AN EFFICIENCY ANALYSIS OF INTERNATIONAL AIRLINE ALLIANCES: AN EMPIRICAL STUDY USING DATA ENVELOPMENT ANALYSIS

TÜLAY DİVARCI

BOĞAZİÇİ UNIVERSITY

2016

AN EFFICIENCY ANALYSIS OF INTERNATIONAL AIRLINE ALLIANCES: AN EMPIRICAL STUDY USING DATA ENVELOPMENT ANALYSIS

Thesis submitted to the

Institute for Graduate Studies in Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

International Trade Management

by

Tülay Divarcı

Boğaziçi University

2016

An Efficiency Analysis of International Airline Alliances:

An Empirical Study Using Data Envelopment Analysis

The thesis of Tülay Divarcı

has been approved by:

Prof. Arzu Tektaş
(Thesis Advisor)



Assist. Prof. Mehtap Işık



Assoc. Prof. Burcu Yakut Çakar
(External Member)



June 2016

DECLARATION OF ORIGINALITY

I, Tülay Divarcı, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
- this is a true copy of the thesis approved by my advisor and thesis committee at Boğaziçi University, including final revisions required by them.

Signature .....

Date .....03/06/2016.....

ABSTRACT

An Efficiency Analysis of International Airline Alliances:

An Empirical Study Using Data Envelopment Analysis

Alliances are inevitable outcomes of globalization and global competition in important industries such as the airline industry. That is the reason why the analyses in this study are not limited with airline level evaluation but assessments for alliances are also performed. This study evaluates the relative efficiencies of international passenger airline alliances, namely Star Alliance, One World and Sky Team, at transforming their inputs into outputs. Via Data envelopment analysis (DEA), four main and two explanatory models are analyzed for the year 2014 with BCC and CCR approaches using different input-output variable combinations such as total passenger seat capacity, fuel cost and seat per aircraft as the input variables and load factor, ASK and RPK as the output variables. Super-efficiency calculations are also performed in order to compare the results found by standard efficiency assessments. Two models employing ASK and load factor as the output variables are utilized to perform the efficiency analysis for the year 2013, as well. It is determined which airlines are playing as benchmarking peers for which airlines. Airline industry is proved to show variable returns to scale characteristics. Star Alliance is found to have the members that can be taken reference most by other two alliances' member airlines for efficiency improvements. The excess amounts of inputs are determined for each alliance and their member airlines. Alliances will be able to identify their strengths and improvement areas and achieve more healthy developments with the help of the implications derived from this study.

ÖZET

Uluslararası Havayolu Birlikleri İçin Verimlilik Analizi: Veri Zarflama Yöntemi İle Deneysel Bir Çalışma

Hava yolu gibi önemli endüstrilerde, işbirlikleri, globalleşmenin ve global rekabetin kaçınılmaz sonucudur. Bu nedenle, bu endüstri için sadece şirketler bazında analizle sınırlı kalmayıp işbirlikleri bazında analiz yapılmıştır. Bu çalışmada, uluslararası hava yolu işbirlikleri olan Star Alliance, One World ve Sky Team'e üye hava taşıyıcı firmalar için girdilerini çıktılara dönüştürmede relatif verimlilik ölçümü yapılmıştır. Veri zarflama analizi yöntemi kullanılarak BCC (değişken getiri ölçekli) ve CCR (sabit getiri ölçekli) yaklaşımları ile koltuk kapasitesi, yakıt maliyeti ve yolcu uçağı başına düşen koltuk sayısı gibi girdiler ile doluluk oranı, arz edilen koltuk kilometre (ASK), ücretli yolcu kilometre (RPK) gibi çıktı kombinasyonlarıyla 2014 yılı için dört temel ve iki yardımcı model analiz edilmiştir. ASK ve doluluk oranını çıktı olarak kullanan iki ayrı model de 2013 yılı için analiz edilmiştir. Standart verimlilik ölçümüne ek olarak süper verimlilik ölçümü de yapılmış ve sonuçlar mukayese edilmiştir. Hangi hava yolu firmalarının hangi hava yolu firmaları tarafından referans alınabileceği tespit edilmiştir. Hava yolu endüstrisinin değişken getiri ölçekli olduğu ispatlanmıştır. Star Alliance'ın diğer hava yolları ittifakları üyeleri tarafından en çok referans alınabilecek üyelere sahip olduğu gözlemlenmiştir. Her bir ittifak ve hava yolu için girdi miktarlarındaki fazlalıklar tespit edilmiştir. Bu çalışmadan çıkan ipuçları işbirliklerine güçlü yönlerini ve gelişim alanlarını belirleyebilerek daha sağlıklı büyümeleri için yardımcı olacaktır.

ACKNOWLEDGEMENTS

It is a great honor for me to have this opportunity to acknowledge the contribution of the people who supported me throughout the course of this research effort.

First and foremost, I thank my husband Gökhan Divarcı to whom I dedicate this thesis and all my life's work. His continuous support, endless patience and unwavering love always motivated me. Without his encouragement, this research would not be produced. I feel most fortunate to have married him.

I would like to express my deepest gratitude to my advisor Professor Arzu Tektaş for her invaluable guidance, encouragement and understanding. Her feedback and experience very much enriched my research.

