MULTI CRITERIA DECISION MAKING APPROACHES IN A NEW DESTINATION SELECTION FOR AIRLINES

(HAVAYOLLARI İÇİN YENİ ROTA SEÇİMİNDE ÇOK KRİTERLİ KARAR VERME YÖNTEMİ YAKLAŞIMLARI)

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LIST OF SYMBOLS

AHP	: Analytic Hierarchy Process
ANP	: Analytic Network Process
ATL	: Atlanta Hartsfield-Jackson International Airport
BOCR	: Benefits - Opportunities - Costs - Risks
CANSO	: Civil Air Navigation Services Organisation
CASK	: Cost of Available Seats per Kilometer
CASM	: Cost of Available Seats per Mile
CCS	: Caracas Simón Bolívar International Airport
DGCA	: Directorate General of Civil Aviation of Turkey
DPS	: I Gusti Ngurah Rai International Airport
ELECTRE	: Elimination and Choice Expressing Reality
HAH	: Prince Said Ibrahim International Airport
HAV	: Havana Jose Marti International Airport
IATA	: International Air Transport Association
ICAO	: International Civil Aviation Organization
IST	: Istanbul International Airport
LAS	: Las Vegas McCarran International Airport
MAUT	: Multi Attribute Utility Theory
MCDM	: Multi Criteria Decision Making
MODM	: Multi Objective Decision Making
NAIADE	: Novel Approach to Imprecise Assessment and Decision Environments
O&D	: Origin and Destination
PHL	: Philadelphia International Airport
SAN	: San Diego International Airport
SAW	: Simple Additive Weighting
SFO	: San Francisco International Airport
TOPSIS	: Technique for Order Preference by Similarity to Ideal Solution
UIO	: Mariscal Sucre International Airport
USD	: United States Dollar

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ABSTRACT

Scheduling is one of the core elements of the aviation industry. Launching a new destination given an origin is the basic step of constructing an airline's network. In this study, it is aimed to select the best new airport destination for an airline in Turkey with the base situated in Istanbul Airport using both one level ANP network and 4 dimensioned BOCR analysis.

This study is unique in terms of plentiful criteria used and a fresh perspective brought by the comparative analysis of BOCR and simple ANP methods. It also fills a gap in the literature caused by the lack of Analytic Network Process applications, especially for destination selection problems.

In this work, first, a brief review of literature is presented including studies using multi-criteria decision making in route evaluation and multiple criteria decision analysis in the airline industry. After the literature survey, the criteria and three candidate airports under consideration are introduced, and their interactions among each other are explained. The model of the problem is constructed both in simple Analytic Network Process (ANP) format and under Benefit, Opportunity, Cost and Risk (BOCR) dimensions. Both normalized statistical direct data and expert opinions based on the 1-9 scale of Saaty are used to determine the weight of each criterion through analysis.

According to simple ANP method, Mariscal Sucre International Airport in Tababela, Quito is the best alternative with the strategic considerations as the most dominant criterion, while BOCR analysis shows that Denpasar, I Gusti Ngurah Rai International Airport is the best under benefit, opportunity and risk dimensions with the passenger demand as the most dominant criterion. As for the cost perspective, Prince Said Ibrahim International Airport situated in Moroni is the best choice, while it is the worst alternative under risk dimension with prestige related costs as the most important criterion.

ÖZET

Tarife planlaması havacılık endüstrisinde en önemli unsurlardan biridir. Belirli bir ana istasyon kalkışlı yeni bir destinasyon belirlemek, bir havayolu ağını oluşturmanın en temel adımıdır. Bu çalışmada ana üssü İstanbul Havalimanı olan Türkiye'deki bir havayolu için hem tek boyutlu ANP hem de 4 boyutlu BOCR analizi uygulanarak en iyi yeni destinasyon seçimi amaçlanmıştır.

Bu çalışma kullanılan çok sayıda kriter olmasından ve karşılaştırmalı BOCR ve basit yapıda ANP çalışmalarının getirdiği taze bakış açısından dolayı eşsiz bir yapıdadır. Aynı zamanda literatürdeki, özellikle ANP uygulamalı destinasyon seçme problemlerindeki kıtlıktan kaynaklanan boşluğu doldurmaktadır.

Bu çalışmada, ilk olarak, havayolu endüstrisinde ve rota belirlemede çok kriterli karar verme yöntemlerini kullanan çalışmaları içeren, özet bir literatür taraması sunulmuştur. Daha sonra, söz konusu kriterler ve üç aday havalimanı tanıtılmış ve kriterlerle aralarındaki etkileşimler açıklanmıştır. Problemin modellemesi hem basit ANP (Analitik Ağ Yöntemi) yapısında, hem de fayda, fırsat, maliyet ve risk boyutları (BOCR) altında iki farklı şekilde gösterilmiştir. Analiz aşamasında kriterler ağırlıklandırılırken, hem Saaty'nin 1-9 skalasına göre ikili karşılaştırmaya dayanan uzman görüşleri hem de normalize istatistiksel verilerden oluşan doğrudan bilgi girişi yapılmıştır.

Tababela, Quito’da yer alan Mariscal Sucre Uluslararası Havalimanı, en baskın kriter olan stratejik faktörler ile en iyi seçimken, BOCR analizine göre Denpasar, I Gusti Ngurah Rai Uluslararası Havalimanı, yolcu talebi en önemli kriter olmak üzere hem fayda ve fırsat hem de risk boyutları açısından en iyi alternatiftir. Maliyet açısından bakıldığında ise Moroni’de yer alan Prince Said Ibrahim Uluslararası Havalimanı en baskın kriter olarak prestij maliyeti ile en iyi seçimken, risk açısından en kötü alternatif olarak karşımıza çıkmaktadır

1.INTRODUCTION

In today's competitive world, airlines must keep on growing in order to maintain their existence in the growing market. "Especially, after the airline deregulation, most carriers have been forced to reexamine both their pricing strategies and operating schedules" (Bard and Cunningham 1987). "In the late 1970s, existing airlines were threatened by intense competition from low-cost new entrants" (Barnhart and Cohn 2004). So, they have started to set their goals around becoming profitable and enlarging their market share.

There are two main steps in the way of reaching this goal of growth within the airline industry. One of them is rising capacity in existing routes by assigning larger fleet or by increasing the flight frequency. The other one is starting routes to new destinations which is a competitive advantage.

Expanding networks can be achieved through strategic airline alliances, that is connecting flights with other airlines flights to reach a final destination based on 'code-sharing' agreements. However, Lederer and Nambimadom (Lederer and Nambimadom , 1998) find that there are advantages and disadvantages in every style of airline network. The point-to-point network, which has direct flights between origin and final destination, may have higher operational costs, but it has better reliability. On the other hand, the hub-and-spoke network reduces the overall cost, but its reliability is lower. A major disadvantage of connecting flights is waiting time in between the flights. Waiting time may be too much for comfort for the transit passengers or not sufficient to make the connection in case of a possible delay in the first leg of the flight. What's more, passengers could have their luggage delayed or lost due to failing in freight transfer and reloading.

Furthermore, “ineffective alliances can lead to loss of market share as in the case of the fall of Swiss Air in 1997 to 2001” (Suen 2002). So, “the direct flights in point-to-point networks allow passengers to travel faster and more comfortably” (O’Kelly ve Bryan 1998).
Schedule planning in airlines is typically broken into a set of four core problems: schedule design, fleet assignment, aircraft maintenance routing, and crew scheduling. Schedule design largely defines the market share an airline will capture, and hence is a key determinant of airline profitability (Barnhart and Cohn 2004). The schedule design process includes evaluation of flight legs to be flown, origin and destination route pairs and departure times.

Schedule planning consists of two phases which are directly dependent and related: the construction phase and the evaluation phase. The construction is based on the projected demand, which is the potential number of passengers and freight to the destination, the market share, and the time slots of the available airports. After this, the draft timetable is then examined during the schedule evaluation phase for operating feasibility, cost and performance considerations. The feasibility checks in this evaluation phase mainly include the fleet routes, fleet size, crew scheduling, and maintenance arrangements (Mathaisel and Etschmaier 1984).

Several studies are performed so as to find the transportation modals which passengers prefer. According to the econometric analysis of business traveler's modal choice conducted by Morrison and Winston (1985), price, travel time, and schedule delay are the most significant factors for passengers. Four different types of networks are being put under a microscope lately, which are related to the study: “direct”, “hub and spoke”, “tour”, and “sub-tour” routings.

Direct routing is a network where the flights are from one city, called the origin city, to directly another, which is the aimed destination. It is also referred to as point to point transportations or non-stop flights.

Assuming that Istanbul and San Francisco are determined as *origin* and *destination pairs*, a direct flight for the flight TK 791 is graphed in Figure 1.1. The 3 lettered codes indicate the IATA codes for the relevant airports. Since IATA codes are used more widely than ICAO codes, all airports in this study are indicated by IATA codes.

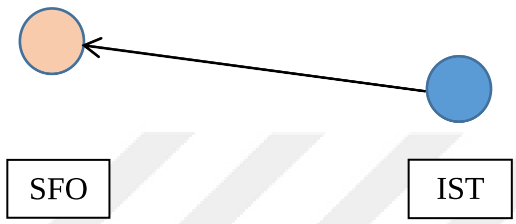

Figure 1.1: Direct Flight

Hub and spoke routing is a network where all passengers travel by airplane to a hub that is a center with high passenger flow and then catch a flight with different aircraft to their final destinations. These transfer passengers may have custom formalities to complete in hub airports, such as claiming their luggage and checking in for the next flight. Their next flight doesn't have to be via the same airline, it can be with a partner airline. The Figure 1.2 shows a hub and spoke network including assumed O&D pairs. In the figure, Istanbul and Atlanta with are important hubs and San Fransisco is shown as s spoke city. A passenger can buy a single ticket from Turkish Airlines and reach SFO by taking the flight TK 312 and then by catching the flight UA 9123 .

[1] https://tr.flightaware.com/live/flight/THY79
[2] https://tr.flightaware.com/live/flight/THY31
[3] https://tr.flightaware.com/live/flight/UAL912

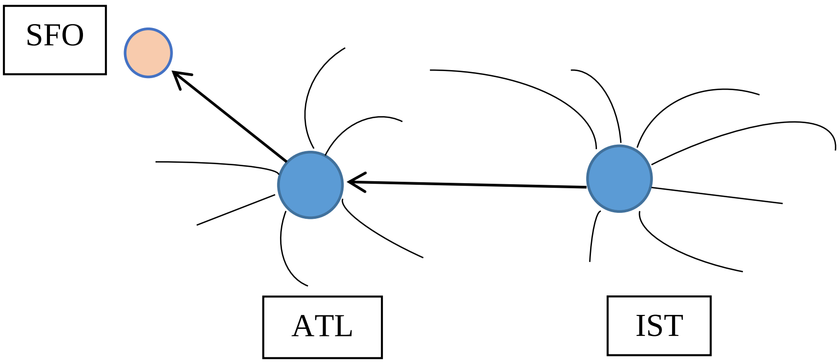

Figure 1.2: Hub and Spoke Network

A tour routing is a network where each plane travels from city to city until all have been visited. Although tours are rare for airlines, in mass transit and freight trucking they are not (Lederer and Nambimadom , 1998). As it is not preferred by airlines, the tour route in the Figure 1.3 is not an existent route in aviation, it is only shown as an illustration of a tour network.

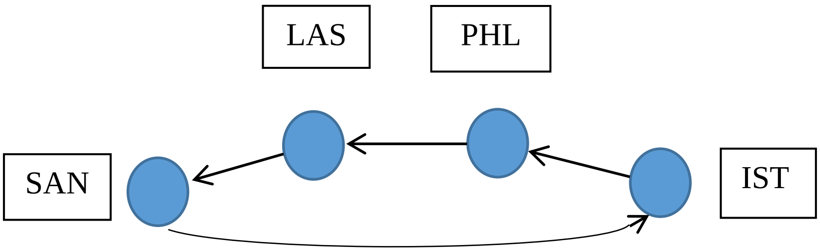

Figure 1.3: Tour Routing

A sub-tour routing is a preferable form of tour network where passengers get on the plane from their origin city, and make fewer amounts of stops at other cities before reaching their final destination. Unlike the hub and spoke network, these passengers are not required to leave the airplane until their final destinations. But the ground time may be even more due to the facts such as refueling of the airplane, crew change and security procedures of multiple flight legs.

In the Figure 1.4 TK 183 is graphed. On this route, passengers going to Caracas board the plane in İstanbul and make a stop in Havana without leaving the aircraft. Similarly, a passenger going to Istanbul from Havana has to stay in the aircraft while the aircraft makes a stop for Caracas.

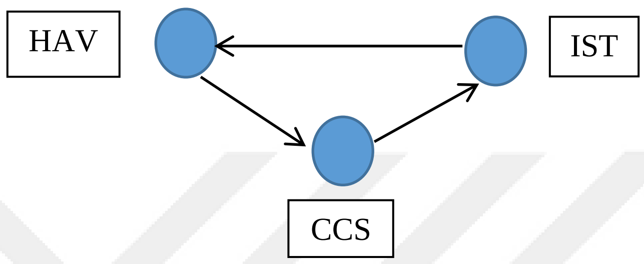

Figure 1.4: Sub-tour Network

1.1 Selection of Alternatives

In this paper, it is aimed to evaluate a direct flight among the hub and spoke networks with potentially high demand and profit. In a hub and spoke network, any airline's schedule contains safety time, which is the time difference between connecting flights, as a buffer against departure delays. This planned safety time causes an increase in total trip time and airline expenditure as more craft are needed, but reduces passengers' chances of arrival after the scheduled time.

It is shown that if schedule reliability is chosen to minimize total airline and passenger costs, schedule reliability is highest for direct routing. Surprisingly, the amount of time that is added to the schedule to buffer delays is relatively less in direct networks than other networks. That is, relatively less time is included in direct schedules to protect against delays, but the reliability of direct networks is highest. This can explain the superior on-time performance and high equipment utilization of non-hub carriers such as Southwest Airlines (Lederer and Nambimadom , 1998).

In practice, the one-stop policy is more service-oriented and would be preferred, enabling the airline to gain higher market shares (Jaillet, et al. , 1996). That's why this study is performed assuming a direct-flight from the origin.

Besides being quality-oriented, all airlines' main objective is minimizing the cost and maximizing the revenue. The total operating cost of an airline occurred through moving each seat for a mile (or kilometer, if the metric system is used) is called CASM, cost per available seat miles (or CASK, cost per available seat kilometers in metric system). According to Abdelghany and Abdelghany (2018), cost per mile for a short-haul flight is higher than that of a long-haul flight, because many cost elements are distributed over more miles.

CASM is also directly related to the number of the available seats, as the definition suggests, meaning that the larger the size of the aircraft, the less is the cost. The Airline in which the study is performed has ordered 6 wide-body (Boeing 787) aircraft for 2019, since the base airport in İstanbul is moved to a larger base with more capacity and flightworthy environment for larger aircraft.

Enlightened by these findings, my starting point is to select the best alternative of destinations for a long-haul, non-stop flight with a wide-body aircraft which allows inter continent flights.

