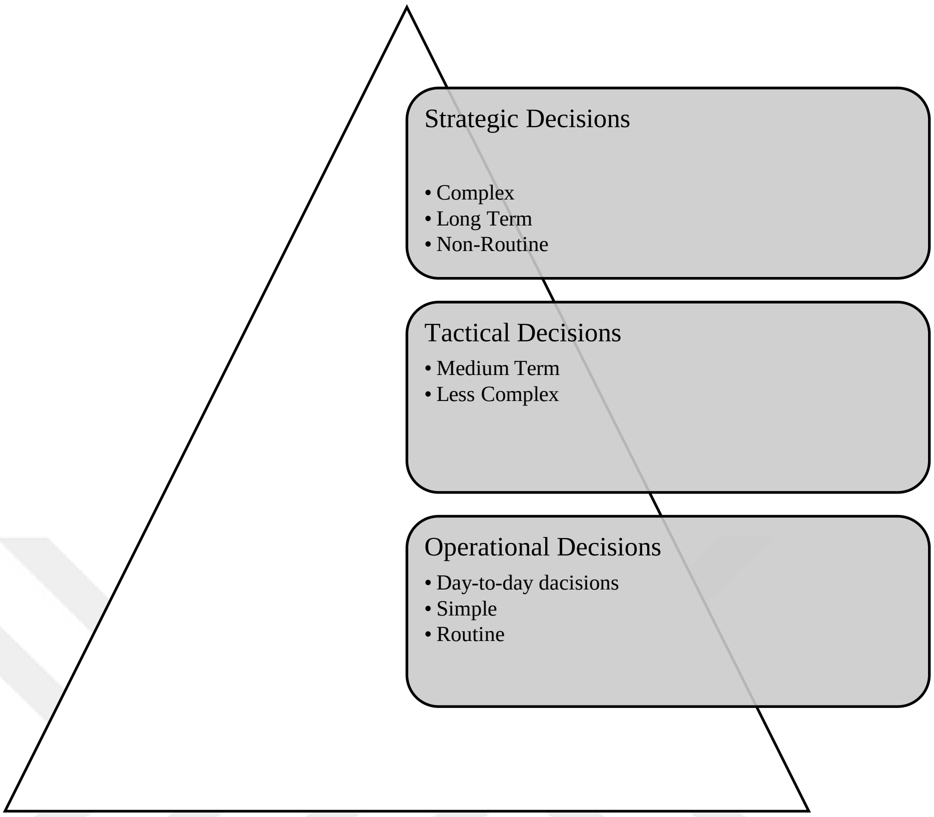

Figure 2.1: The Main Features of Decisions (Sivak & Schoettle, 2012)

Investment management is the totality of strategic decisions taken by organizations to achieve their goals with minimum cost and maximum efficiency. Investment management is evaluated within the framework of strategic decisions in terms of maturity, risk and impact on the organization. Commercial companies continuously prepare strategic plans to meet the growth targets they set for the following year. The majority of these plans, which include strategic decisions for the company, are investment decisions.

Due to being a sector which have also large investments, in aviation sector the importance of strategic decisions taken in the investment comes to the forefront. Aircraft manufacturers, airline companies and airports, which are among the most important members of the aviation sector, are the members which high investments are required.

The risk of the decisions to be taken is very high and it can even lead to bankruptcy of companies with a possible wrong decision. Because these three members have the lowest ROI rate which is abbreviation of "return of investment" rate and their investments are very high.

With the deregulation and fast developing technology in 1978, the airline companies in the world, especially the American-origin airlines, entered a rapid growth phase. Competition between the airline companies began to increase very much due to the large investments made between 1980-2000. From 1980 to 2000, airlines were able to profit enough to cover just their costs. After 2000, profits of airline companies around the world started to increase (Wojahn, O. W., 2012). Strategic decisions taken by airline companies in the 20-year period between 1980-200 have carried them to after the year 2000.

In order to achieve the growth targets for an airline company, the strategic decisions taken with the focus on investment are as follows:

- Establish a new subsidiary
- Starting flights to new markets
- Fleet planning

Among these investments, fleet planning is allocated more budget and carries high risk. As the competition in aviation increased much faster after the 2008 crisis, fleet planning began to emerge as a more important investment.

2.2. Fleet Planning

Fleet planning for an airline company is interested in how many of which aircraft they will buy in their fleet and when they will be included in the fleet. It is pursuing new technologies and looking for new technologies to include more suitable technologies for the airline. In addition, in order to keep the age of the fleet young, the lease or sales contracts are arranged for the aircrafts, which are, needed to get out of the fleet. Fleet planning keeps this action constantly on the agenda, as the young age of the fleet will have a positive impact on the airline company in terms of long-term unit expenses.

In the last 15 years, the airline industry has been going through a period of demand fluctuating. Therefore, airline companies find it hard to keep up with market changes. Rapid development of technology led to increased competition in aviation. For this reason, airline companies have to carry out their supply situation, fleet management and demand management in a very systematic way (Dožić & Kalić, 2015). One of the sub-segments of the fleet investment, which requires major investments for airlines and is vital, is aircraft selection and procurement.

Fleet planning involves two ways of incorporating new aircraft into the fleet:

- Purchasing aircraft

The process that is concluded during certain negotiations based on mutual agreement with the manufacturer under certain conditions.

- Leasing aircraft
  - Wet Leasing

    Leasing the aircraft from another airline company. However, the airline company leases the aircraft so that leaser Airline Company provides the crew and maintenance costs
  - Dry Leasing

    Leasing the aircraft from another airline company. The airline company leases just the aircraft; but leaser Airline Company does not provide the crew and maintenance costs

Fleet planning is one of the strategic decisions of an airline company where the capital needs the most and high budget investments are made. The importance of fleet planning comes to the fore in three different periods for an airline company. Firstly, a new airline company should perform the stage at the first moment during its establishment. Once the capital to be invested is determined, the scheme of how to become an airline company is determined during fleet planning. It is very important since most of the budget to be used during the establishment of the company is allocated to fleet planning. The steps in the table as follow.