I am also thankful to my dissertation committee Assist. Prof. Mehtap Işık and Assoc. Prof. Burcu Yakut Çakar for their insightful comments, feedbacks and contributions. Additionally, I wish to extend my thanks to the members of the Editing Office for their edit prior to submission.

I am also indebted to the management of Turkish Technic, Inc., who supported me to attain my master's degree although I have to be away some days to attend my classes.

Finally, special thanks go to my parents and siblings for their true love and support throughout my lifetime.

To my husband, Gökhan

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: AIRLINE INDUSTRY 3

2.1 Market review and the challenges 3

2.2 The development of Turkish aviation 8

2.3 Airline terminology and definitions 13

2.4 Alliances in airline industry 15

CHAPTER 3: EFFICIENCY ANALYSIS 20

CHAPTER 4: LITERATURE SURVEY 22

CHAPTER 5: METHODOLOGY 31

5.1 Data envelopment analysis 31

5.2 Explanation for CCR and BCC models 36

5.3 Reasons for selecting input-oriented DEA model 38

CHAPTER 6: DEFINING THE SAMPLE AND THE INPUT - OUTPUT VARIABLES 40

6.1 Discussion on input variables 41

6.2 Discussion on output variables 47

6.3 Data collection 49

CHAPTER 7: EMPIRICAL RESULTS 60

CHAPTER 8: EFFICIENCY ANALYSIS OF TURKISH FLAG CARRIER IN THE PRESENCE OF ITS LOW COST AIRLINE 108

CHAPTER 9: CONCLUSION 113

APPENDIX A: DATA CHARACTERISTICS OF THE AIRLINES 119

APPENDIX B: OPERATIONAL DATA FOR THE AIRLINES……..…..…….121

APPENDIX C: BENCHMARKING PEERS 125

REFERENCES 132

LIST OF TABLES

Table 1. Regional Distribution of Scheduled Traffic for 2014 5

Table 2. Members of World's Leading Alliances. 18

Table 3. Previous Studies in Efficiency Analyses of Airlines 30

Table 4. Descriptive Statistics of the Sample of 39 DMUs as per the Year 2014.....62

Table 5. Correlation Matrix for Input Variables.....64

Table 6. Correlation Matrix for Output Variables 64

Table 7. Input and Output Combinations for the DEA 65

Table 8. Standard Efficiency Scores for Six Models under CCR conditions 67

Table 9. Number of DMUs with Respect to Their Standard Efficiency Scores under CCR Conditions 69

Table 10. Percentage of DMUs with Respect to Their Standard Efficiency Scores under CCR Conditions.....70

Table 11. Super Efficiency Scores for Six Models under CCR conditions 71

Table 12. Number of DMUs with Respect to Their Super Efficiency Scores under CCR Conditions 72

Table 13. Super Efficiency Scores for Six Models under CCR conditions 72

Table 14. Standard Efficiency Scores for Six Models under BCC conditions.....74

Table 15. Number of DMUs with Respect to Standard Efficiency Scores under BCC Conditions 75

Table 16. Percentage of DMUs with Respect to Standard Efficiency Scores under BCC Conditions 76

Table 17. Super Efficiency Scores for Six Models under VRS conditions 79

Table 18. Returns to Scale Results for Standard Efficiency Analysis 82

Table 19. Returns to Scale Results for Super Efficiency Analysis.....84

Table 20. Input and Output Quantities for Model 1: Standard Efficiency BCC Results.....86

Table 21. Input and Output Quantities for Model 1: Super Efficiency BCC Results88

Table 22. Input and Output Quantities for Model 2: Standard Efficiency BCC Results.....91

Table 23. Input and Output Quantities for Model 3: Standard Efficiency BCC Results.....93

Table 24. Input and Output Quantities for Model 4: Standard Efficiency BCC Results.....95

Table 25. Average improvements for alliances 97

Table 26. Average improvements for airlines 98

Table 27. Reference Frequencies for Each Alliance as per the Results of BCC Approach.....100

Table 28. Reference Units and Their Frequencies for Model 1, 2, 3 and 4 as per the Results of BCC Approach for Super- and Standard Efficiency Results.....101

Table 29. Overall Efficiency Scores of DMUs for Models 1, 2, 3 and 4 as per the Results of BCC Approach for Super- and Standard Efficiency Results.....102

Table 30. Efficiency Scores for the Year 2013 for Model 2 Employing BCC Method.....105

Table 31. Efficiency Score and Rating of Turkish Airlines at the Global Scale 109

Table 32. Efficiency Scores of the Global Sample under the Presence of Anadolu Jet 110

Table 33. Efficiency Scores of Members of Star Alliance in the Presence of Anadolu Jet 111

Table 34. Data Characteristics of the DMUs for the year 2014……...119

Table 35. Data Characteristics of the DMUs for the year 2013 120

Table 36. 2014 Year Operational Data 121

Table 37. 2013 Year Operational Data……123

Table 38. Benchmarking Peers for Model 1: Standard Efficiency BCC Results 125

Table 39. Benchmarking Peers for Model 2: Standard Efficiency BCC Results 127

Table 40. Benchmarking Peers for Model 3: Standard Efficiency BCC Results 128

Table 41. Benchmarking Peers for Model 4: Standard Efficiency BCC Results 130

LIST OF FIGURES

Figure 1. World passenger traffic 6

Figure 2. World air cargo traffic 6

Figure 3. Oil prices 7

Figure 4. Exchange rate index vs. USD 7

Figure 5. Annual domestic and international aircraft passengers of air carriers registered in Turkey 8