The alternatives under considerations are I Gusti Ngurah Rai International Airport (DPS) in Denpasar City, Bali Island, Indonesia, Asia; Prince Said Ibrahim International Airport (HAH) situated in Moroni, Grande Comore Island, The Comoros, Africa; Mariscal Sucre International Airport (UIO) in Tababela, Metropolitan District of Quito, Ecuador, South America. They are selected among a list of candidates that suggested by the company in which this study is performed. Being located in different continents, the alternatives have different aspects of criteria evaluation. There are several criteria under consideration which are discussed in the section 1.3 in details.

Table 1.1: Alternatives by Locations

ALTERNATIVE AIRPORT CODES	AIRPORT NAMES	CITY	COUNTRY	CONTINENT	REGION IN AVIATION
A_1 DPS	I Gusti Ngurah Rai International Airport	Denpasar City, Bali Island	Indonesia	Asia	Pacific Asia
A_2 HAH	Prince Said Ibrahim International Airport	Moroni, Grande Comore Island	The Comoros	Africa	Africa
A_3 UIO	Mariscal Sucre International Airport	Tababela, Metropolitan District of Quito	Ecuador	South America	Latin America and the Caribbean Region

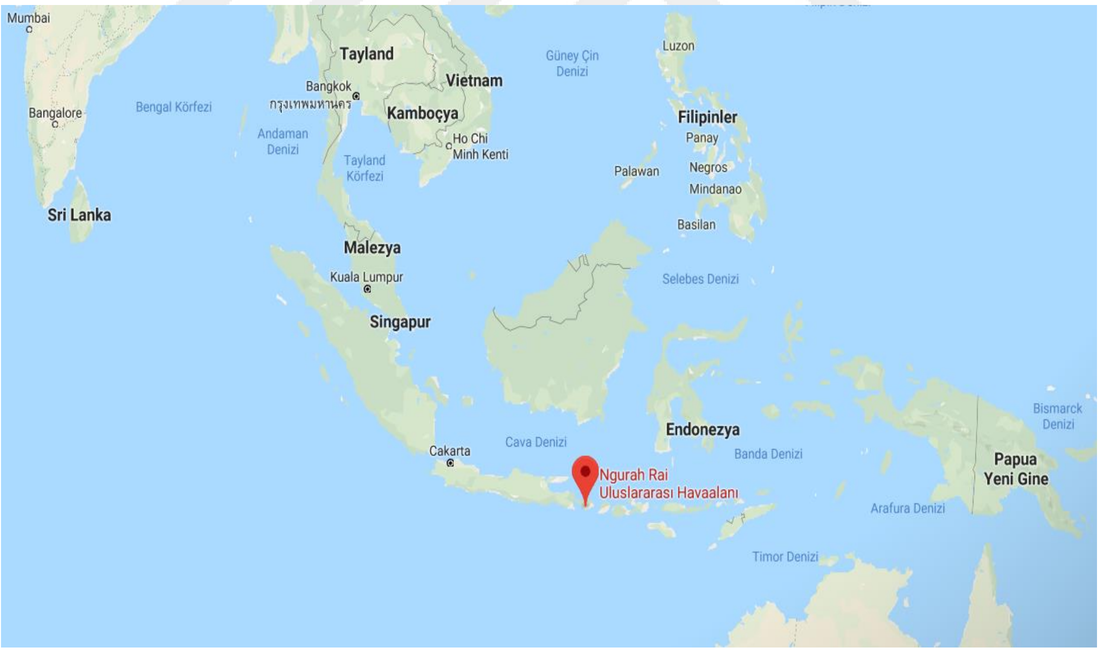

Figure 1.5: Location of DPS on Map

Figure 1.6: Location of HAH on Map

Figure 1.7: Location of UIO on Map

1.2 Selection of Methodology

The researches done in section 1.3 illustrate the complexity of scheduling and feasibility evaluating phases in the airline industry. It can be said that this complexity stems from two main reasons: interdependencies between criteria and planning phases.

Firstly, interdependencies among criteria may hard to see in criteria identification phase and therefore may lead to information redundancy. Considering this interdependent relationship among criteria, Analytical Network Process is an appropriate methodology to use in this thesis study.

Secondly, all planning phases, schedule design, fleet routing, maintenance routing, crew planning in aviation are interdependent. This nature of the airline industry causes a “chicken-egg” effect. Therefore, the data obtained from other planning phases are both input and output for the route evaluation phase. This situation implies that one single method for route selection would not be efficient and an integrated multi-objective optimization based computer systems which handle all of the planning phases simultaneously can be used.

2. LITERATURE REVIEW

In this section, first, a summarized literature review on studies using Multi-Criteria Decision Making (MCDM) techniques is presented. Then some studies having used other methodologies like operation research as a method in route selection are given and the criteria used in route evaluation are listed.

2.1 Studies Used MCDM in Airline Industry

Yau (1993) presented an interactive decision support system for short-term airline schedule design. This system used a simulation process of which results are then used for interactive multi-criteria implemented in the system, through Multi-Attribute Utility Theory (MAUT), to choose the best among the schedule alternatives.

Feng and Wang (2000) used the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for performance evaluation in airlines. They focused on both operational and financial aspects of performance and utilized grey relation analysis.

Tsaur et. al. (2002) evaluated airline service quality using fuzzy set theory to overcome the difficulties by intangible attributes. They used the Analytical Hierarchy Method (AHP) for criteria weighting and TOPSIS in the ranking. They found that the most concerned attribute was courtesy, safety, and comfort.

Lee and Chou (2006) presented a fuzzy multiple criteria decision-making model to the evaluation of airline competitiveness over a period. First, they derivate strength and weakness matrices then they obtained strength and weakness indices for airlines.

Wang and Chang (2007) also applied TOPSIS in evaluating initial training aircraft for Taiwan Air Force Academy under a fuzzy environment. The study is performed with sixteen evaluation criteria with seven alternative aircraft and there were fifteen decision-makers involved.

Chan et al. (2007) used AHP to obtain criteria weights with the aid of commercial software for the selection of supplies of parts and repair and maintenance services. The system is implemented on a Hong Kong based airline and found successful.

Papakostas et al. (2010) used multi-criteria analysis for short term planning of the line maintenance at the airports. The selected decision criteria were cost, remaining useful life of the aircraft, operational risk level, and flight delay.

Bassy et al. (2014) performed a study that uses Multi-Objective Programming for the airline crew scheduling. This study was a composition of both MODM and optimization.

Yury and Andreas (2010), presented a study about flight gate scheduling problems and they approached the problem as multi-criteria multi-mode resource-constrained project scheduling problem with generalized precedence constraints or time windows. Unlike previous approaches of the problem as a single objective counterpart, they tackled it directly through multi-criteria metaheuristic, namely Pareto Simulated Annealing, in order to get a representative approximation of the Pareto front. Possible uncertainty of input data is treated by means of fuzzy numbers.

A study by Sun et al. (2011) utilized MCDM methods to solve an aircraft concept selection problem for a hypothetical airline when considering the robustness of the decision. Three MCDM methods were used to conduct the concept selection, including Elimination and Choice Expressing Reality (ELECTRE), simple additive weighting (SAW) and TOPSIS.

Norese and Carbone (2014) used ELECTRE Tri to improve Italian airports' product offerings and identify new products' value drivers in order to help them through the restrictions of Italian Aviation Authority caused by the economic crisis.

Gomes and Mattos (2014) published a study for an Airline in Brazil that wants to invest in charter flights. The problem has eight alternatives and eleven criteria, whose measurements can be exact, stochastic, or fuzzy. The technique chosen for analyzing and then finding a solution to the problem is the multi-criteria decision aiding method named NAIADE (Novel Approach to Imprecise Assessment and Decision Environments). The method used allows tackling the problems by working with quantitative as well as qualitative criteria under uncertainty and imprecision.

Yang et al. (2010) applied ANP (Analytic Network Process) through the outsourcing of logistic service provider for air cargo transport. ANP Approach was needed due to the inner dependency of elements in activities and integration, and interdependency between the strategic, tactical, integration and alternatives clusters in this study. They found that the second alternative with an integrated information system and global network is the best one with respect to benefits, costs, and risks.

Zhang et. al. (2015) utilized a non-additive fuzzy measure to evaluate airline service quality. They found it more suitable than using conventional additive measures since they may mislead to evaluate airline service quality correctly. The study proposes the fuzzy measure and introduces Marichal entropy of the fuzzy measure to reach a solution. This paper also presented the aggregator Choquet integral with respect to the fuzzy measure. To verify the method's effectiveness, an application study of the comprehensive performance of fifteen US airlines was conducted, using data collected over a ten year period.

Deveci, Demirel, and Ahmetoğlu (2017) applied a type-1 and type-2 fuzzy TOPSIS methods to evaluate potential destinations for an airline in Turkey. They chose North America as the region of study and employed eleven criteria and selected SFO as the best destination.

All the mentioned studies above and MCDM methodologies they used are summarized in the table below.

Table 2.1: Studies Used MCDM

STUDIES	METHODOLOGIES USED							
	AHP	**ANP**	**ELECTRE**	**FUZZY SET THEORY**	**MAUT**	**MODM**	**SAW**	**TOPSIS**
(Yau, 1993)					×			
(Feng and Wang, 2000)								×
(Tsaur et al., 2002)	×							
(Lee and Chou, 2006)				×				
(Chan et al., 2007)	×							
(Wang and Chang, 2007)				×				×
(Papakostas et al., 2010)					×			
(Yang et al., 2010)		×						
(Yury and Andreas, 2010)				×				
(Sun et al., 2011)			×				×	×
(Bassy et al., 2014)						×		
(Gomes and Mattos, 2014)				×				
(Norese and Carbone, 2014)			×					
(Zhang, et al., 2015)				×				
(Deveci et al., 2017)				×				×

2.2 Other Techniques In Route Evaluation

Early research on the schedule designing problem has considered a very limited number of candidate routes and they all consider aircraft as one type, meaning that all aircraft have the same operation costs and seating capacity.

Two pieces of research done in 1963 (Dantzig, 1963) (Kushige, 1963), and one research in 1967 (Miller, 1967) used linear programming to solve the problem. In the 1980s the researchers have started to use other techniques like mixed integer programming (Lamotte and Mathaisel, 1983), and Lagrangian - based algorithms (Balakrishnan et al., 1990).

Aside from the traditional fixed market share flight schedule models which use integer or mixed-integer linear programs, Yan and et al. (2007) developed a short-term scheduling model with variable market share for Taiwan Airline to improve the efficiency in fleet routes and flight schedules.

Bassy et al. (2014) , as mentioned before, used MODM techniques and applied multi-objective optimization methods in New Zealand crew pairing problems with two objectives of minimizing cost and maximizing unit crewing simultaneously

Unlike traditional operations research optimization problems, which deal with a single objective function to be optimized over a set of feasible solutions, MCDM refers to making decisions in the presence of multiple, usually conflicting and non-commensurable criteria (Zanakis, et al. 1998).

2.3 Criteria Used in Route Evaluation

There are several criteria on which focused on the routing evaluation problems. The table below illustrates these criteria and the studies done using them in literature.

Table 2.3: Criteria Used in Studies

STUDIES	CRITERIA USED								
	C_{11}	**C_{12}**	**C_{13}**	**C_{14}**	**C_{15}**	**C_{21}**	**C_{33}**	**C_{41}**	**C_{43}**
(Martín and Román 2004)	×			×		×	×		
(Arslan and Khisty 2006)						×	×	×	
(Graham 2012)		×	×	×			×	×	
(Deveci, Demirel, and Ahmetoğlu 2017)	×		×	×	×	×	×		×

The main criteria are symbolized as C_i, where *i* is the number of relevant main criterion, and sub-criteria are symbolized with two indices as C_{ij}, meaning that *i* is the number of the sub-criterion belonging to *j*th main criterion.

C_1 Economic Considerations: Naturally, like all kinds of enterprises, for the airlines as well profitability is the main objective whereas costs are the main criteria.

C_{11} Passenger Demand for the Region: For this study, to capture a wider scope, this sub-criterion is taken as the estimated number of the passenger flow from all over the world to the region of destination. The relevant values are obtained from statistical data on the internet.

Martín and Román (2004) used passenger flow for the airport and the whole market to choose a hub for airlines. Deveci et al. (2017) set the potential passengers to and from Turkey as one of the most important three criteria in their route selection.

C_{12} Cargo Demand for the Region: This sub-criterion is based on the estimated number of the cargo flow from all over the world to the region of destination for this study. According to IATA, Air cargo makes up approximately 35% of global trade by value. For the airlines carrying both cargo and passengers, the percentage of revenue generated by cargo business is 9% of airline revenues on average, that is more than double the revenues from the first-class segment (IATA Cargo Strategy, 2018).

C_{13} Airplanes Cost: Although this expense item includes all kinds of variable costs that occur when flying the aircraft to the specific destination, such as maintenance and depreciation costs, fuel consumption stands out as the most important cost factor by far in many studies. Graham (2012) and Deveci et al. (2017) used fuel cost as the most important main criterion in his study of constructing freight transport network. In the study, this sub-criterion is also covered by the fuel consumption of airplane flying back and forth to the destination.

There are currently two main grades of engine fuel: Jet A-1 and Jet A, which are both kerosene-type fuels (Nojoumi et al., 2009), however in the corresponding company Jet A-1 is used. Fuel consumption can be thought as a composition of both the amount of fuel in liters which is determined by the length of the route, therefore distance; and fueling rate in the related country’s airport.

C_{14} Airport Facilities Cost: The items like landing fees, parking charges, the cost of hiring gates and counters also vary among airports. Martín and Román (2004) reported that good airport facilities are one of the factors affecting the network structure of an airline. In the study, two dominant factors: landing tolls and parking charges are used to calculate this expense item, since they have the determinant effect. Deveci et al. (2017) took station, gate and parking costs as additional costs in their study.

C_{15} Staff Costs: Crew layover costs and staff relocation costs are calculated based on the cost of living of that particular city, determined by the inflation rates. Crew overtime costs may occur if the destination city is far away or the delay time in the airport of destination is too much to exceed the allowed working hours limitations for the crew, determined by Directorate General of Civil Aviation of Turkey (DGCA). So this sub-criterion is determined by both the annual inflation rate of the country of destination and the distance between the destination airport and İstanbul.

Deveci et al. (2017) assigned the staff cost criterion along with the cost regarding fuel criterion as the highest weight in their study of route evaluation for an airline.

C_2 Strategic Considerations: Strategic considerations consist of the sub-criteria competitiveness index and prestige of the airline.

C_{21} Competitiveness Index: Frequency of service per day is directly related to the competitiveness index since it indicates the number of competitors and flights to the destination. The more competitors' flights are available, the less revenue is generated since cheap ticketed airlines are preferable. It is also related to market share.