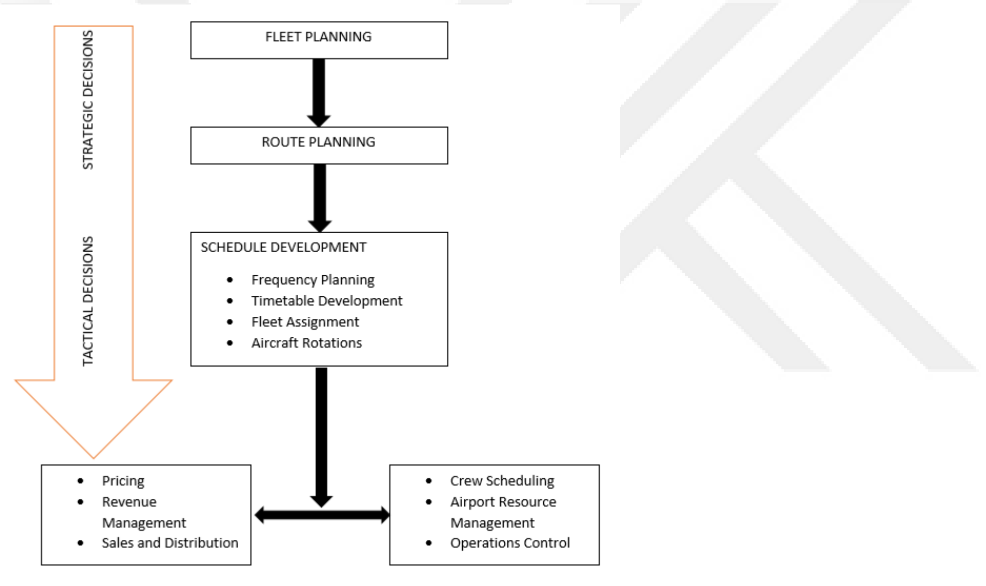

Figure 2.2: The Process of Airline Foundation (Belobaba, 2009)

Secondly, it stands out in character change of an airline. Airline companies are divided into two types according to the way they do business in the world.

- Charter Airlines
- Scheduled Airlines

Charter airlines have not a specific hub; these kind airlines are operating their flights from one point to another. Scheduled airlines rely on the logic of hub; they are gathering and distributing passengers via their hub. Charter airlines may want to turn their structures into a scheduled structure after their rapid growth. This transformation is a strategic decision for an airline and requires a high budget. At this stage, fleet planning comes to the forefront in the first place and is a stage that must be overcome for the airline. The stages of the airline change are as follows.

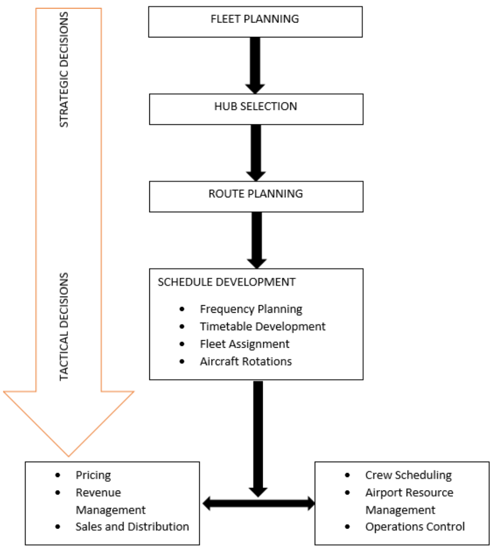

Figure 2.3: The Process of Transformation of Charter Airline (Belobaba, 2009)

Thirdly, it comes to the forefront during the strategic decisions taken by an airline company in order to achieve the level that it envisages as growth target for each year. Airlines use the seat supplied per km as metric, which is called briefly, ASK for growth targets. It is calculated by multiplying the seat to be supplied by the distance to the planned market.

ASK = Seat Capacity * Distance

Since fleet planning plans its growth target within the framework of this metric, it plans the planned aircraft purchases for this year in this respect. Due to the fact that flying to a long-distance market makes this goal easily accessible, the importance of planned investments is also increasing. The budget allocated for the growth target is also very high, because the cost of aircrafts to be purchased for long-distance markets will be high. This high budget once again emphasizes the importance of fleet planning.

The issue of aircraft selection in the field of fleet planning has been applied in various fields and academic studies have been carried out on this topic. In the table below, there is a table of academic studies and brief information about the last 15 years.

Table 2.1: The List of Studies about Aircraft Selection

Author(s)	Publication Year	Subject	Method Used
Bhadra D.	2003	Relationship between selection of aircraft and passenger demands	Standard Multinomial Logit Model
Dekker R. & Listes O.	2005	Senereia based on determining fleet composition	The Underlying Deterministic Model
Harsani W. I.	2006	A model for selection aircraft	MS Excell Programme improved
Wang T. C. & Chang T. H.	2007	A technic Model for choosing training aircraft	TOPSIS
Ozdemir et al.	2011	Aircraft Selection using ANP Metdod	ANP
Sun et al.	2011	Improving a MCDM method for selecting aircraft	ELECTRE & SAW & TOPSIS
Dožić, S., & Kalić, M.	2013	Reducing cost of aircrafts selected by considerin passenger demands and market conditions	FLEET SIZING MODEL
Gomes et al.	2014	Improving a MCDM method for selecting aircraft	THE NAIADE Method
Dožić, S., & Kalić, M.	2014	Improving a methodology for fleet planning	AHP
Dožić, S., & Kalić, M.	2015	Comparing 2 MCDM methods for selecting aircraft	AHP & ESM (Even Steps Method)
Dožić et al.	2018	Fuzzy AHP approach to passenger aircraft type selection	Fuzzy AHP

Bhadra (2003) has worked on a study which considers relationship between selection of aircraft and passenger demands by using Standard Multinomial Logit Model and tried to find the answer to the problem whether the passengers demands are affecting the aircraft selection or not. Listes and Dekker (2005) have prepared a scenario based on fleet composition. Harsani (2007) has prepared an aircraft selection model for Saudi Arabia Airline. Wang and Chang (2007) have offered a technic model to Air Force Academy by using TOPSIS for choosing training aircraft. Ozdemir et al. (2011) have improved a MCDM approach to Turkish Airlines for aircraft selection by using ANP method. Sun et al. (2011) have improved a MCDM method for aircraft selection. Dožić and Kalić (2013) have worked on a study which includes reducing cost of aircrafts selected by considering passenger demands and market conditions. Gomes et al. (2014) has improved a MCDM method which is called NAIDE method for selecting aircraft. Dožić and Kalić (2014) have improved a methodology for airline companies' fleet depatment to select the optimum aircraft for their fleet. Dožić and Kalić (2015) have compared two different MCDM methods which are AHP and ESM methods for selecting aircraft to find out the mot optimum MCDM method for fleet planning.