Figure 6. Turkey's share in world air passenger's statistics in domestic and international flights 9

Figure 7. Turkey's and world's passenger traffic growth rates 9

Figure 8. Turkish Airlines RPK growth over years 11

Figure 9. Turkish Airlines load factor over years, % 12

Figure 10. Alliances' market shares 17

Figure 11. CRS and VRS approaches with input- and output-orientation 34

Figure 12. Technical and scale efficiencies and returns to scale 35

Figure 13. Process diagram for model 4 65

Figure 14. Overall improvement summary for model 5 77

Figure 15. Overall improvement summary for model 6 78

Figure 16. Overall improvement summary for model 1 89

Figure 17. Overall improvement summary for model 2 92

Figure 18. Overall improvement summary for model 3 94

Figure 19. Improvement ratios for model 2 for the year 2013 under VRS conditions 106

Figure 20. Improvement ratios for model 6 for the year 2013 under VRS conditions 107

LIST OF ABBREVIATIONS

AC	Aircraft
AEA	Association of European Airlines
ARL	Airlines
ASK	Available Seat Kilometer
ATK	Available Ton Kilometer
AVG	Average
CAPA	Center for Aviation
CASM	Cost per Available Seat Mile
CRS	Constant Returns to Scale
DMU	Decision Making Units
EBIT	Earnings Before Interest and Tax
FSC	Full Service Carrier
FTE	Full Time Employee
GDP	Gross Domestic Product
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IT	Information Technologies
LCC	Low Cost Carrier
LF	Load Factor
NR	Number
OPR	Operative
OW	One World
PAX / Pax	Passenger

RASM	Revenue per Available Seat Mile
RFTK	Revenue Freight Ton Kilometer
RPK	Revenue Passenger Kilometer
RTK	Revenue Ton Kilometer
SA	Star Alliance
SBM	Slack Based Measure
SPE	Super Efficiency
ST	Sky Team
STE	Standard Efficiency
TRF	Traffic
VRS	Variable Returns to Scale

CHAPTER 1

INTRODUCTION

Airline industry carries undeniable importance in integration and development of societies enhancing mobility, increasing domestic and international trade and creating direct and indirect employment at home and abroad. Although the industry acts as an accelerator for the economic development, it is affected by the local and global political and socio-economic conditions. Although the industry enjoys higher revenue levels as a result of increasing global growth rates, new air travelers and rising emerging markets, the capital-intensive industry has to struggle with high fixed costs, currency fluctuations, jet fuel prices, epidemics, terrorist attacks to survive. In addition to global circumstances, global airlines have to stand competitively strong in order to secure their market share threatened by new comers and low cost airlines. Accordingly, they have to analyze their current positions with respect to their rivals, investigate the deficiencies and set goal to improve their performances.

In that context, this study puts the emphasis on efficiency measures of the major strategic alliances that hold more than 60% of the airline industry in terms of available seat kilometers and revenue passenger kilometers, namely Star Alliance, Sky Team and One World, and each of their members at transforming their inputs into outputs for the year 2014.

In the second chapter, a brief introduction for the global and local airline industry and about the challenges faced is provided. Airline terminology and definitions are explained. Information about the strategic alliances in the airlines industry is provided. In the third chapter, the definitions of efficiency and methods

used in efficiency analysis are discussed. Previous studies that investigate airline efficiencies are mentioned with their input-output variables, methods, findings and sample specifications in the following chapter. The data envelopment analysis is explained in detail in chapter five. Then, reasons to select the sample are discussed, input-output variables are determined and the way of data collection is expressed. The analysis is explained and the results are discussed in detail in the seventh chapter. In the eighth chapter, the Turkish flag carrier Turkish Airlines and its low cost carrier Anadolu Jet are separately investigated within the global sample and within members of Star Alliance in order to evaluate the results of efficiency analyses for the national full service carrier and its subsidiary. Final chapter presents limitations of the study, conclusion, policy implications and recommendations for future studies.

CHAPTER 2

AIRLINE INDUSTRY

2.1 Market review and the challenges

Airline business which is an industry of 758 billion USD is a very significant component of the transportation system and has so much positive impact on the development of societies. [1] ICAO defines air transport as the vital engine of global socio-economic growth and a catalyst for economic development by creating direct and indirect employment, supporting local businesses and tourism, stimulating international trade and foreign investment (International Civil Aviation Organization [ICAO], n.d.). Economies have been more integrated due to increasing mobility by expanding flight networks, increasing departure frequencies, and shorter travel and transport times. Aircraft manufacturers design and launch their superior aircraft in terms of fuel efficiency, extended seat and cargo capacity, lighter material while aircraft component producers make notable investments in their products for performance improvements.

The year 2014 was eventful for the world with political crises in the Middle East and Ukraine and Ebola epidemic in West Africa. In addition to these biggest challenges, there has been a competitive pressure in the airline industry from state-owned Gulf airlines especially for European Airlines on their routes to Asia (Lufthansa Group, n.d.). Director General Tony Tyler of IATA defines 2014 as the year of contrasts for the global air transport industry. [2] Aviation is a long-term growth business and despite the turbulent environment, sales worldwide increased in

[1] According to ICAO (2015), global operating revenues in airline industry were 758 billion USD in 2014 and 720 billion USD in 2013 where operating expenses were 716 billion USD and 695 billion

[2] International Air Transport Association which is the trade association for the world's airlines, representing 84% of total air traffic.