High frequency of flights to the airport causes denser air and ground traffic. Arslan and Khisty (2006) assigned the attribute of the degree of congestion for setting the route choice in their study. Graham (2012) used the frequency of truck trips between origin and destination for constructing a freight transport network.
C_{22} Prestige of the Airline: In order for leading airlines to stand out among its rivals, the destination to be launched plays an important role in terms of prestige. Launching a destination of all the close competitors fly is a must while evaluating a destination where the leading global airlines couldn't accomplish yet is a golden marketing strategy.

C_3 Safety Considerations: Even though most of the passengers have the awareness to choose an airline, based on if it is en route with safety considerations, there are several authorities ensuring the route are planned accordingly.

C_{31} Alternate Diversion Stations: Flying at high altitudes necessitates being prepared for all kinds of emergency situations, such as loss of pressure in the cabin, hijacking and serious health conditions developed. An aircraft diverts to the nearest stations in such cases, when flying over oceans, it may get up to 3 hours to reach an airport. This sub-criterion varies from destination to destination, however, it is not determinant, rather it is the one influenced by other elements.

C_{32} Health Conditions in the Region: The destination's medical capabilities must also be considered by an airline, as they have the accommodating crew and they locate their staff in the region. Some regions might be too risky to fly, as they pose natural disaster or health risks, such as contagious diseases. As an illustration, many airlines canceled their flights to North Africa in the times of Ebola disease. Similarly, more than 1400 flights are canceled in the USA, in the risk of Florence hurricane in 2018 (Akşam 2018).

C_{33} Weather Conditions in the Region: The factors such as visibility, icing or meteorological factors affect the flights. Martín and Román (2004) stated that good weather facilities are effective in an airlines' network structure in their study for hub location evaluation. Arslan and Khisty (2006) found that safety is one of the three most important criteria when choosing a route. Graham (2012) used truck accident rate in selected routes as a criterion through route selection for the freight transport network, as the visibility and bad weather conditions affect the safety directly. The weather conditions directly impact the staff cost criterion, as when the flight time limitations set by DGCA is exceeded; penalties may apply to related airline. A flight may get canceled or delayed due to these limitations until the crew is freshened by resting or until the new crew arrives.

C_4: Geopolitical Considerations: Selecting a destination, not only the conditions of the flight route, but also the geopolitical conditions of destinations matters. This criterion includes economic indicator indices and security related rates of the country of destination, and over-flight conflict zones nearby the destination.

C_{41}: Over-flight Conflict Zones: The nature of conflicts could be various and include, inter alia, escalations of asymmetric warfare, tactical actions of insurgents, provoking skirmishes between the armed forces of countries in political tension and even deliberated launches of weapons in areas out of the political control by legitimate states. Conflicts could also impair the safety of flights on high seas when the dangerous use of weaponry expands outside the territory of sovereignty. (CANSO 2016)

Having a route including these conflict zones increases the risk for accidents and affects the image of an airline as in the Malaysian Airlines example. On 17 July 2014, a passenger aircraft belonging to Malaysian Airlines departed from Amsterdam to Kuala Lumpur, however, disappeared from radar and communication with the crew was lost. The aircraft was flying over the Dnipropetrovs'k flight information region, above temporary restricted areas (CANSO 2016) . This incident affected Malaysian Airline's credibility in a bad way.

Arslan and Khisty (2006) conducted a survey and found that the perceived travel time, is one of three main criteria in the behavior of choosing a route, as over-flight conflict zones criterion directly affect total trip time because it causes the route to be extended.

C_{42} Security Considerations: Security considerations are important as they directly affect an airline's prestige. Airlines with high accident and incident rates are not preferable and therefore they are under the risk of going out of business. The risk of destroying an airlines prestige and having to pay for compensation to the staff families in case of incidents must also be considered. One of the leading airlines in Turkey had the incident in Beirut when two pilots, which are on the way to the hotel for their layover, kidnapped by Lebanese extremist group in 2015. In this study, the global peace index, which can be considered as the opposite of the crime rates, of the countries of destination is taken as the security parameters.

C_{43} Political Economy: Under this criterion, economic indicators of the country of destination is contained. In the study, for positive dimensions including opportunity and benefit, the gross domestic product of the country of destination is accounted, since developing business opportunities affect trade relations as well as the political relations with the country. For the negative dimensions, namely for the cost and risk aspects, the inflation rate of the country of destination is used for calculating this sub-criterion.

3. METHODOLOGY AND MODELING

In this section, firstly, the selection process of problem and methodology is presented by flowcharts in the Figure 3.1 and 3.2. Constructing the flowchart in the Figure 3.1, the study by Gürbüz (2019) is used as an aid to show the steps of AHP and ANP. The selected methodology. ANP on BOCR basis provides a comparative analysis of alternatives in the sense of deciding which one to select under benefit and opportunity dimensions, and which one to avoid, under cost and risk dimensions. The proposed model is constructed, both in simple ANP structure and BOCR structure with subnets in paragraph 3.1, following by the priority calculations in paragraph 3.2 and results in paragraph 3.3.

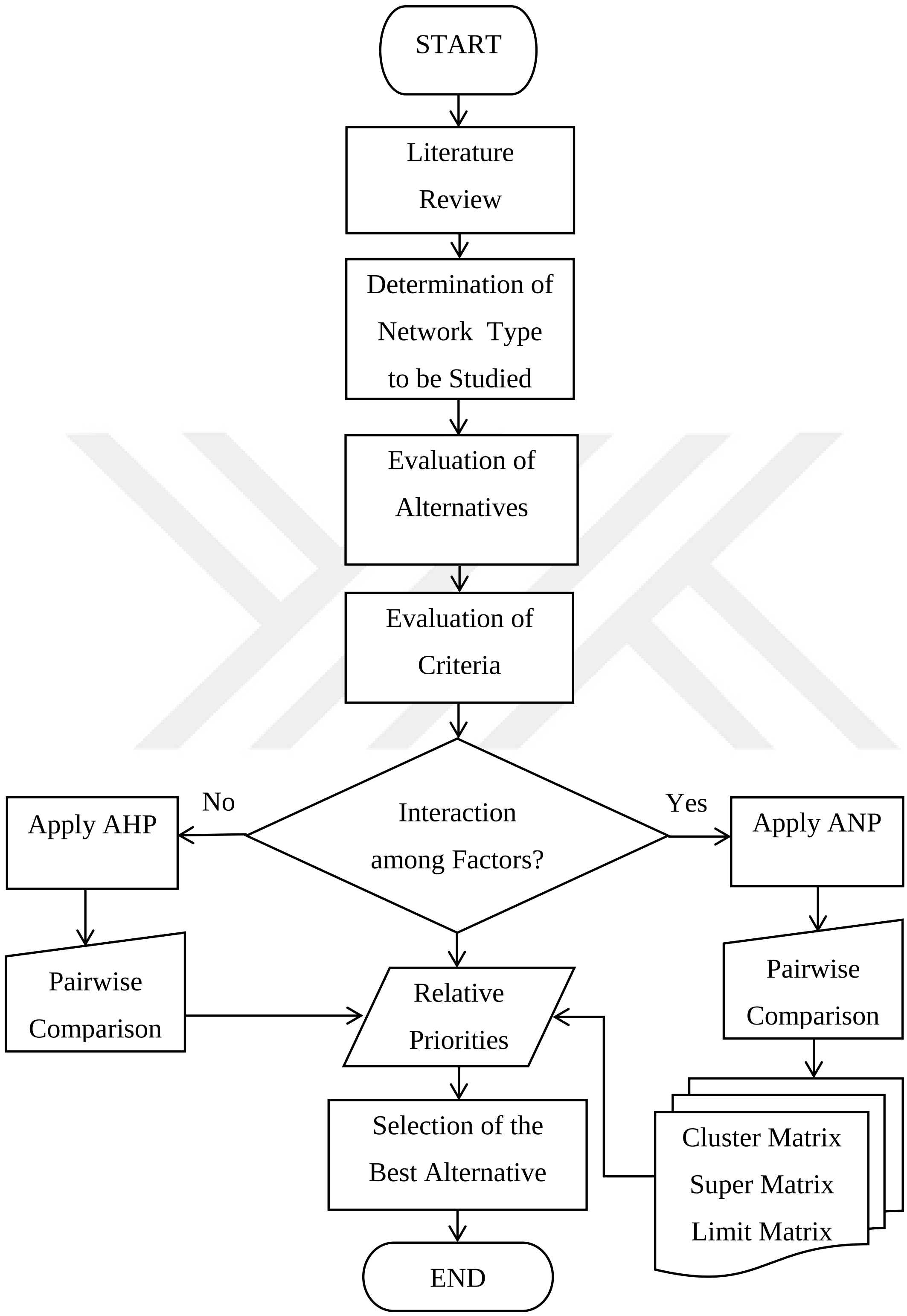

Figure 3.1: Selection Between AHP and ANP Flowchart

As mentioned before, due to the nature of route selection in aviation, dependencies must be taken into account. ANP is an extension of analytic hierarchy process AHP, developed by Saaty, considering these complex interactions among criteria and alternatives. The structure is therefore close to AHP structure and consists of three levels of clusters: goal, criteria, and alternatives. However, unlike the AHP, the model in the ANP is no longer linear, considering the dependent nature of the problem. Therefore, a hierarchy is not necessary for the ANP model, where clusters replace the levels and each cluster contains nodes or elements (Ishizaka and Nemery, 2013).

Using AHP and its extensions like ANP, some researchers have proposed breaking down the problem into sub-problems (Azis 1990), (Clayton, et al. 1993). In this way, the criteria having opposite influences can be separated into two, positives that needed to be maximized: benefit and opportunity; and negatives that needed to be minimized: cost and risk. This problem is also approached through BOCR methodology.

The dependencies in ANP are also called feedbacks. In a model, feedbacks are shown by a line which connects the relevant elements or clusters. Two types of dependencies are under consideration: inner dependency in the cluster (dependency among nodes within the cluster), and outer dependency which is between different clusters or levels. A full network can include source nodes, transient nodes that fall on paths from source nodes, lie on cycles, or fall on paths to sink nodes; and finally sink nodes. “A source node is an origin of paths of influence (importance) and never a destination of such paths. A sink node is a destination of paths of influence and never an origin of such paths” (Saaty, 2008)

3.1 Construction of the Model

The steps in the application of ANP is shown by a flowchart below. Each step is also explained verbally through modeling and analysis.

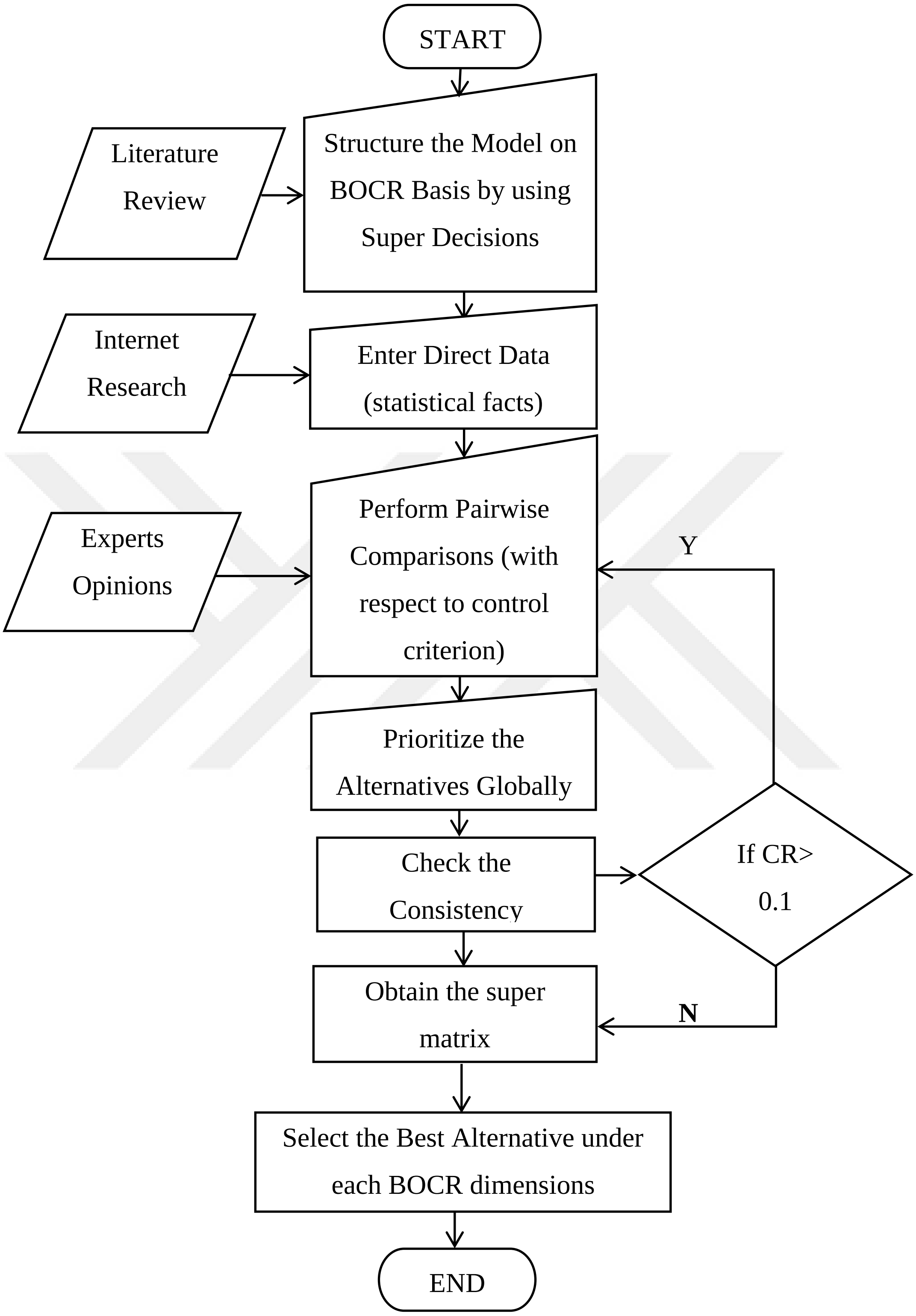

Figure 3.2: ANP Flowchart

Table 3.1: The Criteria

	Number of Sub criterion	**Explanation**
C_1		Economic Considerations
	C_{11}	Passenger Demand for the Region of Destination
	C_{12}	Cargo Demand for the Region of Destination
	C_{13}	Airplanes' Costs (Refueling Cost)
	C_{14}	Airport Facilities Cost (Landing Tolls, Parking Charges)
	C_{15}	Staff Costs (Crew Layover Costs, Crew Operational Costs)
C_2		Strategic Considerations
	C_{21}	Competitiveness Index (Frequency of Service per Day)
	C_{22}	The prestige of the Airline
C_3		Safety Considerations
	C_{31}	Alternate Diversion Stations (on the Route)
	C_{32}	Health Conditions in the Region of Destination (Medical Capabilities and Contagious Diseases)
	C_{33}	Weather Conditions in the Region (Visibility, Icing)
C_4		Geopolitical Considerations
	C_{41}	Over-flight Conflict Zones (Zones of Terrorism and War)
	C_{42}	Security Considerations (Crime Rates- Global Peace Index)
	C_{43}	Political Economy Considerations (Gross Domestic Product, Inflation Rate)

Table 3.2: Influence Matrix of the Problem

	Alternatives			**Criteria**												
	A_1	**A_2**	**A_3**	**C_{11}**	**C_{12}**	**C_{13}**	**C_{14}**	**C_{15}**	**C_{21}**	**C_{22}**	**C_{31}**	**C_{32}**	**C_{33}**	**C_{41}**	**C_{42}**	**C_{43}**
A_1				×	×	×	×	×	×	×		×	×	×	×	×
A_2				×	×	×	×	×	×	×		×	×	×	×	×
A_3				×	×	×	×	×	×	×		×	×	×	×	×
C_{11}	×	×	×						×	×		×			×	×
C_{12}	×	×	×						×	×		×				×
C_{13}	×	×	×								×		×	×	×	×
C_{14}	×	×	×	×	×					×						×
C_{15}	×	×	×	×	×				×	×	×	×	×	×		×
C_{21}	×	×	×	×	×		×					×	×	×	×	×
C_{22}	×	×	×	×				×	×		×	×	×	×	×	×
C_{31}	×	×	×											×		
C_{32}								×					×			×
C_{33}																
C_{41}	×	×	×			×										
C_{42}								×				×				×
C_{43}				×	×			×	×			×			×	

The detailed explanation of the criteria presented in the Table 3.1 is given in paragraph 2.3. The goal of the problem is to evaluate the best alternative of destination considering these criteria. However, the cluster goal is removed from the influence matrix, because in this case, the weight of the criteria depends on the alternatives available (Ishizaka and Nemery 2013). In the Table 3.2, the topmost row indicates the elements influencing, whereas the leftmost column shows the elements influenced. Intersection cells are marked by a cross if dependency exists.