Fleet planners are responsible for all processes in the selection and purchase of new aircraft. Airline companies need specific procedures for the rapid implementation of these processes (Hoff et al., 2010). Fleet planners must take into account both the corporate and financial risks of the airline and the change of the market with the passenger perspective. Since short-term demand imbalance will create risks for the airline, so fleet planners should take steps to minimize these risks (Tsai et al., 2012). While in previous year the airline companies added new aircraft to their fleets, the unit cost was the most important parameter that airline companies paid attention. With the increasing competition, new parameters are added to this parameter (Hoffman, 2009). Because the increase in competition did not force the airline companies to evaluate the fleet planning only in terms of the company, but also forced the passengers to evaluate the required parameters.

2.3. Problem Definition and Criteria

2.3.1. Problem Definition

With the rapid development of the aviation sector, fleet planning, which has become a more important issue by separating from investment management, has started to form the biggest part of the investments to be made by the airline companies for the following years. In the last decade, airlines have increased rapidly and maintained their profits consistently except for the global economic crisis in 2009. Particularly based on low profit margins between 1980 and 2000, post-2000 profit margins were a success for airlines with low ROIC rates which is the abbreviation of “Return of investment cost”.

The aviation sector is important for governments as it enlarges many sectors. The taxes collected from the most important revenue sources of the governments affected by aviation have increased from 45 billion dollars to 129 billion dollars in the last 20 years (IATA, 2018). For this reason, the airline companies are important and important investments for the companies are important because the investments are also important. Therefore, Fleet planning is very important as a pioneer of these investments.

In this study, a model has been tried to be formed about the purchase of aircraft that an airline company plans to make on behalf of its future investments for the fleet planning department. Since the model to be created will affect the purchasing decision of the company, it will be made within the framework of certain criteria. These criteria may vary depending on the state of the art technology and the growth strategy of the Airline Company. Opinions of experts were taken regarding the determination of criteria. These experts are employees of the Turkey's largest airline, Turkish Airlines.

Turkish Airlines was founded in 1933. Turkish Airlines, which is the flag carrier airline of Turkish Republic, is the world's most performed country since 2015. It has been selected as the best airline company in Europe 5 times due to its successes between 2011-2015.

Turkish Airlines continues to invest continuously for years to come and is one of the airline companies that are constantly demanding aircraft from aircraft manufacturers. Aircraft manufacturers do not respond quickly to the demand, as there is not much in the world. For this reason, large airline companies demand aircraft within a minimum of 10 years of planning. In the table below, there is a table about the most airline companies that ordered as of September 2019.

Table 2.2: The Order List of Airlines as of SEP 2019 (CAPA, 2019)

Rank	Airline	Widebody	Narrowbody	Other	Total
1	Lion Air	6	415	19	440
2	IndiGo	0	337	30	367
3	AirAsia	0	366	0	366
4	VietJet Air	0	337	0	337
5	Emirates	277	0	0	277
6	United Airlines	72	171	32	275
7	Wizz Air	0	270	0	270
8	American Airlines	47	190	29	266
9	Delta AirLines	44	137	81	262
10	Southwest Airlines	0	261	0	261
11	Qatar Airways	133	105	0	238
12	Flydubai	0	237	0	237
13	Norwegian Air Shuttle	25	184	0	209
14	SkyWest Airlines	0	0	204	204
15	Turkish Airlines	48	147	0	195
16	Lufthansa	84	103	0	187
17	Frontier Airlines	0	184	0	184
18	SpiceJet	0	168	15	183
19	Aeroflot	17	50	100	167
20	China Eastern Airlines	20	103	35	158

Turkish Airlines continues to increase its long-term planned investments. Despite the loss of Turkish Airlines after the aviation crisis in 2016, short-term investments continued to shrink, while long-term investments continued to increase. Most of these investments are used within the framework of fleet planning. The following table summarizes the investments of the last 4 years.

Table 2.3: The Table of Investment of Turkish Airlines in last 4 Years[1]

	2015	2016	2017	2018
Short Term Investments	$ 62	$ 349	$ 195	$ 519
Lond Term Investment	$ 248	$ 295	$ 371	$ 444
Net Profit	$ 1.069	$ -77	$ 233	$ 753

2.3.2. Criteria Definition

At the stage of determining the criteria, a literature review was carried out first. After the literature review, 14 criteria were decided by including expert opinions. Generally, the criteria determined by airline companies are determined directly or indirectly in the direction of decreasing unit expenses. Airline companies calculate their unit revenue through a metric called CASK used in the aviation industry. It is calculated by proportioning the total expenses spent for the aircraft to the seat supplied per km. It is calculated from the following formula.

CASK = Total Expenses / (Seat Capacity*Km)

The fleet planning team has planned as the criteria they usually take into account in their studies during the long-term investments. There are 3 experts who are consulted for filling the decision matrix. The first one is working as engineer in the revenue management department and has 6 years of experience. Two other experts work as specialist in the fleet planning department and have 7 years of experience in this department. In this context, 14 criteria were determined.

[1] http://investor.turkishairlines.com/en/financial-operational/financial-statements/1/2019/all-period

The defined criteria and definitions are as follows:

1) Purchase cost: The cost incurred while purchasing the aircraft from the supplier (Gomes et al., 2014).
2) Fuel efficiency: The fuel is an important cost item for airlines, so aircraft with better fuel performance are preferred because they are more cost-effective in long run.
3) Terms of payment: Because of the high purchase cost, airlines often use loans in different currencies when purchasing a new aircraft for their fleet. The payment plan may vary depending on the type of supplier and the aircraft purchased (Dožić & Kalić, 2015).
4) Maintenance cost: Aircrafts are subject to seasonal and compulsory maintenance. The maintenance cost is crucial in long term (Yılmaz, 2006).
5) Insurance of aircraft: Each aircraft is insured before joining the fleet. Insurance companies determine insurance charges based on various factors such as supplier company and aircraft type.
6) Handling costs: Costs applied by airport authorities and ground handling companies vary according to aircraft type and model. The handling costs are increasing when the aircraft has the heavier and higher unit volumes.
7) Commonality of the fleet: Airlines should consider their cockpit crew when determining the composition of their fleet. As the pilot training varies from supplier to supplier, if the airline does not have enough pilots who have been trained for the aircraft the airline bought, it will have to keep that aircraft on the ground until training a suitable crew (Dožić et al., 2018).
8) Seat capacity: Seat capacity is one of the parameters that directly affect the profitability, since airlines are trying to keep the maximum seats in the air (Dožić & Kalić, 2015).
9) Cabin structure: Different cabins mean extra income for the airlines due to passenger preferences. So, the structure of the upper segment cabins such as first

class, business or premium economy class is also an important parameter for the airlines.