2014 which enabled global airline industry almost double its net profit (Lufthansa Group, n.d.; Boeing, n.d.). Efficiency gains through process improvement and careful balancing of capacity as well as the fall in oil prices are contributing to improved financial sustainability. Additionally, the Eurozone is starting to gain economic momentum and North America is leading the economic acceleration.

Demand for air travel is evolving due to drivers such as GDP development, increasing population, emerging technology leading to new airplanes with improved capabilities and worldwide commerce. Boeing forecasts that world fleet will have a 43,560 aircraft size in 2034 while it was 21,600 in 2014 and 40% of all new airplanes being delivered will be to airlines in Asia Pacific region since Asia Pacific will become prominent in global aviation mostly because of increasing GDP and continued liberalization in the structure of its airline industry while share of Europe and North America in all traffic will decrease to 38% by 2034 from 73% in 1994 (Boeing, n.d.).

Demand for cargo and passenger services, measured in RFTK and RPK, respectively, accelerated in 2014, with regional disparities (Tyler, 2015; ICAO, 2015). While world GDP increased 3.1% in 2014, world passenger traffic in terms of RPK and world cargo traffic in terms of RTK increased by 4.9% and 4.7%, respectively, and world fleet expanded by 3.6% (Boeing, n.d.). World passenger traffic almost doubled between 2003 and 2013 from 10 billion passengers to 20 billion passengers, respectively (World Bank, n.d.). According to Table 1, Europe, North America and Asia Pacific are the three leading regions in air transport scores with the highest shares. It is seen from Table 1 that Asia Pacific alone captures 33.5% of world passenger traffic and 39.4% of FTK despite its relatively low load factors.

Table 1. Regional Distribution of Scheduled Traffic for 2014. Adapted from "Tables Relating to the World of Air Transport in 2014," by ICAO, n.d., p. 3

By ICAO Statistical Region	ASK (m)	Aircraft departures (th)	PAX Carried (m)	RPK (m)	PAX LF (%)	RFTK (m)	RTK (m)	ATK (m)	LF (%)
Europe	10833	8134	871832	1660547	81	43283	202854	283730	71
Percentage of world TRF	24.7	24.6	26.4	27.0		22.3	26.4	24.7	
Africa	1211	1003	72320	139112	69	3218	16384	29484	56
Percentage of TRF	2.8	3.0	2.2	2.3		1.7	2.1	2.6	
Middle East	2817	1196	173714	547832	78	25371	77760	122120	64
Percentage of world TRF	6.4	3.6	5.3	8.9		13.1	10.1	10.6	
Asia and Pacific	12870	9219	1107166	19268003	78	76444	253421	370229	68
Percentage of world TRF	29.3	27.9	33.5	31.4		39.4	33	32.3	
North America	13387	10844	838089	1550535	83	40310	182560	288103	63
Percentage of world TRF	30.5	32.8	24.5	25.2		20.8	23.8	25.1	
Latin America and	2734	2639	240229	319.683	78	5387	35600	53155	67
Percentage of world TRF	6.2	8.0	7.3	5.2		2.8	4.6	4.6	
Total	43852	33035	3303349	6144510	80	194012	768579	1146820	67

While the technological advancement and sophisticated aircraft parts enable the industry to provide better and higher quality service to their customers, the industry is getting more and more capital intensive and it is greatly affected by the overall economic situation. The growth of low cost carriers, the open skies agreement, the formation of global alliance networks, privatization, code share agreements, terrorist attacks, fluctuating unprecedented oil prices, currency fluctuations and large-scale strikes have significant influence on the industry. However, despite the effects of aforementioned factors, air transportation is resilient and growing over the years. Figures 1 and 2 show that both worldwide passenger and cargo traffic demonstrate an increasing trend through its history although they sometimes suffer from contradictions due to global shocks such as Iran-Iraq war in 1980, Gulf crises in 1991, Asian crisis in late 1990s, 9/11 attack in 2001, SARS outbreak in 2003 and world recession in 2009 such that RPK has increased 5 times and RTK has increased almost three times over last quarter-century.

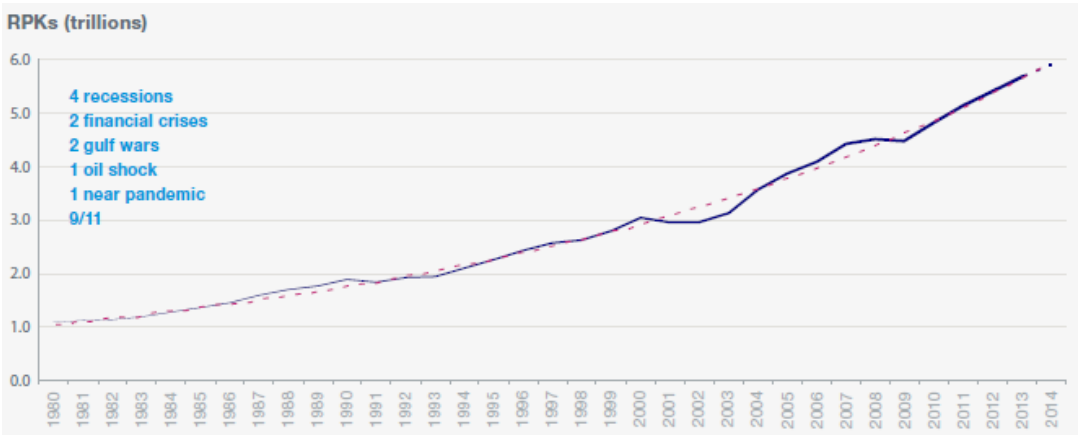

Figure 1. World passenger traffic "Source: [Boeing, n.d.]".