According to the influence matrix in the Table 3.2, C_{11} affects C_{14} and C_{15} as the more is the number of passengers, the more staff is needed. Also, when the passenger demand is high in a destination, that destination should be in every prestigious airlines' schedule as a non-stop flight, ensuring the comfort and ease of the travel, since the term prestige comes from being quality-oriented. Therefore the strategic criteria C_{21} and C_{22} are influenced. Increasing passenger demand results in an increased gross domestic product, meaning that C_{43} is impacted by both C_{11} and C_{12}.

Similarly, C_{12} has an effect on C_{14} and $C_{15,}$ as the higher is the cargo demand, the more staff and the much operation time are needed. C_{21} is dependent on C_{12} because higher demand attracts more airlines.

C_{13} only influences C_{41} because, when there are over-flight conflict zones, most of the time the zone is either prohibited by the country or avoided by the airlines for political reasons. This situation causes longer distance of travel and therefore more amount of fuel and depreciation of the aircraft.

C_{14} impacts on C_{21}, since the cost of airports decreases the revenue generated from that destination and the number of airlines which interested in the destination.

C_{15} directly exerts influence on C_{22}. Assigning a five-star quality accommodation for their employees illustrates a level of prestige of that airline.

The competitiveness index is directly related to the frequency of flights, so the more the number of competitor flights, the more chance of divided cargo and passenger demand among competitors. That's why C_{21} influences both C_{11} and C_{12}. The frequency of service increased also means the operation time increased in that destination due to a busy schedule, therefore C_{15} is impacted. The more the number of flights, the more intense trade relations and opportunities for the countries of origin and destination pairs, meaning that C_{43} is under the influence.

The prestige of the airlines is one of the significant factors defining the demand factors C_{11} and C_{12}. As mentioned before the quality of accommodation of the employees is a sign of prestige level in the market, C_{15} and C_{22} have two-way relationships. Prestigious airlines have more counters and specially designated facility areas in the airport indicating that C_{22} acts on C_{14}.

Having at least two alternate aerodromes en-route is a must for long- haul flights according to the company regulations in which the study is performed. Depending on the daily conditions of the flight, the number of possible diversion stations selected varies. Different airlines select a different number of C_{31} en-route, the less number of alternates means the more time elapsed for landing in case of emergencies such as an engine failure or a passenger having a serious health problem (heart attack, cerebral hemorrhage). And this risk factor of not landing in time (for hospital etc.) affects prestige C_{22} strategy in terms of increased safety. Alternative destination airports having a route across the oceans or poles have less number of alternates, in order to have an adequate amount of alternates, the route is extended causing increased operation time, C_{15}, and fuel consumption C_{13}.

When the city of destination provides a broad range of qualified health care (C_{32}), more passengers (C_{11}) tend to come to the city for the cure of several diseases, just like in the case of Houston, being an international medical center. Similarly, medicine and medical equipment affect the cargo demand C_{12}.

On the contrary, if the area has contagious diseases such as Ebola or Zika, the demand would be lower for the destination and the competitors (C_{21}) would have cold feet for the destination due to health concerns. The risk of staff getting ill also increases. In such cases, the airline must plan an extra flight or crew attendant to replace the sick one, or sometimes serious delays are under consideration influencing C_{15}. Besides, airline prestige (C_{22}) can be shaken in staff mortality cases. The medical capabilities or lack of it directly affect a country in terms of the level of development, in return affecting the criteria C_{42} and C_{43}.

Weather conditions of the desired destination (C_{33}) have a great role in operation time, therefore on the fuel and crew expenses (C_{13} and C_{15}). The daily route can be altered in order to avoid the safety hazards en-route unless they don't have close proximity of the destination, however, if the area of the destination is treated as a low visibility or hurricane zone, the rate of late or canceled flights is high. International Civil Aviation (ICAO, 2005) sets the minimum visibility limit as 5 kilometers for altitudes at or lower than 900 meters or 3000 feet in annex 2. When the flight is operated at around this visibility limit, the pilot must either take the acceptable risk of landing/ take off anyway or divert to a safer close alternate airport. In both cases, the prestige of airline (C_{22}) is under risk. Also, because of the heavy weather conditions, the time interval for flights are limited causing the low frequency of flight for airlines (C_{21}). For instance, Turkish Airlines changed the operation time after the accident at Kathamandu Tribhuvan Airport, caused by dense fog. The countries having a tropical climate (due to heavy rains) and the countries located closer to the poles (due to snowstorms) often create the risk of low visibility and hydroplaning.

Over-flight conflict zones (C_{41}) cause route extensions, so this results in increased operation time meaning increased aircraft's depreciation and fuel consumption (C_{13}). For example, Pakistani airspace has been closed for over a month and the flight time for India cities (Delhi and Bombay) from Istanbul extended about 2 hours. For this reason, recently India flights have become extended range flights for those departing from Turkey, which are flights with the flight time of one leg exceeding 8 hours (for one way).

After returning such flights, the crew gains one day off and if they have a flight next day of return, this duty is removed from them. So a rise in the crew working hours and additional crew replacement cost (for the next day's duty) occurs (C_{15}). Since flying over conflict zones poses risk for airlines prestige "A Sibir Airlines flight from Tel Aviv, Israel, to Novosibirsk, Russia, is shot down and plunges into the Black Sea" (CNN, 2018). Although the Ukrainian Military denied the responsibility at first, they accepted later. Similarly, the Malaysian Airlines' passenger aircraft departed from Amsterdam to Kuala Lumpur, disappeared from radar due to flying over the Dnipropetrovs'k flight information region, above temporary restricted areas (CANSO 2016). What's more, some extremist groups can target the aircraft flying-over conflict zones, so that they can hijack and use the aircraft to attack the target zones as in the case of planes crashing the twin towers of the World Trade Center in New York City, United States of America. These crashes and accidents affect an airlines credibility significantly (C_{21}). Because of the risks and low profitability due to increased operational costs explained above, some airlines would avoid the destinations that would require flying over risky zones (C_{21}). Since these zones are not safe to land in case of an emergency, the number of alternate airports (C31) is very limited.

Having a high crime rate of crimes such as terrorism and kidnapping in the country of destination would directly lower the passenger demand (C_{11}). However, it wouldn't necessarily affect the cargo demand in the same way. For example, in most of the countries of South America, the crime rates are high, and people hesitate to go there, but their products remain to be popular. As an instance, coffee and grains such as quinoa or chia are exported mostly from this area. Countries of destination having security issues can also target the airplanes on the ground to deliver a political message (C_{13}). Security-related incidents have a negative impact on airlines' prestige (C_{21}), as in the case of a leading airline from Turkey of which two pilots are kidnapped by Lebanese extremist group in on the way to the hotel for their layover, in Beirut, in 2015. Lower passenger demand and higher security concerns decrease the overall flight frequency in the destinations under security threats (C_{22}). Countries of terrorism and unrest in terms of security also suffer from weak political economy (C_{43}).

The strong political economy of the country of the destination means strong trade relations, implying more cargo and people transfers (C_{11} and C_{12}). However, when the inflation is high, the costs of services provided from the destination in between the flights, such as refueling, supplying water, technical maintenance (C_{13}), hiring counters and gates, landing fees (C_{14}), and hotels for layovers, daily allowance paid by airlines to the staff (C_{15}) skyrocket. Medical Capabilities (C_{32}) and crime rates (C_{42}) are also directly related to a country's development level. Developed countries like USA, England, and Germany are usually prestigious lines for airlines. Since flying to these destinations is a must for quality-oriented airlines, it directly proportional to an airline's prestige and popularity of the destination in terms of competitor flights (C_{21} and C_{22}).

The analysis is based on the following hypotheses:
(i) The flight is non-stop for the desired destination,
(ii) Regional competitor flights and demands are taken into consideration for alternative airports, not the airport-focused values,
(iii) The same type of aircraft is planned for all candidate destinations with the same number of cabin and flight attendants.
(iv) There is no interaction among alternatives.

The problem structure is constructed using Super Decisions Software, version 2.10.0. A screenshot of the model showing the dependencies in the clusters is presented below. The arrows indicate the direction of interdependencies between the clusters and a circular arrow above a cluster indicates that the cluster is interdependent with interactions among their nodes.

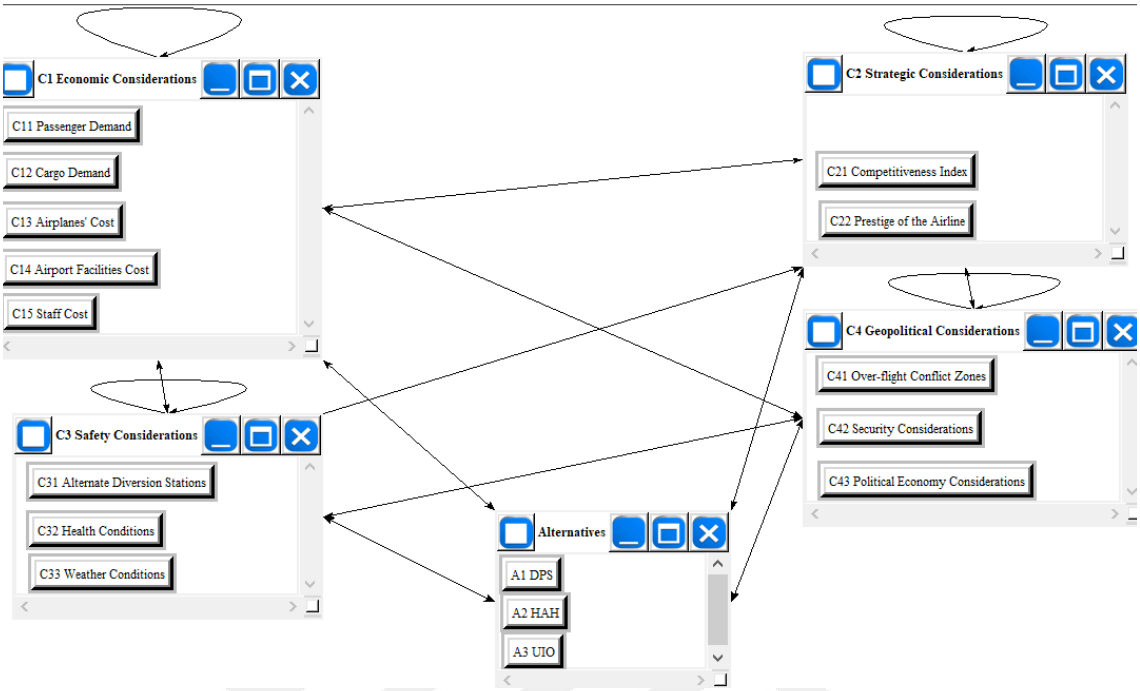

Figure 3.3: ANP Model of the Problem

The simple network illustrated in the Figure 3.3 can be divided into sub-networks of benefits, opportunities, costs, and risks by evaluating the sub-criteria in accordance with these dimensions.

Evaluation process can be done by asking the criteria four questions: “What is beneficial for the time being?” when asked, the answer gives us the benefit criteria; “What presents the opportunity in the future?” the answer gives us the opportunity criteria; “What incurs cost?” the answer gives us the cost criteria; “What poses a risk in the future?” the answer gives us the risk criteria (Saaty and Hall, 1999). The Table 3.3 below is prepared in the light of these questions.