10) Flight range: The maximum distance that the aircraft can travel from one point to another without landing. This criterion is important for airlines whose objective is to reach far and large markets (Gomes et al., 2014).
11) Cargo capacity: Cargo is a critical revenue item for airlines. Although an airline has cargo aircrafts, the cargo carrying capacity of passenger aircrafts is important (Dožić & Kalić, 2014).
12) Noise pollution: Airport authorities of some countries give flight permits according to the sound level of aircraft during landing and taking off. For this reason, an aircraft purchased may not be used to certain markets due to the noise that it generates (Yeh & Chang, 2009).
13) Delivery time: It is an important criterion for airlines to include the aircraft purchased from the supplier in the inventory as early as possible. While there are very few companies producing aircraft in the world, the fact that there are too many airlines makes this supply period very important. Aircraft fleet creates opportunity cost for the airline during late entry.
14) Maximum take-off weight: Aircrafts must not exceed a certain weight while taking off. This threshold is called the maximum take-off weight. When this threshold is high, more passengers, luggage and cargo can be transported by the aircraft, which provides higher revenue for the airline (Dožić & Kalić, 2014).

Some of these criteria have been used as a criterion for the models applied in previous academic studies. The following table shows the criteria used by an academic study conducted by whom.

Table 2.4: The List of Academic Studies according to used Criteria

Criteria	Author(s)	Publication Year
Purchase cost	Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S	2014
	Yeh, C. H., & Chang, Y. H.	2009
	Ozdemir, Y., Basligil, H., & Karaca, M.	2011
	Dožić, S., & Kalić, M.	2014
	Bruno, G., Esposito, E., & Genovese, A.	2015
	Yılmaz S.	2006
Fuel Efficiency	Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S	2014
	Sun, X., Gollnick, V., & Stumpf, E.	2011
	Ozdemir, Y., Basligil, H., & Karaca, M.	2011
Terms of Payments	Dožić, S., & Kalić, M.	2014
	Dožić, S., & Kalić, M.	2015
Maintence Cost	Yılmaz S.	2006
	Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S	2014
	Ozdemir, Y., Basligil, H., & Karaca, M.	2011
Commonality of Fleet	Dožić, S., Lutovac, T., & Kalić, M	2018
	Dožić, S., & Kalić, M.	2014
Seat Capacity	Dožić, S., & Kalić, M.	2014
	Dožić, S., & Kalić, M.	2015
Cabin Structure	Sun, X., Gollnick, V., & Stumpf, E.	2011
Fligt Range	Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S	2014
	Yılmaz S.	2006
	Dožić, S., Lutovac, T., & Kalić, M	2018
	Sun, X., Gollnick, V., & Stumpf, E.	2011
	Dožić, S., & Kalić, M.	2014
	Yeh, C. H., & Chang, Y. H.	2009
Cargo Capacity	Yılmaz S.	2006
	Dožić, S., & Kalić, M.	2014
Noise Pollution	Yeh, C. H., & Chang, Y. H.	2009
Delivery Time	Ozdemir, Y., Basligil, H., & Karaca, M.	2011
Maximum Take-off Weight	Sun, X., Gollnick, V., & Stumpf, E.	2011
	Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S	2014
	Dožić, S., & Kalić, M.	2015
	Dožić, S., Lutovac, T., & Kalić, M	2018
	Wang, T. C., & Chang, T. H.	2007

3. DEMATEL and WEIGHTED DISTANCE METRIC

3.1. DEMATEL

The DEMATEL method was developed between 1972-1976 at the Battelle Memorial Institute in Geneva within the scope of the Human affairs and Science program. It is often used to solve complex and highly intertwined systematic problems (Tzeng et al., 2010).

This method also shows the effect of the variables to each other that will affect the decisions of the decision makers (Hori & Shimizu, 1999). This method associates variables in this way, which provides a sort between variables. It tries to find out which variable is dominant for decision-makers. Since the direct affect of a variable to decision maker's decision is not correct, the effects of variables to each other are examined (Rochimah, 2013).

The DEMATEL method is used not only for effectiveness level of criteria but also for finding out of an impact map of all criteria. The DEMATEL method is dividing the criteria as cause and effect factors. This way makes easier to have a decision for decision makers. By building a criteria affect map, decision makers can have their decision easier (Falatoonitoosi et al., 2013). The initial influence matrix is showing the cause and effects of each criteria and contextual relationship among the all criteria. This matrix can be converted a map or a diagram of affect. This map shows the direct and indirect effects of criteria and helps the decision maker for final decision (Tzeng et al., 2010).

There is a figure below which is representing an impact map. The factor i is affecting the factors j and k directly, though it is affecting other factors indirectly.

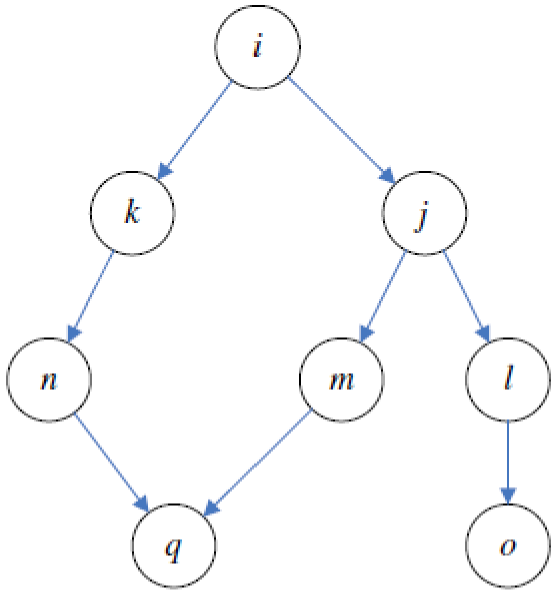

Figure 2.4: An Example of Impact Map (Tzeng et al., 2010).

MCDM methods are used for the problems which have multiple criteria at the same time and these criteria are both cause and effect criteria. The DEMATEL method is harmonizing all criteria by dividing to them and building a criteria map for decision makers (Hung et al., 2012). Building an impact map for criteria makes the more flexible decision made process. Decision makers can see easily how much any criteria have an impact on their final decision. There are several areas that DEMATEL method used and the aviation industry is one of these areas that DEMATEL method used.

DEMATEL method has been used rarely in Air Transport industry. The table below shows the studies in aviation industry which have used DEMATEL method.