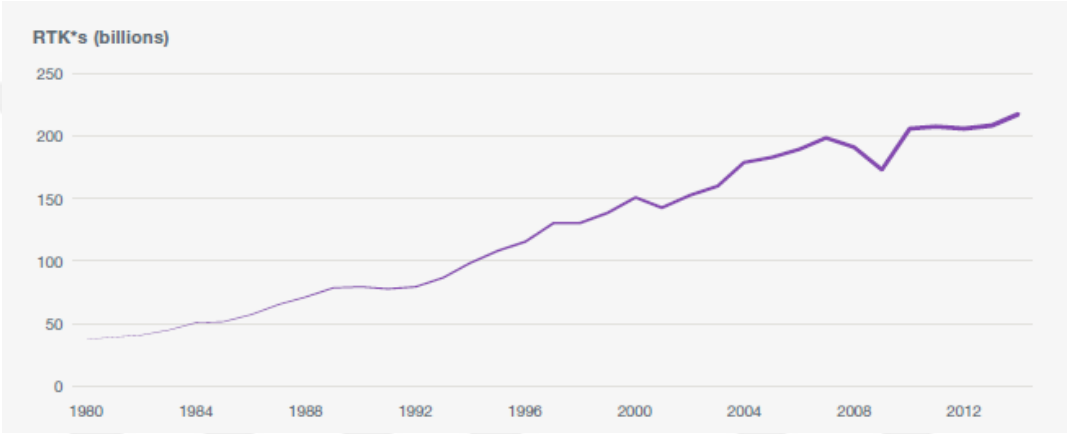

Figure 2. World air cargo traffic "Source: [Boeing, n.d.]".

Other issues that airline industry is dealing with are jet fuel prices and currency fluctuations, as previously mentioned. Fuel is airlines' major cost component such that, in 2014, it was 45.5% for Asiana Airlines, 23.3% for Scandinavian Airlines, 60.9% for Garuda Indonesia, 28% for Finnair, 38% for Thai Airways, 36% for Royal Jordanian Airlines (Asiana Airlines, 2015; Scandinavian Airlines, n.d.; Garuda Indonesia , 2015; Finnair, n.d.; Thai Airways International, n.d.; Royal Jordanian Airlines, n.d). As shown in Figures 3 and 4, crude oil price is sharply decreasing after 2012, but conversely US dollar is getting stronger and so despite the decline in airlines' major cost share, airlines have to account for a recent significant strengthening of the US dollar. Since costs and expenses are often paid in US dollars, the currency volatility may temper the near-term benefit of lower oil prices for some

regions due to varying economic prospects. Airplane costs, spare parts and maintenance expenses and aviation insurance premium are mostly in US dollars whereas airlines generate their revenues in different currencies and hence appreciation or depreciation against US dollars affects airlines' operating profit. Additionally, international volumes and revenues of global airlines may be influenced by high exchange volatility depending on airline's network structure and changes in traveler purchasing power, respectively. On contrast, since they may have hedging tactics to smooth the effects, the airline profit profile in general remains strong (Boeing, n.d.). Aeromexico, for instance, states in its annual report for the year 2014 that over 50% of its expected fuel consumption is hedged and it manages to reduce exposure to currency fluctuations since 57% of its revenues and 66% of its costs are in US dollars (Grupo Aeromexico, n.d.).

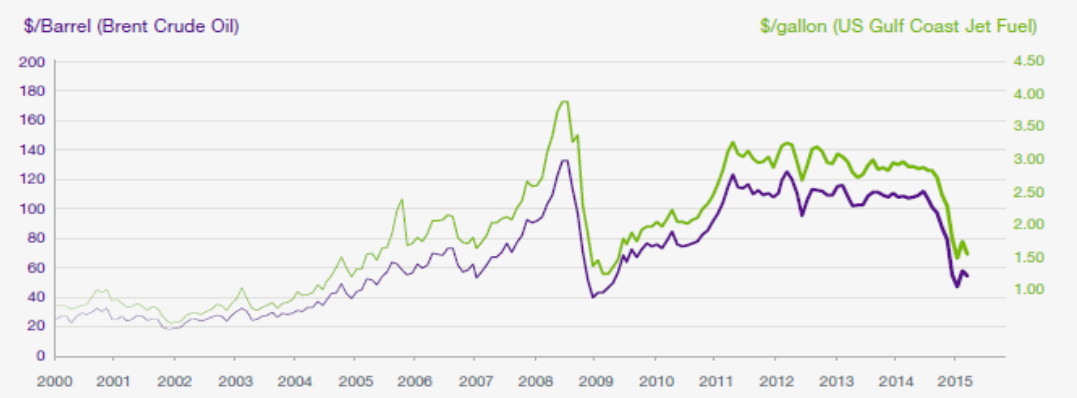

Figure 3. Oil prices "Source: [Boeing, n.d.]".