Table 3.3: Dimensions of the Criteria

Subcriteria	**Dimensions of the Subcriteria**
C_{11} Passenger Demand	Benefit, Opportunity
C_{12} Cargo Demand	Benefit, Opportunity
C_{13} Airplanes’ Costs	Cost
C_{14} Airport Facilities Cost	Cost
C_{15} Staff Costs	Cost
C_{21} Competitiveness Index	Benefit, Opportunity, Cost
C_{22} Prestige of the Airline	Benefit, Opportunity, Cost, Risk
C_{31} Alternate Diversion Stations	Cost, Risk
C_{32} Health Conditions in the Region	Opportunity, Cost, Risk
C_{33} Weather Conditions in the Region	Risk
C_{41} Over-flight Conflict Zones	Cost, Risk
C_{42} Security Considerations	Cost, Risk
C_{43} Political Economy Considerations	Benefit, Opportunity, Cost

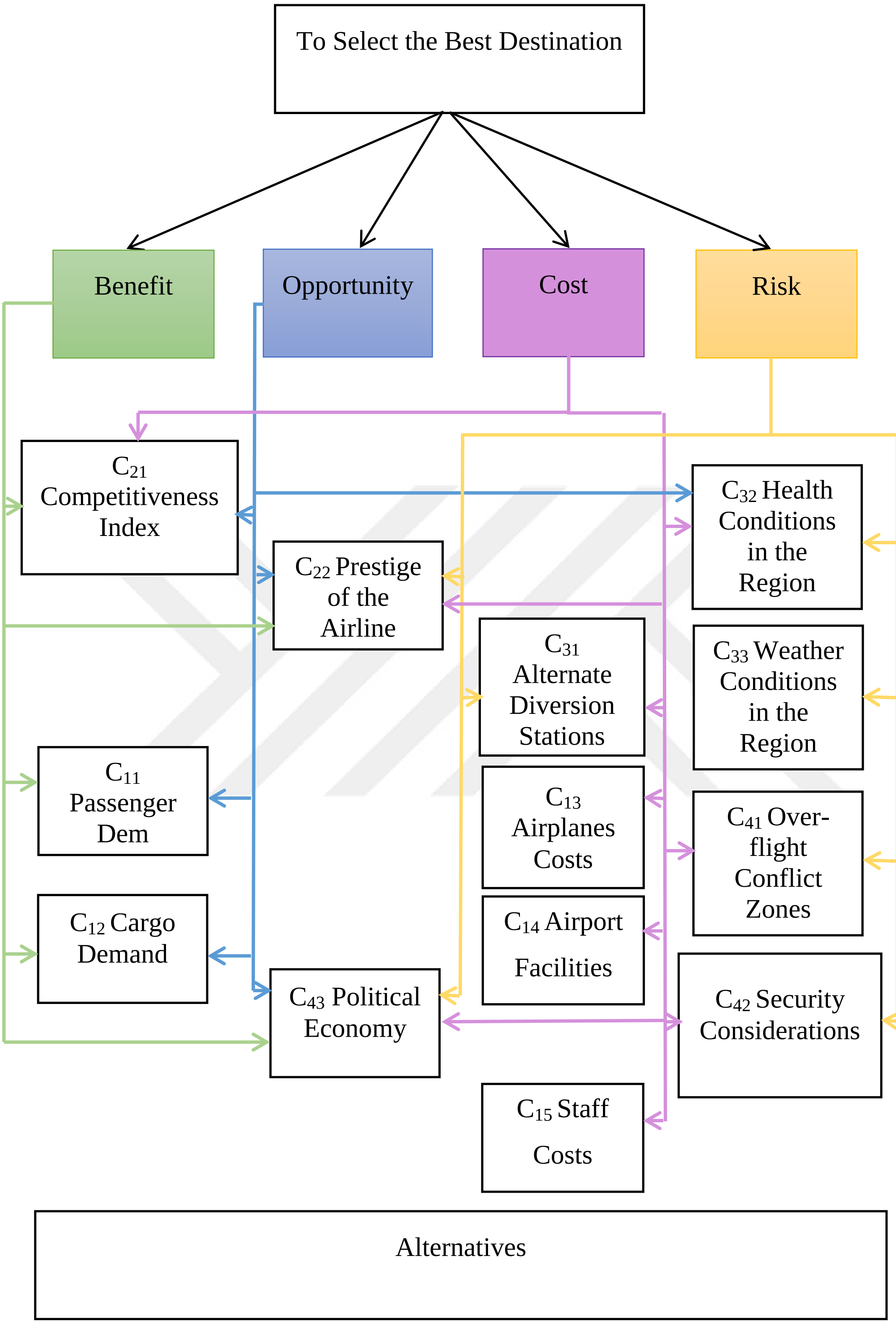

Figure 3.4: One Level Network under BOCR Dimensions

Figure 3.4 shows the BOCR structure of the model all in one level while the screenshot taken from super decisions in the Figure 3.5 illustrates the top-level structure of the 2 leveled modeling. With subnets of benefit, opportunity, cost and risk in the Figure 3.6, Figure 3.7, Figure 3.8 and Figure 3.9 respectively.

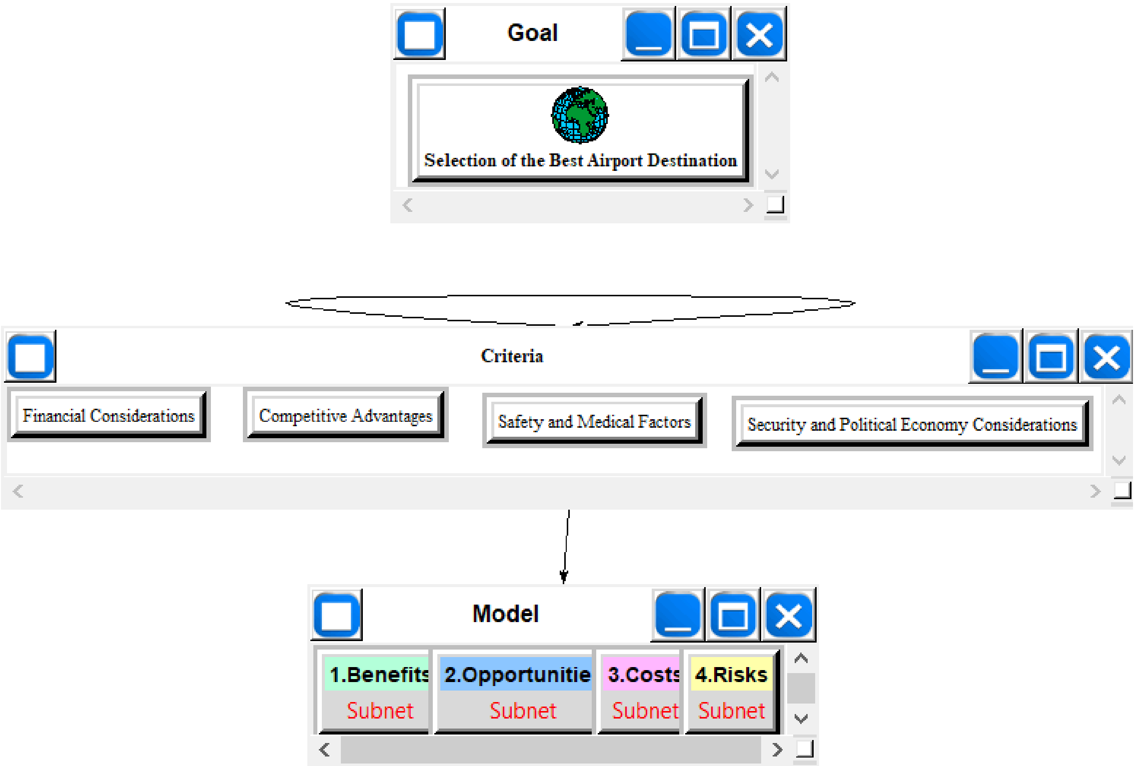

Figure 3.5: Top Level Structure of the BOCR Model

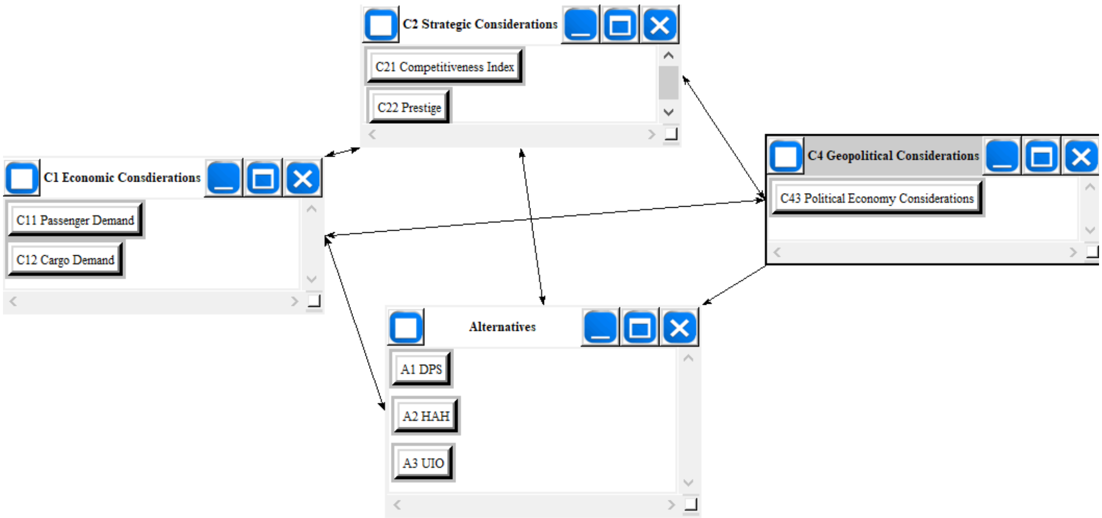

Figure 3.6: Benefit Subnet of the BOCR Model

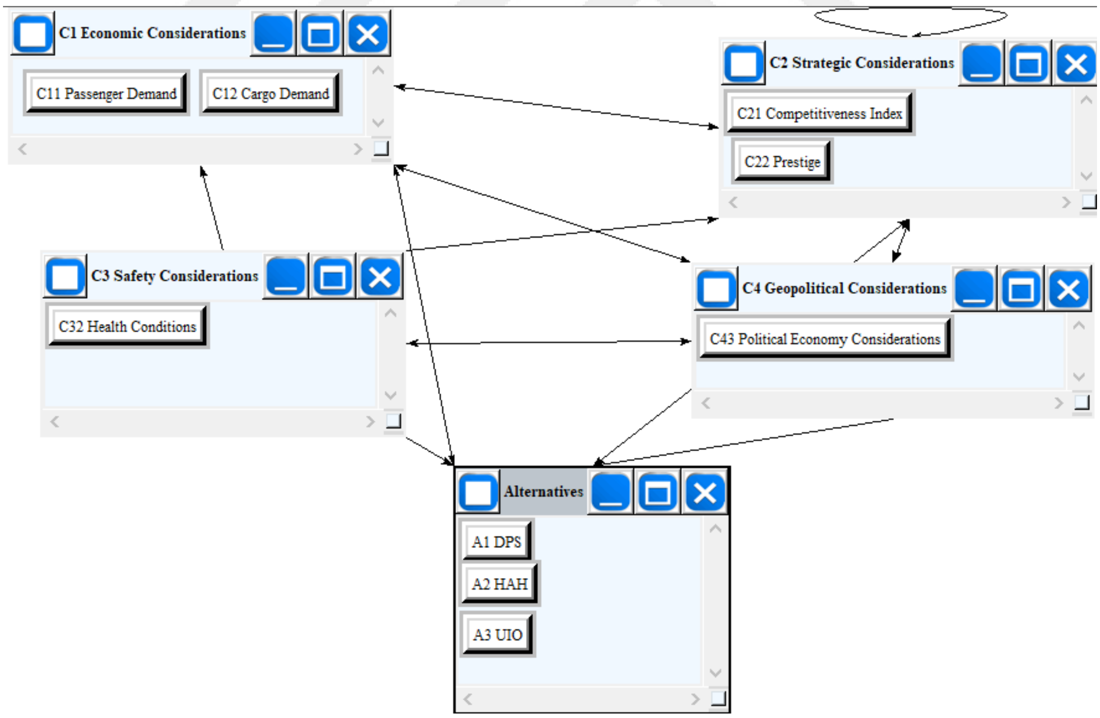

Figure 3.7: Opportunity Subnet of the BOCR Model

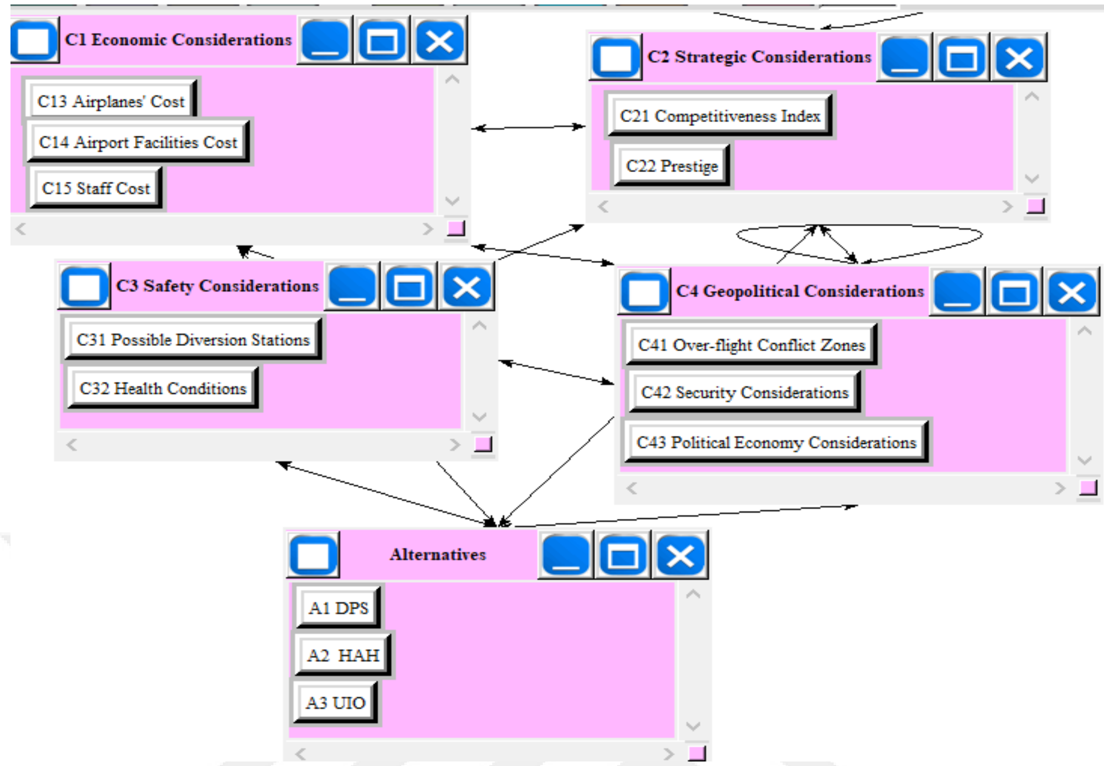

Figure 3.8: Cost Subnet of the BOCR Model

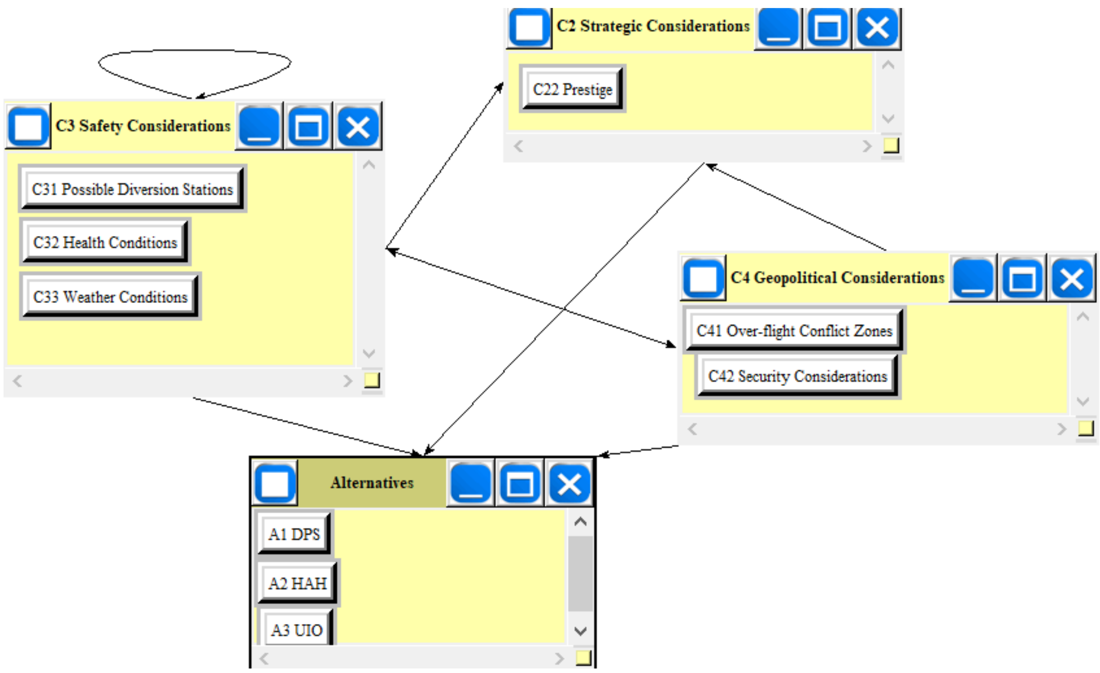

Figure 3.9: Risk Subnet of the BOCR Model

3.2 Priority Calculations

After the model of the problem is constructed, the next step is priority calculation. As in AHP, prioritization is based on pairwise comparisons. In order to calculate the priorities after the model is constructed both direct data obtained from statistical facts, which are presented in this chapter, and a questionnaire is prepared for expert opinions reflecting the company's targets and limitations. The decision-maker is asked 4 different groups (under each of BOCR dimensions) of pairwise comparisons with respect to their control criterion. As an illustration, for Benefit dimension, in order for the expert to compare the clusters C_1 and C_4 with respect to C_2, he is asked: "In the perspective of prestige and competitive benefits (meaning that control criterion is C_2 cluster) that the company will acquire from launching the destination which is more important? Passenger and Cargo Demands (C_1 cluster) or political economy benefits (C_4 cluster) that the country of destination has?" Pairwise comparisons are made using a 1-9 scoring scale developed by Saaty is given in the Table 3.4 (Saaty, 2008). With the questions replied, most of the local priorities are obtained.