Table 3.1: The List of Studies which used DEMATEL method in Aviation Industry (Dožić, 2019)

Author(s)	Publication Year	Subject
Liou et al.	2007	Aircraft Safety
Tsai & Hsu	2008	CSR Programs
Hsu et al.	2010	Safety Management Systems
Liou & Chuang	2010	Ground Handlers Selection
Wang et al.	2011	Service Quality
Liou	2012	Strategic Alliance Partner Selection
Chang et al.	2015	CSR Programs
Lee et al.	2018	CSR Strategy
Lin & Vlachos	2018	Improving Service Quality

Liou et al. (2007) and HSU et al. (2010) have used DEMATEL method for safety programs in aviation industry. Tsai and Hsu (2008), Chang et al. (2015) and Lee et al. (2018) have worked on studies which consider CSR programs by using DEMATEL method. Liou and Chuang (2010) have used DEMATEL method for selection of ground handler for airline companies. Wang et al. (2011), Lin and Vlachos (2018) have used DEMATEL method for improving airline service quality. Liou (2012) has used DEMATEL method for selecting strategic alliance partner for Airline Company.

In this research, DEMATEL methodology is used to calculate the importance degrees of aircraft selection criteria which are determined by experts. Then, some of them are eliminated from the list using a threshold value.

The steps required to implement this method are as follows:

i. Calculation the initial criteria matrix which is called *A matrix*. This matrix is obtained from decision maker and score of each criterion affecting each other is calculated. The decision maker gives score each criteria from 0 to 4. The scale is defines as below:

Table 3.2: Table Scale using for relationships between criteria (Tzeng et al., 2010)

0	No influence
1	Low influence
2	Moderate influence
3	Strong influence
4	Extreme strong influence

ii. After obtaining the initial matrix, it is needed to normalize the initial matrix to obtain *D matrix*. Therefore the formula as follows will be used for the normalization (Hsu et al., 2012)

D= s.A, where

$$s = \min\left[\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}\left|a_{ij}\right|},\frac{1}{\max_{1\le i\le n}\sum_{i=1}^{n}\left|a_{ij}\right|}\right] \quad (3.1)$$

iii. In the next step , *T matrix* which is called the total relatin matrix must be obtained by using the formula as follows (Rochimah, 2013):

$$T = D(I - D)^{-1} \quad (3.\ 2)$$

iv. In the next step, the importance and relation indicators must be calculated. The *T matrix* represents the structure showing the relationship between the criteria. Importance and relationship indicators explain the general character of the matrix. A positive value of the relation indicator confirms that the given criteria constitutes the cause, whereas a negative value proves the effect character of the criteria. The absolute value of the indicator defines the intensity of the effect nature of the object. These indicators are calculated with formulas as follows (Rochimah, 2013).

$$r = [\mathbf{r}_i]_{\mathbf{nx1}} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1} \quad (3.3)$$

$$c = [\mathbf{c}_i]_{\mathbf{1xn}} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1xn} \quad (3.4)$$

v. In the next step, the weight of each criteria is calculated by using the formula as follows (Dalalah et al., 2011).

$$w_i = ((r_i + c_j)^2 + (r_i - c_j)^2)^{1/2} \quad (3.5)$$

vi. In the final step, the weights need to be normalised with the formula as below.

$$\omega_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{3.6}$$

3.2. Weighted Distance Metric Based Evaluation Method

The weighted distance metric method is used to measure the distance of each alternative for each criteria from the target criteria. Decision makers first set a target for each criterion in order to make decisions with the specified criteria. With this method, the distance of each alternative to the targets set for the criteria is calculated. The alternatives can be ranked by using deviations from the target product criterian values (Alptekin & Karsak, 2011).

There are several step to apply this method:

1. In first step, the alternatives with the criteria which are selected must be normalised. Since all values for each criteria are on different scales. For normalization, the formulas as below can be used:

For benefit criteria

$$x_{normalised} = \frac{\mathrm{x}}{x_{max}} \tag{3.7}$$

For cost criteria

$$x_{normalised} = \frac{\mathrm{x_{min}}}{X} \quad (3.8)$$

2. Specify the target values for each criteria by the decision maker.
3. Normalized target values by using the equations which are used for criteria
4. Calculation of distance metric for each alternatives from the target values by using the formula as follows (Alptekin & Karsak, 2011).

$$d_p^k = \left(\sum_j \omega_j\, (\max(0, (x_j^* - x_{jk})))^p\right)^{1/p} \quad , \quad p = 1,2; k = 1,2, . . . s \quad (3.9)$$

5. For each alternative the distance to the target are calculted. The alternative which has the smallest distance is selected.

4. MCDM APPROACH BASED ON DEMATEL and WEIGHTED DISTANCE MEASURE FOR FLEET PLANNING

In this thesis, the model for fleet planning will be examined in two stages. In the first stage, the criteria will be determined and the weighting of these criteria for decision makers will be calculated. In the second stage, the final decision will be made amongst the alternatives by using these criteria and weights.

4.1. Determination of Criteria using DEMATEL Method

DEMATEL method is used for the selection and weighting of criteria in the model which is intended to be applied for fleet planning decisions. 14 criteria which have been important for the company in the last 3 years have been determined by using the information of the Turkish Airlines fleet planning experts. These criteria are as follows:

Table 4.1: The Table of Criteria

C1	Purchase cost
C2	Fuel efficiency
C3	Terms of payment
C4	Maintenance cost
C5	Insurance charges
C6	Handling costs
C7	Commonality of the fleet
C8	Seat capacity
C9	Cabin structure
C10	Flight range
C11	Cargo capacity
C12	Noise pollution
C13	Delivery time
C14	Maximum take-off weight

Decision makers made comparison of these criteria in pairs. Decision-makers rated how much these criteria affect each other on a scale. This scale is between 0-4 indicated in the literature study. The scale is as follows:

Table 4.1: The Table of Scale

0	No influence
1	Low influence
2	Moderate inflence
3	Strong influence
4	Extreme strong influence

The comparison matrix of the criteria determined by the decision-makers is as follows. This matrix is called the *A matrix.*

Table 4.2: The Initial Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0	3	3	2	2	0	0	0	0	1	0	0	0	0
C2	4	0	1	2	1	0	0	3	1	1	3	0	0	2
C3	3	0	0	0	3	0	0	0	0	0	0	0	1	0
C4	2	0	1	0	3	0	3	0	0	0	0	0	0	0
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	1	0	0	1	0	0	0	1	0	0	1	0	0	4
C7	2	0	0	3	1	0	0	0	0	0	0	0	1	0
C8	3	2	0	1	0	2	0	0	2	1	2	0	2	2
C9	3	1	0	0	0	1	0	3	0	0	2	0	1	2
C10	3	3	0	0	0	0	0	3	2	0	3	0	0	0
C11	3	2	0	0	0	2	0	2	0	0	0	0	0	2
C12	3	0	0	0	0	3	0	0	0	0	0	0	0	0
C13	3	0	4	0	0	0	0	0	0	0	0	0	0	0
C14	3	4	0	2	0	3	0	4	2	3	3	0	0	0