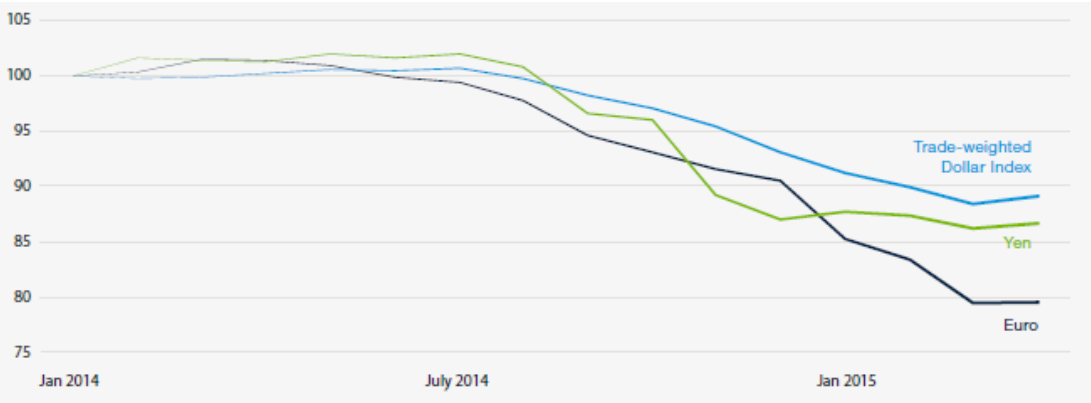

Figure 4. Exchange rate index vs. USD "Source: [Boeing, n.d.]".

2.2 The development of Turkish aviation

Turkey has been experiencing a significant increase since early 2000 in the number of passengers that use air transport. Figure 5 provides a general historical view on the market in terms of the number of passengers carried. The sharp increase in the number could be easily seen in Figure 5. According to the data retrieved from World Bank database, over 74 million passengers flew on domestic and international lines in aggregate in 2013 whereas it was just about 11 million in 2003, which corresponds to almost six fold increase within 10 years.

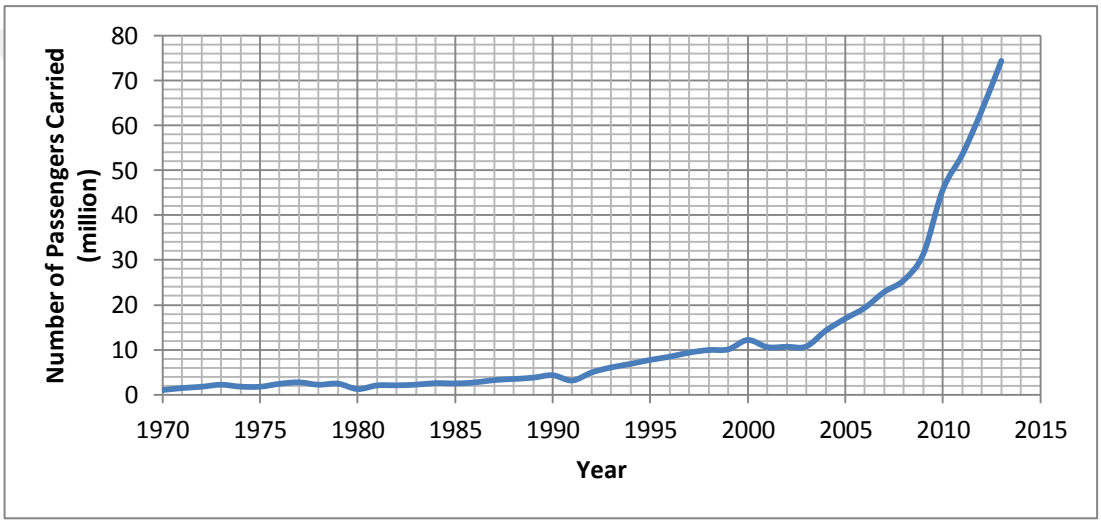

Figure 5. Annual domestic and international aircraft passengers of air carriers registered in Turkey "Source: [World Bank, n.d.]".

Similarly, Turkey's share in the world air passenger's traffic is steadily increasing. According to Figure 6, although it used to be fluctuating within the period prior to 2000s almost on the same level, share of Turkey is steadily increasing after that date. This is mostly due to the introduction of competition into the Turkish airline market with deregulation on 20th October 2003.