Table 3.4: The 1-9 Fundamental Scale

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	Experience and judgment slightly favor one activity over another
3	Moderate importance	
4	Moderate plus	Experience and judgment strongly favor one activity over another
5	Strong importance	
6	Strong plus	An activity is favored very strongly over another; its dominance demonstrated in practice
7	Very strong or demonstrated importance	
8	Very, very strong	The evidence favoring one activity over another is of the highest possible order of affirmation
9	Extreme importance	
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption

The rest of the priorities are entered as normalized direct data into the software. Direct data entries are the statistical values obtained from several sources on the internet. The alternative destination airports and associated statistical data are as follows:

I Gusti Ngurah Rai International Airport (DPS) is located in Denpasar City, Bali Island, Indonesia, Asia. The destination is situated in the Pacific Asia Region in aviation literature.

Prince Said Ibrahim International Airport (HAH) is located in Moroni, Grande Comore Island, The Comoros, Africa. The destination is situated in the Africa Region in aviation literature.

Mariscal Sucre International Airport (UIO) is placed in Tababela, Metropolitan District of Quito, Ecuador, South America. The destination is situated in Latin America and the Caribbean Region in aviation literature.

According to Annex 2 to the Convention on International Civil Aviation (ICAO, 2005) minimum visibility limit is 5 kilometers for altitudes at or lower than 900 meters or 3000 feet.

Denpasar has a tropical monsoon climate and the average visibility is 11 km, the related graph of the city taken from World Weather Online (2019) is presented in figure 3.10.

Figure 3.10: The Visibility Graph for Denpasar

Moroni has a tropical wet climate, with an average visibility of 18 km. The related graph of the city taken from World Weather Online (2019) is presented in the Figure 3.11.

Figure 3.11: The Visibility Graph for Moroni

Quito has a subtropical highland climate the average visibility is 11 km, the related graph of the city taken from World Weather Online (2019) is presented in the Figure 3.12

Figure 3.12: The Visibility Graph for Quito

Since the alternatives have similar types of climate without the possibility of snowstorms, the visibility factor is considered to compare the alternatives with respect to weather conditions criterion. The normalization process is applied using the *Manhattan Distance Method* and visibility is treated as a cost type criterion, since lack of visibility is used for risk assessment. Normalized value of the visibility is denoted by C_{33}'.

Table 3.5: The Matrix Entries for C_{33}

	A_1	**A_2**	**A_3**
Visibility (C_{33})	11	18	11
C_{33}'	0,38	0,23	0,38

For the criterion C_{43}, the gross domestic product of alternatives in 2016 and 2017 are used for comparisons under benefit and opportunity dimensions, whereas inflation rates are used for comparisons under cost and risk. These data are obtained from the website of the Republic of Turkey Ministry of Foreign Affairs (2016). Normalization is based on Manhattan Distance and GDP is treated as a benefit type criterion, to be used under opportunity and benefit dimensions, whereas, inflation is treated as a cost-type criterion to be used under cost and risk dimensions. The global peace index is the opposite of crime rates, therefore it is treated as a cost-type criterion while normalizing, and the normalized value is denoted by . C_{42}'. Finally, since the Comoros' index is not included in the report, another close island, having a similar average is taken from the report (Madagascar) (IFEP, 2018).

Table 3.6: The Matrix Entries for C_{42} and C_{43}

	A1	**A2**	**A3**
GDP (in billions of USD)	868	649	97,8
Inflation Rate (%)	5,5	0,8	1,7
Normalized Values of Inflation Rate	0,09	0,62	0,29
Normalized Values of GDP	0,54	0,40	0,06
The Global Peace Index (C_{42})	1,853	1,766	1,987
C_{42}’	0,34	0,35	0,31

Data for the tables below obtained from The Logistics Capacity Assessment (Kealey, 2018) and ICAO (ICAO, 2014) online sources whereas the bird-fly distance between the base airport (IST) and candidate destination is measured using the application Google Maps. Since the route can change due to weather and other conditions, the actual flight distance can change and these values are only approximate indicators. Landing and parking fees are the most dominant factors calculating airport facilities, so a combination of them is used as C_{14} and refueling cost is the most important factor calculating aircraft’s expenses, therefore, distance multiplied by refueling fee is used as C_{13} computing pairwise comparison among alternatives. The combination of Inflation and normalized distance value is used as $C_{15,}$ The normalized value of criteria are denoted by *Cij*’ where *i,j* € {1,2,…,n}.

$$C_{13} = \text{Refueling Cost x Distance} \tag{3.1}$$

$$C_{14} = \text{Landing Fee + Parking Charges} \tag{3.2}$$

Table 3.7: Tariffs for Alternative Airports

	C_{14}		**C_{13}**			**C_{13} Total**	**C_{13}'**	**C_{14} Total**	**C_{14}'**
	Landing Fee (USD/ton)	Parking Charges (USD/ton)	Refueling Cost (USD / liter)	Distance from IST (km)	Normalized Distance				
A_1	4,01	0,41	0,91	10350	0,28	9,42	0,261	4,42	0,594
A_2	10	0,10	1,14	6060	0,47	6,91	0,355	10,10	0,26
A_3	15,75	2,17	0,56	11430	0,25	6,40	0,384	17,92	0,146

In the company for USA layovers $50/day is given as allowance to a cabin attendant, whereas approximately $10/hour is paid for the flight, considering the return leg as well, approximately, $20 multiplied by the flight time is paid as the operational cost to a cabin attendant. From these data, it can be derived that for a flight, layover allowance, therefore inflation rate is 2.5 times more dominant than operation cost of the crew. Average staff cost can be obtained as shown in the following Equation 3.3.

$C_{15} = 2\times$ Flight Time $\times$ [(# of cabin attendants$\times$10) + (# of flight attendants $\times$ 40)] + 2.5 $\times$ (Inflation Rate) $\times$ (# of crew) (3.3)

Given that the hourly operation cost is $10 for a cabin attendant and $40 for a flight attendant; and the number of cabin attendant is 14, whereas the number of flight attendants is 3 for the flights and considering this, numbers are same for each alternative, C_{15} is calculated for each alternative. Approximate estimated time can be calculated through a variety of tools based on the approximate bird fly distances and the normalization is done based on the Manhattan Distance Method.

Table 3.8: C_{15} for Alternatives

	Estimated Time of Flight	**Normalized Inflation Rate**	**C_{15}**	**C_{15}'**
A1	14,30	0,09	7449,75	0,25
A2	8,00	0,62	4162,00	0,45
A3	12,50	0,29	6504,25	0,29

The values for the Table 3.9 are obtained from the Air Transport Action Group's Report (2018) prepared by Oxford Economics. In order to capture a wider scope, in terms of competitor flights and demands, the regional values are taken into consideration. Again the normalization process is done based on Manhattan Distance Method and C_{11} and C_{12} are treated as a benefit-type criterion while C_{21} treated as a cost-type criterion.

Table 3.9: Regional Air Traffic

	Regions		
	Asia Pacific **A_1**	**Africa** **A_2**	**Latin America and the Caribbean Region** **A_3**
C_{11} Total Annual Passengers from Europe (millions)	316	98	1500
C_{12} (value in USD millions)	2,1	0,968	22,2
C_{21} (in number of airlines)	181	161	331
C_{11}'	0,17	0,05	0,78
C_{12}'	0,08	0,04	0,88
C_{21}'	0,37	0,42	0,20

Pairwise comparing, consistency check is done to ensure that priorities are meaningful. Up to 10% inconsistency of 500 randomly filled matrices is allowed in AHP and its extensions (Ishizaka and Nemery, 2013). Consistency requires two rules to be respected: transitivity and reciprocity rules.

Transitivity Rule means that if a person indicated that they care about alternative *A* twice as much as alternative *B* and about alternative *B* three times as much as alternative *C*, then this person is expected to care about the alternative *A* six times as much as alternative *C*. Otherwise the pairwise comparisons are not logical.

$$a_{ij} = a_{ik} \times a_{kj} \tag{3.4}$$

Where a_{ij} is the comparison of alternative *i* with *j*. Reciprocity Rule means that if a person cares about the alternative *A* twice as much as alternative *B*, then they care about alternative *B* half as much as alternative *C*.

$$aij = \frac{1}{aji} \tag{3.5}$$

Where *i* and *j* are any alternatives within the matrix. The consistency index *CI* and the consistency coefficient *CR* are calculated as follows where *R* is the average random index, which is based on the matrix size; n is the number of factors (Saaty 2008). All pairwise comparisons in the study are ensured to be lower than 10% by the software.

$$CI = \frac{(\lambda_{max} - n)}{(n - 1)} \tag{3.6}$$

$$CR = \frac{CI}{RI} = \frac{(\lambda_{max} - n) \div (n - 1)}{RI} \tag{3.7}$$

4. RESULTS

In this section, first, the results regarding the simple ANP model and then the results regarding the BOCR model are given. Each network's and subnet's results consist of 4 matrices: cluster matrix, unweighted supermatrix, and limiting priorities. The altenative cluster is denoted by *A* through all of the including tables.

After the local priorities are obtained through comparisons, the local priority vectors are placed in the appropriate columns of a matrix. This matrix showing the relationship among the components is called supermatrix. "It is actually a partitioned matrix, where each matrix segment represents a relationship between two elements or clusters in a system" (Meade and Sarkis, 1999). Through the supermatrix, the global priorities are obtained. The supermatrix complies with the influence matrix, having zero cells when there is no relationship between the components. The value "1 in a cell indicates one-directional independency between the components.

In the unweighted supermatrix of benefit dimension in the Table 4.5, C_{21} affects C_{22} while C_{22} has no impact on C_{21}, that's why the corresponding cell has the value 1. Similarly, in the Table 4.11, C_{22} has no effect on C_{13} and the corresponding cell is zero.

Turning a supermatrix into column stochastic, with each column of the matrix sums to 1, the weighted supermatrix is obtained. Being a column stochastic, a matrix is able to raise its powers.

“Raising a matrix to powers gives the long-term relative of the elements on each other. To achieve convergence on the importance weights, the weighted supermatrix is raised to the power of *2k+1*, where *k* is an arbitrarily large number, and this new matrix is called the limit supermatrix” (Saaty, 1996). The limiting priorities from which the conclusions derived are illustrated in the Tables 4.3, 4.6, 4.9 and 4.12.

4.1 Results of the Simple ANP Model

Cluster matrix, unweighted matrix and limiting priorities for the simple ANP model are presented in the tables below.

Table 4.1: Cluster Matrix of the Simple ANP Method

	Alternatives	C_1 Economic Considerations	C_2 Strategic Considerations	C_3 Safety Considerations	C_4 Geopolitical Considerations
Alternatives	0	0,082	0,205	0,232	0,170
C_1 Economic Considerations	0,440	0,393	0,105	0,085	0,078
C_2 Strategic Considerations	0,341	0,308	0,450	0,065	0,282
C_3 Safety Considerations	0,076	0,060	0,000	0,491	0,053
C_4 Geopolitical Considerations	0,143	0,157	0,240	0,127	0,418

Table 4.2: Unweighted Supermatrix of the Simple ANP Method

		Alternatives			C_1 Economic Considerations					C_2 Strategic Considerations		C_3 Safety Considerations			C_4 Geopolitical Considerations		
		A_1	A_2	A_3	C_{11} -	C_{12}	C_{13}	C_{14}	C_{15}	C_{21}	C_{22}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}	C_{43}
Alternatives	A_1	0	0	0	0,17	0,08	0,261	0,594	0,252	0,374	0,342	0	0,626	0,384	0,25	0,34	0,54
	A_2	0	0	0	0,05	0,04	0,355	0,26	0,455	0,424	0,081	0	0,094	0,233	0,095	0,35	0,4
	A_3	0	0	0	0,78	0,88	0,384	0,146	0,293	0,202	0,577	0	0,28	0,383	0,655	0,31	0,06
C_1 Economic Considerations	C_{11}	0,533	0,571	0,543	0	0	0	0	0	0,687	0,531	0	0,673	0	0	0,8	0,348
	C_{12}	0,214	0,227	0,226	0	0	0	0	0	0,186	0,074	0	0,225	0	0	0	0,275
	C13	0,138	0,104	0,108	0	0	0	0	0	0	0	0,333	0	0,75	0,75	0,2	0,209
	C_{14}	0,051	0,04	0,043	0,667	0,25	0	0	0	0	0,256	0	0	0	0	0	0,068
	C_{15}	0,062	0,054	0,08	0,333	0,75	0	0	0	0,126	0,138	0,667	0,101	0,25	0,25	0	0,098
C_2 Strategic Considerations	C_{21}	0,25	0,666	0,200-	0,2	1	0	1	0	0	0	0	0,2	0,167	0,2	0,2	0,667
	C_{22}	0,75	0,333	0,8	0,8	0	0	0	1	1	0	1	0,8	0,833	0,8	0,8	0,333
C_3 Safety Considerations	C_{31}	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
	C_{32}	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1
	C_{33}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C_4 Geopolitical Considerations	C_{41}	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	C_{42}	0	0	0	0	0	0	0	0,25	0	0	0	0,25	0	0	0	1
	C_{43}	0	0	0	1	1	0	0	0,75	1	0	0	0,75	0	0	1	0

Table 4.3: Limiting Priorities of the Simple ANP Method

	Element	Local Weights Normalized by Cluster	Limiting Priorities
Alternatives	A_1 DPS	0,353	0,082
	A_2 HAH	0,168	0,039
	A_3 UIO	0,480	0,111
C_1 Economic Considerations	C_{11} Passenger Demand	0,392	0,105
	C_{12} Cargo Demand	0,119	0,032
	C_{13} Airplanes' Cost	0,085	0,023
	C_{14} Airport Facilities Cost	0,206	0,055
	C_{15} Staff Cost	0,198	0,053
C_2 Strategic Considerations	C_{21} Competitiveness Index	0,343	0,106
	C_{22} Prestige of the Airline	0,657	0,203
C_3 Safety Considerations	C_{31} Alternate Diversion Stations	0,702	0,022
	C_{32} Health Conditions	0,298	0,009
	C_{33} Weather Conditions	0,000	0,000
C_4 Geopolitical Considerations	C_{41} Over-flight Conflict Zones	0,301	0,048
	C_{42} Security Considerations	0,224	0,036
	C_{43} Political Economy Considerations	0,475	0,076

4.2 Results of the BOCR Model

Cluster matrix, unweighted matrix and limiting priorities for each dimension of the BOCR model are presented in the tables below.