Once *A matrix* has been obtained, this matrix must be normalized. The parameter s is obtained using the formula (3.1).

$$s = \min\left[\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}\left|a_{ij}\right|}, \frac{1}{\max_{1\le i\le n}\sum_{i=1}^{n}\left|a_{ij}\right|}\right] \tag{3.1}$$

The maximum values of columns and rows obtained by this formula and the *s* value is 0,03030303

After obtaining s parameter, with the help of formula as follows D= s.A, it will be normalized and obtained *D matrix.*

Table 4.3: The D Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0,00	0,09	0,09	0,06	0,06	0,00	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,00
C2	0,12	0,00	0,03	0,06	0,03	0,00	0,00	0,09	0,03	0,03	0,09	0,00	0,00	0,06
C3	0,09	0,00	0,00	0,00	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00
C4	0,06	0,00	0,03	0,00	0,09	0,00	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C5	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	0,00
C6	0,03	0,00	0,00	0,03	0,00	0,00	0,00	0,03	0,00	0,00	0,03	0,00	0,00	0,12
C7	0,06	0,00	0,00	0,09	0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00
C8	0,09	0,06	0,00	0,03	0,00	0,06	0,00	0,00	0,06	0,03	0,06	0,00	0,06	0,06
C9	0,09	0,03	0,00	0,00	0,00	0,03	0,00	0,09	0,00	0,00	0,06	0,00	0,03	0,06
C10	0,09	0,09	0,00	0,00	0,00	0,00	0,00	0,09	0,06	0,00	0,09	0,00	0,00	0,00
C11	0,09	0,06	0,00	0,00	0,00	0,06	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,06
C12	0,09	0,00	0,00	0,00	0,00	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C13	0,09	0,00	0,12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C14	0,09	0,12	0,00	0,06	0,00	0,09	0,00	0,12	0,06	0,09	0,09	0,00	0,00	0,00

In the next step, *T matrix* is obtained by using formula as follows $T = D(I - D)^{-1}$. Obtained *T matrix* is as below:

Table 4.4: The T Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0,03	0,10	0,10	0,07	0,08	0,00	0,01	0,01	0,01	0,04	0,01	0,00	0,00	0,01
C2	0,18	0,05	0,05	0,08	0,06	0,02	0,01	0,12	0,05	0,05	0,12	0,00	0,01	0,08
C3	0,10	0,01	0,01	0,01	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00
C4	0,07	0,01	0,04	0,01	0,10	0,00	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C5	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	0,00
C6	0,06	0,03	0,01	0,05	0,01	0,02	0,00	0,06	0,01	0,02	0,05	0,00	0,00	0,13
C7	0,07	0,01	0,01	0,10	0,05	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,03	0,00
C8	0,15	0,10	0,03	0,05	0,02	0,08	0,00	0,04	0,07	0,05	0,09	0,00	0,07	0,09
C9	0,14	0,07	0,02	0,02	0,01	0,05	0,00	0,12	0,02	0,02	0,09	0,00	0,04	0,08
C10	0,14	0,13	0,02	0,02	0,02	0,02	0,00	0,12	0,07	0,01	0,12	0,00	0,01	0,03
C11	0,13	0,09	0,02	0,02	0,01	0,08	0,00	0,09	0,01	0,02	0,03	0,00	0,01	0,08
C12	0,10	0,01	0,01	0,01	0,01	0,09	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,01
C13	0,11	0,01	0,13	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C14	0,18	0,17	0,03	0,09	0,03	0,12	0,01	0,17	0,09	0,11	0,14	0,00	0,01	0,05

After obtaining the *T matrix*, *r* and *c* parameters, which are the significance and relationship values of the criteria, are calculated. These parameters are obtained using the following formulas (3.3) and (3.4).

$$r = [\mathbf{r}_i]_{\mathbf{nx1}} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1} \tag{3.3}$$

$$c = [\mathbf{c}_i]_{\mathbf{1xn}} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1xn} \tag{3.4}$$

The r and c parameters of each criterion obtained by these formulas are as follows:

Table 4.5: The Table of r and c Parameters

Criteria	***r***	***c***
C1	0,48	1,45
C2	0,88	0,78
C3	0,26	0,47
C4	0,34	0,55
C5	0,00	0,51
C6	0,46	0,48
C7	0,28	0,14
C8	0,84	0,74
C9	0,67	0,34
C10	0,72	0,32
C11	0,58	0,66
C12	0,27	0,00
C13	0,29	0,23
C14	1,20	0,57

After calculating these parameters, the impact weight of each criteria on the decision of the decision maker is calculated by the following formula (3.5).

$$w_i = ((r_i + c_j)^2 + (r_i - c_j)^2)^{1/2} \tag{3.5}$$

However, it is necessary to normalize the weight values obtained with this formula. The following formula (3.6) is used for normalization.

$$\omega_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{3.6}$$

The first calculated weights and normalized weights of each criterion are as follows:

Table 4.6: The Weight of all Criteria

Criteria	**wi**	***wi normalized***
C1	1,94	13,3%
C2	1,66	11,4%
C3	0,74	5,1%
C4	0,89	6,1%
C5	0,51	3,5%
C6	0,94	6,5%
C7	0,42	2,9%
C8	1,58	10,9%
C9	1,01	6,9%
C10	1,04	7,2%
C11	1,24	8,5%
C12	0,27	1,8%
C13	0,51	3,5%
C14	1,78	12,2%

Since the problem would be much more complicated if all these criteria were processed, the decision makers decided to use the criteria, which its weight more than 7%, in the decision process. Thus, six of the 14 criteria will affect the outcome of the decision-making process. These criteria are as follows:

Table 4.7: The Table of Selected Criteria

	Criterion	*wi*	*wi normalized*
C1	**Purchase Cost**	1,94	13,3%
C2	**Fuel Efficiency**	1,66	11,4%
C8	**Seat Capacity**	1,58	10,9%
C10	**Flight Range**	1,04	7,2%
C11	**Cargo Capacity**	1,24	8,5%
C14	**Maximum Take-off Weight**	1,78	12,2%

Purchasing cost is the most important parameter among the criteria. As the first investment cost that comes to the forefront in every company's important investments, price is very important for airline companies in purchasing aircraft. Fuel performance is also an important criterion for airline companies in order to reduce long-term costs.

Airline companies demand high capacity for such investments to get minimum cost and maximum efficiency. Capacity means increased revenue. Likewise, cargo capacity indirectly leads to an increase in revenue. 30% of the revenues of the major airline companies is composed of cargo revenue. Passenger and cargo capacity has an effect on take-off weight. Therefore, this parameter is a high benefit criterion for airline companies.