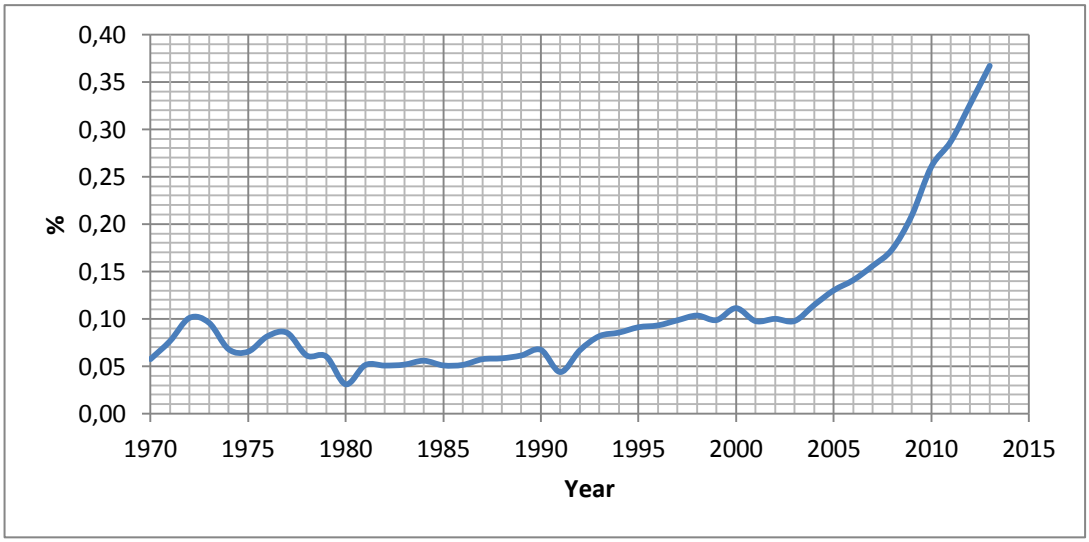

Figure 6. Turkey's share in world air passenger's statistics in domestic and international flights "Source: [World Bank, n.d.]".

Figure 7 shows the growth rates in Turkey and world passenger traffic. As previously discussed, this figure clearly shows the impacts of global situation on airline industry as increases or declines in the traffic for the corresponding years. It is also notable that Turkey started to show a parallel trend with the world after 1990s and even has had higher growth rates for the last decade.

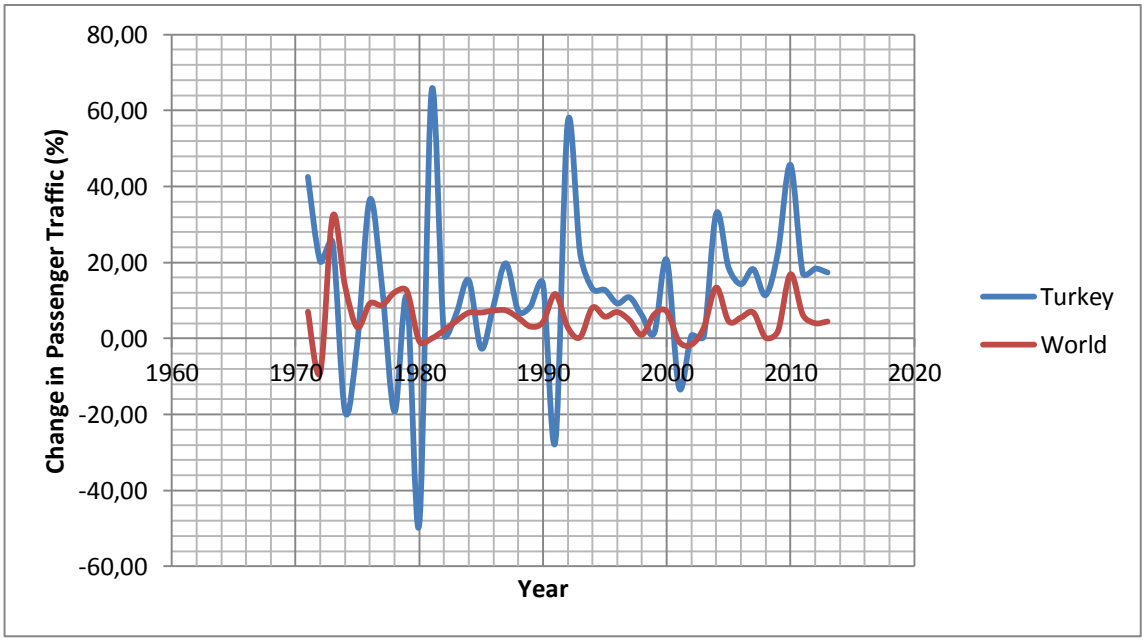

Figure 7. Turkey's and world's passenger traffic growth rates "Source: [World Bank, n.d.]".

Another remarkable growth is observed in airline fleets. Despite high capital and qualified personnel requirements, the total fleet size of 150 aircraft in 2002 has become more than 400 aircraft in 2014. The increase in the bilateral air transport agreements with foreign countries as per Chicago Convention burst international air traffic of Turkish airline operators. Turkey had bilateral air transport treaties with 81 countries in 2002 whereas it became 157 in 2013 and similarly the number of international destinations flown by Turkish operators increased to 236 in 2013 from 60 in 2002 (Directorate General of Civil Aviation, n.d.). All these factors have helped the expansion of Turkish airline fleet for the growing industry.

The Turkish flag carrier, Turkish Airlines, which was established in 1933 with only 5 aircraft with total 28 seat capacity is now operating 300 aircraft with almost 50,000 seat capacity to 264 destinations (45 domestic) all over the world and carrying 48 million passengers by over weekly 10,000 flights (Turkish Airlines, n.d.b).

According to Turkish Airlines' 2014 year annual report (n.d.), Turkish Airlines, with the world's largest fourth flight network, flies to 219 international destinations in 108 countries. The goal of Turkish Airlines is to reach 135 million passengers in 2023 with a target fleet of 450 aircraft for the same year, while Turkish Airlines carried almost 55 million passengers in 2014. The company made 845 million USD profit, thanks to decreased fuel prices, in 2014 over its 11 billion USD revenue and 1,069 million USD in 2015 with an increase of 27 percent with respect to the previous year (www.centreforaviation.com).