Table 4.4: Cluster Matrix of Benefit Subnet

	Alternatives	C_1 Economic Consdierations	C_2 Strategic Considerations	C_4 Geopolitical Considerations
Alternatives	0	0,528	0,252	0,594
C_1 Economic Consdierations	0,833	0	0,078	0,157
C_2 Strategic Considerations	0,167	0,333	0,505	0,249
C_4 Geopolitical Considerations	0	0,140	0,165	0

Table 4.5: Unweighted Super Matrix of Benefit Subnet

		A			**C_1**		**C_2**		**C_4**
		A_1	A_2	A_3	C_{11}	C_{12}	C_{21}	C_{22}	C_{43}
A	A_1	0	0	0	0,368	0,080	0,367	0,696	0,467
	A_2	0	0	0	0,108	0,040	0,417	0,075	0,346
	A_3	0	0	0	0,524	0,880	0,216	0,229	0,188
C_1	C_{11}	0,833	0,833	0,875	0	0	0,857	0,857	0,750
	C_{12}	0,167	0,167	0,125	0	0	0,143	0,143	0,250
C_2	C_{21}	0,750	0,667	0,200	0,800	1	0	0	0,833
	C_{22}	0,250	0,333	0,800	0,200	0	1	0	0,167
C_4	C_{43}	0	0	0	1	1	1	0	0

Table 4.6: Limiting Priorities of Benefit Subnet

	Element	**Local Weights Normalized by Cluster**	**Limiting Priorities**
Alternatives	A_1 DPS	0,443	0,152
	A_2 HAH	0,154	0,053
	A_3 UIO	0,403	0,138
C_1 Economic Consdierations	C_{11} Passenger Demand	0,848	0,283
	C_{12} Cargo Demand	0,152	0,051
C_2 Strategic Considerations	C_{21} Competitiveness Index	0,421	0,136
	C_{22} Prestige	0,365	0,118
C_4 Geopolitical Considerations	C_{43} Political Economy Considerations	0,214	0,069

Table 4.7: Cluster Matrix of Opportunity Subnet

	Alternatives	C_1 Economic Considerations	C_2 Strategic Considerations	C_3 Safety Considerations	C_4 Geopolitical Considerations
Alternatives	0	0,311	0,300	0,537	0,586
C_1 Economic Considerations	0,667	0	0,098	0,114	0,115
C_2 Strategic Considerations	0,333	0,196	0,443	0,268	0,242
C_3 Safety Considerations	0	0	0	0	0,057
C_4 Geopolitical Considerations	0	0,493	0,159	0,082	0

Table 4.8: Unweighted Matrix of Opportunity Subnet

		A			C_1		C_2		C_3	C_4
		A_1	A_2	A_3	C_{11}	C_{12}	C_{21}	C_{22}	C_{32}	C_{43}
A	A_1	0	0	0	0,307	0,617	0,374	0,559	0,649	0,424
	A_2	0	0	0	0,090	0,285	0,424	0,089	0,072	0,314
	A_3	0	0	0	0,602	0,098	0,202	0,352	0,279	0,262
C_1	C_{11}	0,900	0,889	0,900	0	0	0,9	0,889	0,875	0,612
	C_{12}	0,100	0,111	0,100	0	0	0,1	0,111	0,125	0,388
C_2	C_{21}	0,167	0,800	0,250	0,800	1	0	0	0,857	0,833
	C_{22}	0,833	0,200	0,750	0,200	0	1	0	0,143	0,167
C_3	C_{32}	0	0	0	0	0	0	0	0	1
C_4	C_{43}	0	0	0	1	1	1	0	1	0

Table 4.9: Limiting Priorities of Opportunity Subnet

	Element	**Local Weights Normalized by Cluster**	**Limiting Priorities**
Alternatives	A_1 DPS	0,445	0,141
	A_2 HAH	0,195	0,062
	A_3 UIO	0,360	0,114
C_1 Economic Considerations	C_{11} Passenger Demand	0,878	0,241
	C_{12} Cargo Demand	0,122	0,033
C_2 Strategic Considerations	C_{21} Competitiveness Index	0,448	0,111
	C_{22} Prestige	0,552	0,137
C_3 Safety Considerations	C_{32} Health Conditions	0,054	0,009
C_4 Geopolitical Considerations	C_{43} Political Economy Considerations	0,946	0,153

Table 4.10: Cluster Matrix of Cost Subnet

	Alternatives	C_1 Economic Considerations	C_2 Strategic Considerations	C_3 Safety Considerations	C_4 Geopolitical Considerations
Alternatives	0	0,421	0,278	0,333	0,261
C_1 Economic Considerations	0,450	0	0,056	0,048	0,174
C_2 Strategic Considerations	0,300	0,316	0,222	0,429	0,391
C_3 Safety Considerations	0,100	0	0	0	0,087
C_4 Geopolitical Considerations	0,150	0,263	0,444	0,190	0,087

Table 4.11: Unweighted Super Matrix of Cost Subnet

		A			**C_1**			**C_2**		**C_3**		**C_4**		
		A_1	A_2	A_3	C_{13}	C_{14}	C_{15}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{43}
A	A_1	0	0	0	0,305	0,390	0,365	0,329	0,081	0,297	0,105	0,345	0,394	0,829
	A_2	0	0	0	0,305	0,390	0,365	0,374	0,731	0,163	0,637	0,547	0,406	0,121
	A_3	0	0	0	0,390	0,219	0,270	0,297	0,188	0,540	0,258	0,109	0,200	0,050
C_1	C_{13}	0,691	0,641	0,691	0	0	0	0	0	0,25	0	0,167	1	0,691
	C_{14}	0,091	0,067	0,091	0	0	0	0	0,750	0	0	0	0	0,091
	C_{15}	0,218	0,293	0,218	0	0	0	1	0,250	0,750	1	0,833	0	0,218
C_2	C_{21}	0,800	0,167	0,750	0	1	0	0	0	0	0,143	0,167	0,125	0,750
	C_{22}	0,200	0,833	0,250	0	0	1	1	0	1	0,857	0,833	0,875	0,250
C_3	C_{31}	1	1	1	0	0	0	0	0	0	0	1	0	0
	C_{32}	0	0	0	0	0	0	0	0	0	0	0	0	0
C_4	C_{41}	1	1	1	1	0	0	0	0	0	0	0	0	0
	C_{42}	0	0	0	0	0	0,750	0	0	0	0,750	0	0	1
	C_{43}	0	0	0	0	0	0,250	1	0	0	0,250	0	1	0

Table 4.12: Limiting Priorities of Cost Subnet

	Element	Local Weights Normalized by Cluster	Limiting Priorities
Alternatives	A_1 DPS	0,251	0,085
	A_2 HAH	0,496	0,168
	A_3 UIO	0,253	0,086
C_1 Economic Considerations	C_{13} Airplanes' Cost	0,528	0,114
	C_{14} Airport Facilities Cost	0,153	0,033
	C_{15} Staff Cost	0,319	0,069
C_2 Strategic Considerations	C_{21} Competitiveness Index	0,342	0,084
	C_{22} Prestige	0,658	0,162
C_3 Safety Considerations	C_{31} Possible Diversion Stations	1	0,043
	C_{32} Health Conditions	0	0
C_4 Geopolitical Considerations	C_{41} Over-flight Conflict Zones	0,607	0,095
	C_{42} Security Considerations	0,114	0,018
	C_{43} Political Economy Considerations	0,279	0,044

Table 4.13: Cluster Matrix of Risk Subnet

	Alternatives	C_2 Strategic Considerations	C_3 Safety Considerations	C_4 Geopolitical Considerations
Alternatives	0	1	0,066	0,101
C_2 Strategic Considerations	0,649	0	0,561	0,674
C_3 Safety Considerations	0,279	0	0,244	0,226
C_4 Geopolitical Considerations	0,072	0	0,129	0

Table 4.14: Unweighted Super Matrix of Risk Subnet

		A			**C_2**	**C_3**			**C_4**	
		A_1	A_2	A_3	C_{22}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}
A	A_1	0	0	0	0,293	0	0,655	0,264	0,547	0,332
	A_2	0	0	0	0,067	0	0,095	0,436	0,109	0,342
	A_3	0	0	0	0,641	0	0,250	0,301	0,345	0,326
C_2	C_{22}	1	1	1	0	1	1	1	1	1
C_3	C_{31}	1	1	1	0	0	0	0	1	0
	C_{32}	0	0	0	0	0	0	1	0	0
	C_{33}	0	0	0	0	0	0	0	0	0
C_4	C_{41}	1	1	1	0	0	0	0	0	0
	C_{42}	0	0	0	0	0	1	0	0	0

Table 4.15: Limiting Priorities of Risk Subnet

	Element	**Local Weights Normalized by Cluster**	**Limiting Priorities**
Alternatives	A_1 DPS	0,294	0,125
	A_2 HAH	0,067	0,028
	A_3 UIO	0,638	0,271
C_2 Strategic Considerations	C_{22} Prestige	1	0
C_3 Safety Considerations	C_{31} Possible Diversion Stations	1	0
	C_{32} Health Conditions	0	0
	C_{33} Weather Conditions	0	0
C_4 Geopolitical Considerations	C_{41} Over-flight Conflict Zones	1	0
	C_{42} Security Considerations	0	0

4.3 Revised Results of BOR Dimensions

When the main problem is broken down into subnets, the number of sub-criteria in the clusters of each subnet changes. In order to prevent the model from losing sensitivity, a revised model is formed by clustering the criteria which have remained single in the previous modeling

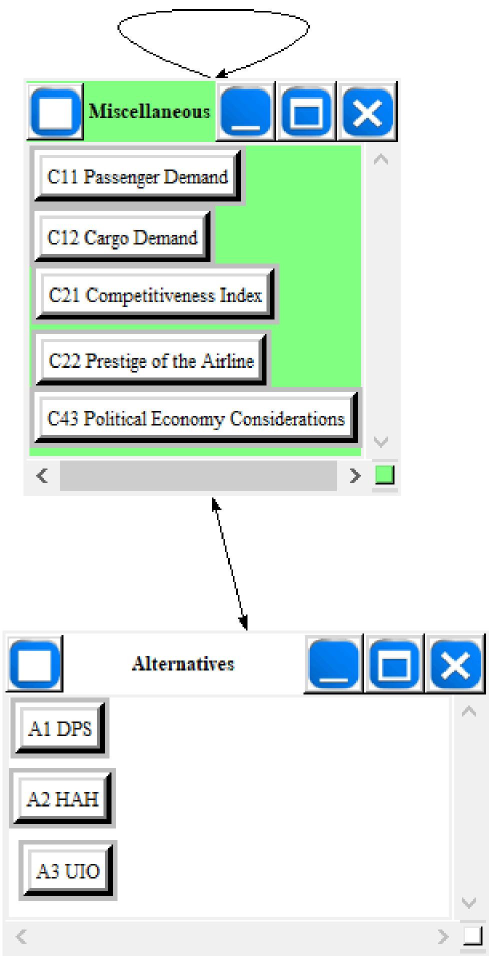

Figure 4.1: Revised Model of Benefit Subnet

Table 4.16: Revised Cluster Matrix of Benefit Subnet

	Alternatives	Miscellaneous
Alternatives	0	0.400
Miscellaneous	1	0.600

Table 4.17: Revised Unweighted Super Matrix of Benefit Subnet

		Alternatives			Miscellaneous				
		A_1	A_2	A_3	C_{11}	C_{12}	C_{21}	C_{22}	C_{43}
Alternatives	A_1	0	0	0	0,368	0,350	0,374	0,384	0,540
	A_2	0	0	0	0,108	0,250	0,424	0,152	0,400
	A_3	0	0	0	0,524	0,400	0,202	0,465	0,060
Miscellaneous	C_{11}	0,442	0,472	0,304	0	0	0,278	0,700	0,318
	C_{12}	0,093	0,264	0,088	0	0	0,056	0,300	0,273
	C_{21}	0,155	0,176	0,253	0,300	0,300	0	0	0,182
	C_{22}	0,310	0,088	0,355	0,500	0	0,444	0	0,227
	C_{43}	0	0	0	0,200	0,700	0,222	0	0

Table 4.18: Revised Limiting Priorities of Benefit Subnet

	Element	Local Weights Normalized by Cluster	Limiting Priorities
Alternatives	A_1 DPS	0,390	0,112
	A_2 HAH	0,225	0,064
	A_3 UIO	0,385	0,110
Miscellaneous	C_{11} Passenger Demand	0,321	0,230
	C_{12} Cargo Demand	0,125	0,089
	C_{21} Competitiveness Index	0,172	0,123
	C_{22} Prestige of the Airline	0,269	0,192
	C_{43} Political Economy Considerations	0,114	0,081

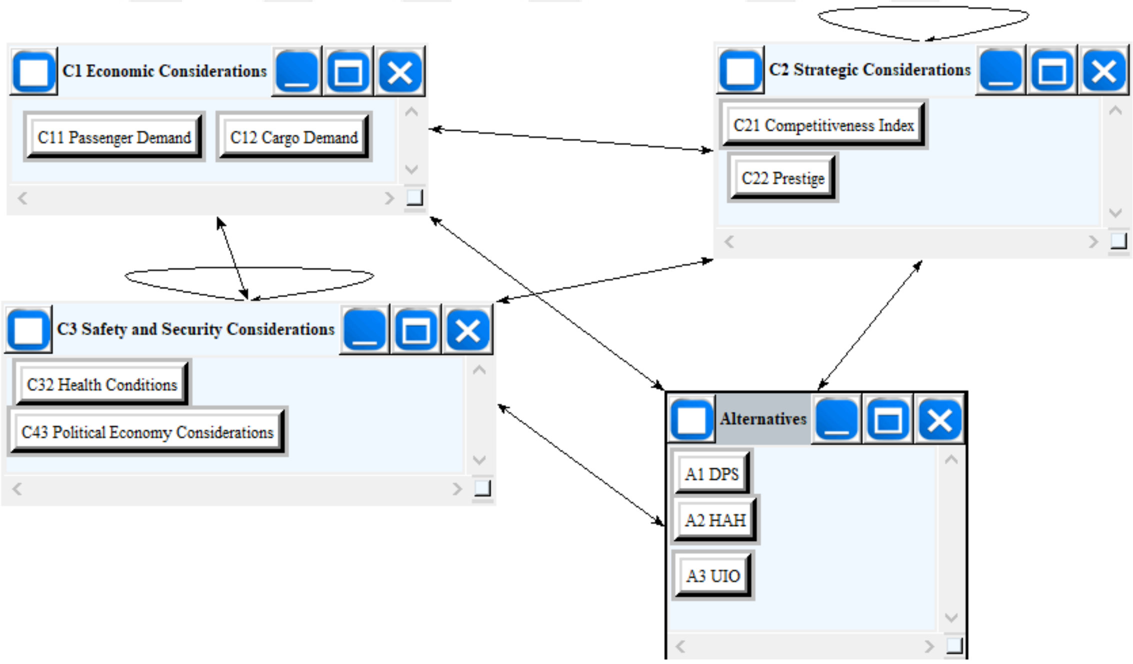

Figure 4.2: Revised Model of Opportunity Subnet

Table 4.19: Revised Cluster Matrix of Opportunity Subnet

	Alternatives	C_1 Economic Considerations	C_2 Strategic Considerations	C_3 Safety and Security Considerations
Alternatives	0	0,387	0,214207	0,325
C_1 Economic Considerations	0,547	0	0,082568	0,067
C_2 Strategic Considerations	0,345	0,169	0,401784	0,149
C_3 Safety and Security Considerations	0,109	0,443	0,301	0,460047