While the flight range did not come to the forefront in previous years, with the growth of the airline sector and the increase in competition, companies want to reach farther markets with less cost. In recent years, it has been an important criterion for the purchase of aircraft especially for flight range airlines.

4.2. Ranking the Alternatives with a Weighted Distance Based Measure

A distance measure based on a weighted distance metric is employed to select an alternative from 4 hypothetical alternatives. Two of the criteria, namely the purchasing cost and the fuel efficiency, selected for the evaluation of these alternatives are cost-type criteria, and the rest are benefit-type criteria. The assessment values for each alternative under each criterion are shown in the table below.

Table 4.9: Performance Values of Alternatives

	C1($)	C2(l)	C8	C10(km)	C11(m^3)	C14(kg)
A1	351.400.000	2,82	467	14816	176.3	447700
A2	206.800.000	2,6	270	15186	124.5	227950
A3	317.400.000	2,81	315	15001	149.5	280000
A4	403.900.000	3,27	525	15201	181.4	575000

Since the data in this table are on different scales, they should be normalized. The following formulas (3.7) and (3.8) are used to normalize the data in the table.

For benefit criteria

$$x_{normalised} = \frac{\mathrm{x}}{x_{max}} \qquad (3.7)$$

For cost criteria

$$x_{normalised} = \frac{\mathrm{x}_{\min}}{x} \tag{3.8}$$

The normalization table obtained after the calculations is as follows:

Table 4.10: Normalized Performance Values for Each Alternative

	C1	C2	C8	C10	C11	C14
A1	0,59	0,92	0,89	0,97	0,97	0,78
A2	1,00	1,00	0,51	1,00	0,69	0,40
A3	0,65	0,93	0,60	0,99	0,82	0,49
A4	0,51	0,80	1,00	1,00	1,00	1,00

Fleet-planning experts should set goals for each criteria. The set target values are shown in the table below.

Table 4.11: Target Values for Each Criterion

	C1($)	C2(l)	C8	C10(km)	C11(m^3)	C14(kg)
Target	150.000.000	2,9	320	15000	150	250000

These data should also be normalized. The normalized table is as follows. The formulas used for the criteria for normalization are used.

Table 4.12: The Normalized Table of Target Values

	C1	C2	C8	C10	C11	C14
Target	1,38	0,90	0,61	0,99	0,83	0,43

Once these values are obtained, the distance from each alternative is calculated using the following formula (3.9).

$$d_p^k = \left(\sum_j \omega_j \left(\max(0, (x_j^* - x_{jk})) \right)^p \right)^{1/p} \quad , \quad p = 1,2; k = 1,2, . . . s \qquad (3.9)$$

In this application, the calculation for a p value will be made. In case of close values, it is appropriate to calculate for other values. If the values are not close, the other values do not need to be calculated. The criterion distances calculated for each alternative are shown in the table below.

Table 4.13: The Calculated Distance of Alternatives from Target for each Criteria

	C1	**C2**	**C8**	**C10**	**C11**	**C14**
A1	0,105	0,000	0,000	0,001	0,000	0,000
A2	0,050	0,000	0,010	0,000	0,012	0,005
A3	0,097	0,000	0,001	0,000	0,000	0,000
A4	0,115	0,012	0,000	0,000	0,000	0,000

Total distances are as follows.

Table 4.14: The Total Distance of each Alternative

	Total Distance
A1	0,106
A2	0,077
A3	0,098
A4	0,127

In the light of these results, A2 type aircraft is the most suitable option among the alternatives using the target values determined for the criteria.

5. CONCLUSION

Fleet planning is strategic investment decisions that cost huge costs for airline companies. Fleet planning is an important area not only for airline companies but also for companies in many sectors such as logistics, rent a car etc. Commercial companies make decisions for fleet planning periodically in order to keep the productivity at the highest level and to achieve the growth targets.

Airline companies need intensive analysis when deciding on the aircraft, which is the most important investment on behalf of their companies, both for their own passengers and for their passengers. The rapid increase in competition has forced the airline companies to evaluate aircraft selection in terms of passengers. Passengers in some markets pay attention to the aircraft they use when traveling. Airline companies also have to pay attention to certain criteria from their point of view, because large investments may start difficult processes for companies to return. Analysis, which are not good made, may have consequences for the financial statements of the companies. Therefore, fleet planning is an investment that needs to be made based on a model within the framework of certain procedures and rules.

In this study, a road map has been developed for airline companies to evaluate and plan their fleet planning with the criteria they consider important from their point of view. The selection and evaluation of the criteria and the determination of the effects of these criteria on their decisions are left to the employees of the airline companies. Airline companies can choose the most appropriate alternative for their interests in order not to go beyond the targets they set and to force the companies financially.

In future studies, the risk of each alternative for the company can be calculated within the framework of fleet planning. This risk criterion can be evaluated by the company authorities as a result of the studies and the effect of the result can be taken into account.

REFERENCES

Alptekin, S. E., & Karsak, E. E. (2011). An integrated decision framework for evaluating and selecting e-learning products. Applied Soft Computing, 11(3), 2990-2998.

Bhadra, D. (2010). Choice of aircraft fleets in the US domestic scheduled air transportation system: findings from a multinomial logit analysis, Journal *of the Transportation Research Forum* (Vol. 44, No. 3).

Belobaba, P., Odoni, A., & Barnhart, C. (Eds.). (2009). The global airline industry (Vol. 23). John Wiley & Sons. Celmins (1987 a, b)

Chang, B., Chang, C. W., & Wu, C. H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria, *Expert systems with Applications*, *38*(3), 1850-1858.

Chang, D. S., Chen, S. H., Hsu, C. W., & Hu, A. H. (2015). Identifying strategic factors of the implantation CSR in the airline industry: The case of Asia-Pacific airlines. Sustainability, 7(6), 7762-7783.

Cheng, C. C., Chen, C. T., Hsu, F. S., & Hu, H. Y. (2012). Enhancing service quality improvement strategies of fine-dining restaurants: New insights from integrating a two-phase decision-making model of IPGA and DEMATEL analysis. *International Journal of Hospitality Management*, *31*(4), 1155-1166.

Dalalah, D., Hajahneh, M., & Batieha, F. (2011). A fuzzy multi-criteria decision making model for supplier selection. Expert Systems with Applications, 38, pp. 8384-8391.

Dožić, S., & Kalić, M. (2013, November). Two-stage airline fleet planning model. In Proceedings of the 1st Logistics International Conference. LOGIC (pp. 28-30).

Dožić, S., & Kalić, M. (2014). An AHP approach to aircraft selection process, *Transportation Research Procedia*, *3*, 165-174.

Dožić, S., & Kalić, M. (2015). Comparison of two MCDM methodologies in aircraft type selection problem. *Transportation Research Procedia*, *10*, 910-919.

Dožić, S., Lutovac, T., & Kalić, M. (2018). Fuzzy AHP approach to passenger aircraft type selection, *Journal of Air Transport Management*, *68*, 165-175.

Dožić, S. (2019). Multi-criteria decision making methods: Application in the aviation industry. Journal of Air Transport Management, 79, 101683.

Falatoonitoosi, E., Leman, Z., & Sorooshian, S. (2013). Modeling for green supply chain evaluation. *Mathematical Problems in Engineering*, *2013*.

Gomes, L. F. A. M., de Mattos Fernandes, J. E., & de Mello, J. C. C. S. (2014). A fuzzy stochastic approach to the multi criteria selection of an aircraft for regional chartering. *Journal of Advanced Transportation*, *48*(3), 223-237.

Harasani, W. I. (2006). Evaluation and Selection of a Fleet of Aircraft for a Local Airline. Journal of King. Abdulaziz University: Engineering Sciences, 17(2), 3-16.

Hsu, Y. L., Li, W. C., & Chen, K. W. (2010). Structuring critical success factors of airline safety management system using a hybrid model. Transportation Research Part E: Logistics and Transportation Review, 46(2), 222-235.

Hsu, C. C. (2012). Evaluation criteria for blog design and analysis of causal relationships using factor analysis and DEMATEL. Expert Systems with Applications, 39(1), 187-193.

Hoff, A., Andersson, H., Christiansen, M., Hasle, G., & Løkketangen, A. (2010). Industrial aspects and literature survey: Fleet composition and routing. *Computers & Operations Research*, *37*(12), 2041-2061.

Hoffman, P. C. (2009). Fleet management issues and technology needs. *International Journal of Fatigue*, *31*(11-12), 1631-1637.

Hori, S., & Shimizu, Y. (1999). Designing methods of human interface for supervisory control systems. *Control engineering practice*, *7*(11), 1413-1419.

Lee, K. C., Tsai, W. H., Yang, C. H., & Lin, Y. Z. (2018). An MCDM approach for selecting green aviation fleet program management strategies under multi-resource limitations. Journal of Air Transport Management, 68, 76-85.

Lin, R. J. (2013). Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production*, *40*, 32-39.

Lin, W. R., Wang, Y. H., & Hung, T. E. (2012). Selecting mobile banking system service for consumers by using a combined DEMATEL and ANP approach. *Journal of Accounting, Finance & Management Strategy*, *7*(1), 1.

Lin, H. F., & Huang, Y. W. (2015). Factors affecting passenger choice of low cost carriers: An analytic network process approach. Tourism Management Perspectives, 16, 1-10.

Liou, J. J., Tzeng, G. H., & Chang, H. C. (2007). Airline safety measurement using a hybrid model. Journal of air transport management, 13(4), 243-249.

Liou, J. J., & Chuang, M. L. (2010). Evaluating corporate image and reputation using fuzzy MCDM approach in airline market. Quality & Quantity, 44(6), 1079-1091.

Liou, J. J. (2012). Developing an integrated model for the selection of strategic alliance partners in the airline industry. Knowledge-Based Systems, 28, 59-67.

Listes, O., & Dekker, R. (2005). A scenario aggregation–based approach for determining a robust airline fleet composition for dynamic capacity allocation. *Transportation Science*, *39*(3), 367-382.

Lee, K. C., Tsai, W. H., Yang, C. H., & Lin, Y. Z. (2018). An MCDM approach for selecting green aviation fleet program management strategies under multi-resource limitations. *Journal of Air Transport Management*, *68*, 76-85.

Ozdemir, Y., Basligil, H., & Karaca, M. (2011). Aircraft selection using analytic network process: A case for Turkish airlines. In *Proceedings of the World Congress on Engineering (WCE)* (Vol. 8, pp. 9-13).

Pineda, P. J. G., Liou, J. J., Hsu, C. C., & Chuang, Y. C. (2018). An integrated MCDM model for improving airline operational and financial performance. *Journal of Air Transport Management*, *68*, 103-117.

Rochimah, S. (2013, October). Integration of DEMATEL and ANP methods for calculate the weight of characteristics software quality based model ISO 9126. In *2013 International Conference on Information Technology and Electrical Engineering (ICITEE)* (pp. 143-148). IEEE.

Sivak, M., & Schoettle, B. (2012). Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy. *Transport Policy*, *22*, 96-99.

Sun, X., Gollnick, V., & Stumpf, E. (2011). Robustness Consideration in Multi-Criteria Decision Making to an Aircraft Selection Problem. Journal of Multi-Criteria Decision Analysis, 18(1-2), 55-64.

Tsai, W. H., Lee, K. C., Liu, J. Y., Lin, H. L., Chou, Y. W., & Lin, S. J. (2012). A mixed activity-based costing decision model for green airline fleet planning under the constraints of the European Union Emissions Trading Scheme. *Energy*, *39*(1), 218-226.

Tzeng, G. H., Chen, W. H., Yu, R., & Shih, M. L. (2010). Fuzzy decision maps: a generalization of the DEMATEL methods. *Soft Computing*, *14*(11), 1141-1150.

Wang, T. C., & Chang, T. H. (2007). Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. *Expert Systems with Applications*, *33*(4), 870-880.

Wojahn, O. W. (2012). Why does the airline industry over-invest?. Journal of Air Transport Management, 19, 1-8.

Yeh, C. H., & Chang, Y. H. (2009). Modeling subjective evaluation for fuzzy group multicriteria decision making. European Journal of Operational Research, 194(2), 464-473.

Yılmaz, S. (2006). Application of AHP and fuzzy AHP to aircraft selection.

BIOGRAPHICAL SKETCH

Murat Yilanli was born in Aydın in 1990. He started Adnan Menderes Anatolian High School in 2004 and graduated in 2008. He preferred Istanbul Technical University Industrial Engineering Department in 2009 and graduated from this department in 2012. In 2017, he launched Galatasaray University Logistics and Financial Management Master Program. Simultaneously, he works for Turkish Airlines as revenue management engineer. He is the co-author of the paper entitled "Determining aircraft selection criteria weights in airline industry" which was published in the Proceedings of the Multidisciplinary Academic Conference Management, Marketing, and Economics 2019 (MAC-MME 2019)