Table 4.20: Revised Unweighted Super Matrix of Opportunity Subnet

		A			**C_1**		**C_2**		**C_3**	
		A_1	A_2	A_3	C_{11}	C_{12}	C_{21}	C_{22}	C_{32}	C_{43}
A	A_1	0	0	0	0,307	0,617	0,374	0,559	0,649	0,359
	A_2	0	0	0	0,090	0,285	0,424	0,089	0,072	0,114
	A_3	0	0	0	0,602	0,098	0,202	0,352	0,279	0,527
C_1	C_{11}	0,875	0,857	0,875	0	0	0,875	0,889	0,875	0,333
	C_{12}	0,125	0,143	0,125	0	0	0,125	0,111	0,125	0,667
C_2	C_{21}	0,167	0,800	0,250	0,800	1	0	0	0,857	0,667
	C_{22}	0,833	0,200	0,750	0,200	0	1	0	0,143	0,333
C_3	C_{32}	0	0	0	0	0	0	0	0	1
	C_{43}	1	1	1	1	1	1	0	0	0

Table 4.21: Revised Limiting Priorities of Opportunity Subnet

	Element	Local Weights Normalized by Cluster	Limiting Priorities
Alternatives	A_1 DPS	0,464	0,141
	A_2 HAH	0,122	0,037
	A_3 UIO	0,413	0,125
C_1 Economic Considerations	C_{11} Passenger Demand	0,850	0,196
	C_{12} Cargo Demand	0,150	0,035
C_2 Strategic Considerations	C_{21} Competitiveness Index	0,421	0,096
	C_{22} Prestige	0,579	0,131
C_3 Safety and Security Considerations	C_{32} Health Conditions	0,315	0,075
	C_{43} Political Economy Considerations	0,685	0,164

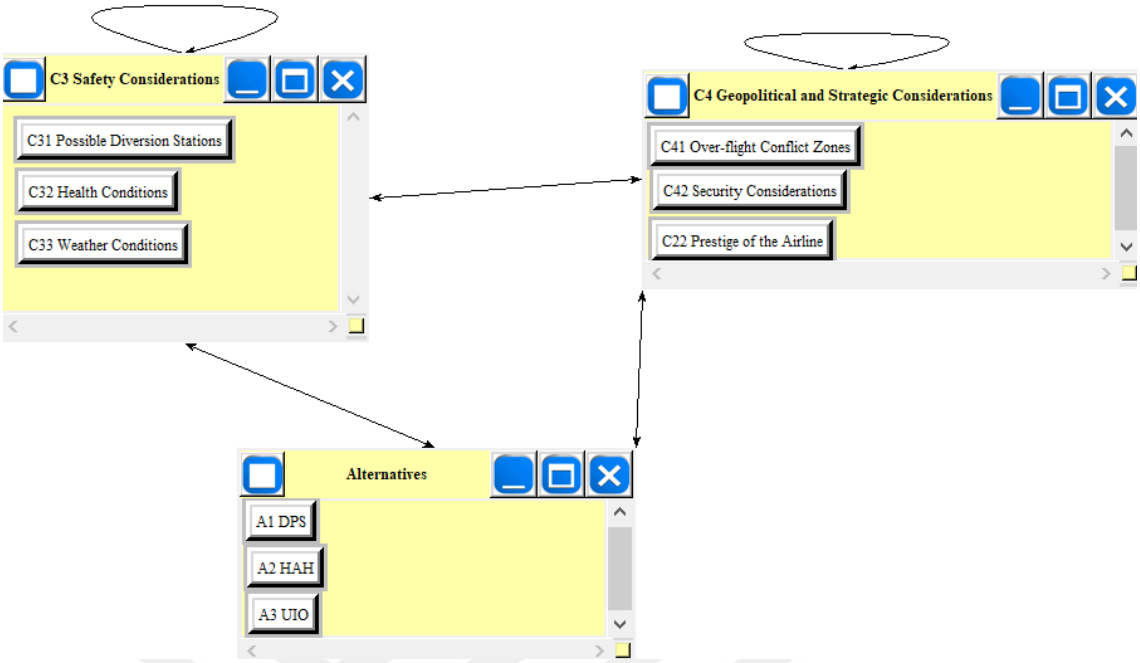

Figure 4.3: Revised Model of Risk Subnet

Table 4.22: Revised Cluster Matrix of Risk Subnet

	Alternatives	**C_3 Safety Considerations**	**C_4 Geopolitical and Strategic Considerations**
Alternatives	0	0,117	0,157
C_3 Safety Considerations	0,833	0,614	0,594
C_4 Geopolitical and Strategic Considerations	0,167	0,268	0,249

Table 4.23: Revised Unweighted Super Matrix of Risk Subnet

		A			C_3			C_4		
		A_1	A_2	A_3	C_{31}	C_{32}	C_{33}	C_{22}	C_{41}	C_{42}
A	A_1	0	0	0	0	0,655	0,264	0,528	0,547	0,614
	A_2	0	0	0	0	0,095	0,436	0,140	0,109	0,117
	A_3	0	0	0	0	0,250	0,301	0,333	0,345	0,268
C_3	C_{31}	1	1	1	0	0	0	0	1	0
	C_{32}	0	0	0	0	0	1	0	0	0
	C_{33}	0	0	0	0	0	0	0	0	0
C_4	C_{22}	0,833	0,667	0,857	1	0,800	1	0	1	1
	C_{41}	0,167	0,333	0,143	0	0	0	0	0	0
	C_{42}	0	0	0	0	0,200	0	0	0	0

Table 4.24: Revised Limiting Priorities of Risk Subnet

	Element	**Local Weights Normalized by Cluster**	**Limiting Priorities**
Alternatives	A_1 DPS	0,528	0,184
	A_2 HAH	0,140	0,048
	A_3 UIO	0,333	0,116
C_3 Safety Considerations	C_{31} Possible Diversion Stations	1	0,296
	C_{32} Health Conditions	0	0
	C_{33} Weather Conditions	0	0
C_4 Geopolitical and Strategic Considerations	C_{22} Prestige of the Airline	0,970	0,346
	C_{41} Over-flight Conflict Zones	0,030	0,011
	C_{42} Security Considerations	0	0

4.4 Final Synthesis of BOCR Dimensions

Synthesizing the whole model is done using the additive method which is the process of multiplying the priorities of each alternative obtained from limit super matrices under each BOCR dimension (the BOCR letters in the equation) by the weights of the BOCR dimensions, as shown in equation 4.1 as *p*. Since the dimensions cost and risk show negative impacts, reciprocals of their final priorities are used. However, in this study all the factors contributing to risk and cost dimensions are normalized as cost-type criteria, that's why their final priorities can be treated as the other positive dimensions, benefit, and opportunity. The priorities of BOCR dimensions are set by decision-maker as shown in the Table 4.25

$$p_1 B + p_2 O + p_3 \frac{1}{C} + p_4 \frac{1}{R} \qquad (4.1)$$

Table 4.25: Final Synthesis of Priorities of Alternatives

	Benefit	Opportunity	Cost	Risk	Additive Synthesis	Normalized Values
Dimension Weight	0,3	0,2	0,2	0,3		
A_1 DPS	0,112	0,141	0,085	0,184	0,134	0,420
A_2 HAH	0,064	0,037	0,168	0,049	0,075	0,230
A_3 UIO	0,110	0,125	0,086	0,116	0,110	0,350

5. DISCUSSION

The study analyzed both the simple ANP Network and BOCR Network. The simple ANP method shows that the third alternative UIO is the best destination to launch with the most dominant criterion C_{11} passenger demand, followed by the criteria C_{14} airport facilities cost and C_{15} staff cost. DPS is ranked as the second-best choice.

The BOCR analysis gives 4 answers with respect to 4 different perspectives and the final synthesis provides the best choice as a combination of four dimensions. As it can be seen from the limit matrix of benefit subnet, DPS stands out as the best alternative and followed closely by UIO in the perspective of benefits. HAH is ranked as the worst alternative. As for the benefits to the company, C_{11} is the most important criterion. It's a logical assumption, considering the number of the passengers who will actually pay for the flight to the selected destination is the key factor for profitability and therefore benefits. C_{22} comes as the second important criterion, which stands for the prestige that the company will benefit from opening the destination. C_{21} showing the competitiveness index is the third dominant criterion; this can be thought in terms of market share that the company will gain while opening the destination. C_{12} and C_{43} have close values making them the least important factors. Most of the airlines have separate cargo aircraft, without seating configuration for passengers, therefore a direct flight is not the most profitable way to carry regular freights when they can be transferred having multiple stops, possibly smaller aircraft. For the urgent delivery cargos, with more profit, the aircraft's cargo compartment is dedicated, however, they are in much smaller amount comparing the benefit from the passenger demand.

As for the opportunities angle, DPS has the lead among the alternatives and HAH comes last. Similar to benefit perspective passenger demand is also the most dominant criterion, which is why DPS shines out as the best in terms of benefit related gaining. C_{22} comes forefront as the second most important criterion under opportunities dimension. According to expert increasing prestige is slightly more dominant than increasing the market share in terms of opportunities to capture. Cargo related opportunities are the least important one among others.

Under the cost dimension, in contrast to the benefit and opportunity dimensions, HAH becomes the most prominent alternative while DPS is the worst choice by a narrow margin. Prestige related cost is the most important criterion which can be simply any expenditures made by an airline to maintain it's prestige. Airplane's cost criterion comes as the second dominant criterion, it is not surprising, considering how major space fuel costs take up in terms of all kinds of costs occurs. Airport facilities cost, such as landing fees or hiring gates and air bridges is turned out to be the least influencing criterion.

Under Risk dimension, DPS is again the best alternative and HAH is the worst one. The most dominant criterion is prestige related risks which an airline can go under by opening the destination such as the risk of staff mortality due to health issues of the destination. For example, situated in Africa content, HAH is exposed to risks by malaria and ebola diseases, while UIO can be under the risk of Zika, a disease seen in South America. Because of the insufficient interactions of C32 and C33, their effect is unseen in the matrix which prevents the analysis evaluating the direct effect weather and health risks on the alternatives. However, their influences can still be seen through other criteria affected by them like the most prestige criterion which can also be explained in health risks. Possible diversion stations on the route are the second dominant criterion under risk. This is also related to the risks of an airlines prestige to be shaken. Not having many numbers of diversion stations along the route causes more time elapsed for landing in case of emergencies such as an engine failure or a passenger having a serious health problem. And this risk factor of not landing in time (for hospital etc.) affects prestige strategy with respect to safety credibility of the airlines.

According to the decision-maker, benefit and risk aspects are more important than opportunity and cost. The overall result for the BOCR analysis shows that DPS is the best destination considering all aspects together with respect to the company perspective.

6. CONCLUSION

In this study, both simple ANP method and BOCR analysis are applied to select the best destination. Simple ANP analysis shows that UIO is the best alternative with the most dominant criteria as strategic considerations, C_{22}, which stands for the prestige of the company and C_{21}, the competitiveness index, respectively. HAH comes as the worst choice both in the final synthesis of BOCR and simple ANP analysis.

As for the benefit, risk and opportunity aspects, DPS stands out as the best alternative with the passenger demand as the most dominant criterion. Under the Cost dimension, HAH is the best choice, while it is the worst alternative under risk-related concerns, which is expected as it is situated in Africa continent. According to the final synthesis, DPS is the best destination under BOCR analysis. The Analysis shows that passenger related earnings and prestige related losses are essential according to the company.

The weights of BOCR dimensions set by decision-maker reflect the company's view for the big picture. According to this weighting, benefit and risk merits are equally more important than opportunity and cost dimensions. It is understandable in the sense that the company values the benefits, the immediate results, as well as the risk of losing competitive advantages since the company is quality-oriented on contrary to smaller cost-oriented airlines.

Table 6.1: The Final Rankings

	RANKINGS					
Alternatives	**Benefit**	**Opportunity**	**Cost**	**Risk**	**Overall BOCR**	**Simple ANP**
A_1 DPS	1	1	3	1	1	2
A_2 HAH	3	3	1	3	3	3
A_3 UIO	2	2	2	2	2	1

6.1 Thesis Contribution

While most of the studies done in this field benefit multi-criteria decision analysis with the use of optimization, the literature has still a lack of studies with ANP related methodologies in destination selection problems.

This study is unique in terms of the comparative analysis of BOCR, which enables everyone to see the problem in different dimensions and simple ANP network. Especially in aviation risk factors are as important as the benefit and cost factors due to industry's very nature, and every dimension must be considered separately, it is seen from the study that the results can vary taking these dimensions under consideration.

This study also differentiates in terms of the abundant numbers and characteristics of criteria under consideration. Being a graduate engineer, the author is able to evaluate benefit and cost type criteria and her profession as a cabin attendant helps her see the risk and opportunity factors in the aviation industry closely.

6.2 Limitations and Future Studies

There are several limitations to perform ANP analysis. One of them is it takes a considerable time for the experts working as manager positions to pairwise compare, especially under BOCR analysis, the number of comparisons to be made increase even more. Since airline's managers, among all managers, have a lack of time to think thoroughly and respond to all questions related to comparisons, this analysis is hard to perform effectively.

Secondly, software programs come short of evaluating all dependencies, when the interaction is one-directional or insufficient to make comparisons. In order to prevent these *zero effects* as much as possible in the study, the criteria which remain alone in their clusters in the subnets are combined to form a new cluster in order to show their individual influences in a revision section.

For future studies, a group decision making can be applied to evaluate the problem in wider angles. Pilots and cabin crew who execute the flights to selected destinations can also be included in the group as *operators* in addition to the *managers* who stand out as only decision-makers in most of the studies, in order to approach the problem from different perspectives.

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