According to Figure 8 Turkish Airlines has an increasing RPK, meaning that, year by year, it carries more passengers per kilometer flown. Furthermore, it has better growth rates than the world average. Although the global rate was negative in

times of wide spread crises like 2008 debt crisis, Turkish Airlines increased its RPK even in these difficult years.

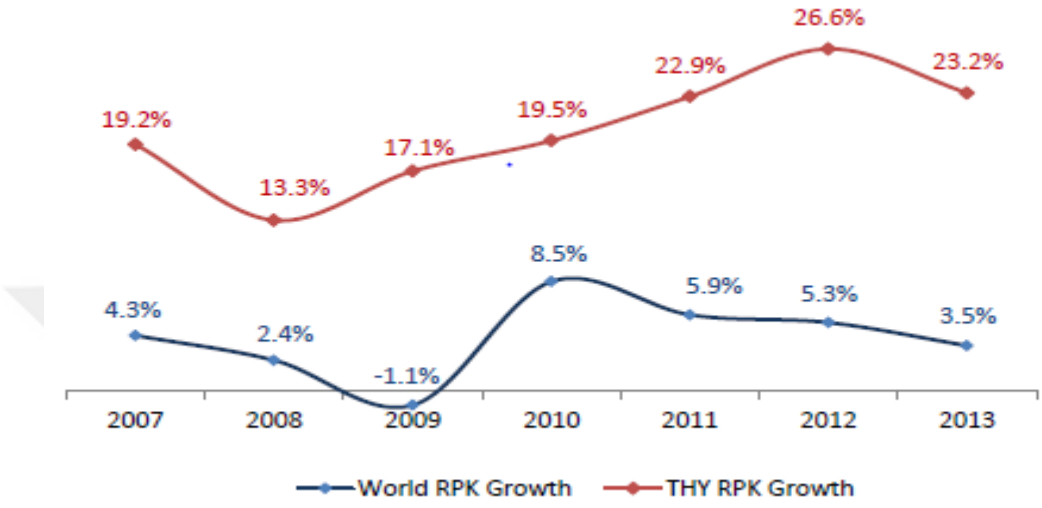

Figure 8. Turkish Airlines RPK growth over years "Source: [Turkish Airlines, n.d.a]".

Turkish Airlines is also improving its performance in load factor, i.e., Turkish Airlines can sell more proportion of its output, seats, over years. According to Figure 9, it increases from 72.7% in 2007 to 79.0% in 2013 which is still 79.0% for the year 2014. Another fact which is observed from Figure 9 is that Turkish Airlines can operate domestic flights with better load factor comparing to international flights. This may be because international flights are mostly operated with bigger aircraft due to required range necessary for overseas distances and since the amount supplied is bigger, the proportion sold may become less. Turkish Airlines has more international passengers than domestic passengers and more flight frequencies accordingly, which supports the reason of less load factor in international flights.

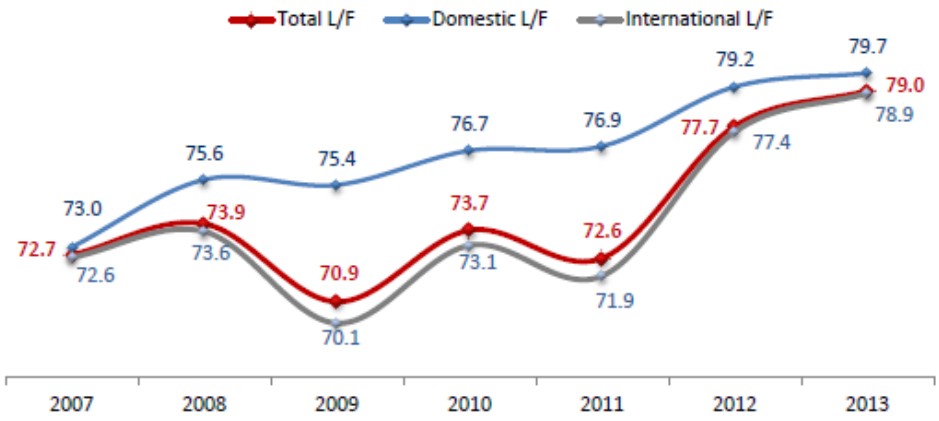

Figure 9. Turkish Airlines load factor over years, %. "Source: [Turkish Airlines, n.d.a]".

ASK, which shows seat availability per kilometer flown, is another metric that Turkish Airlines is improving with respect to previous years such that ASK performance has changed by 18% from 2011 to 2012 and 21.1% from 2012 to 2013 and reached 135,330 million in 2014.

Regarding the organizational structure, Turkish Airlines Group is composed of 13 subsidiaries some of which are wholly owned Turkish Airlines companies whereas some are joint ventures with local or foreign partners. The subsidiaries perform in different specific industries such that Turkish Do&Co is an airline catering company, Turkish Technic is serving in MRO (Maintenance, Repair, and Overhaul) industry and Sun Express is another airline operator which is based in Antalya. Turkish Technic, in particular, established in 2006, conducts its activities by supplying the full range of maintenance, repair, and technical support with the goal of becoming an important regional air transport technical maintenance base (Turkish Airlines, n.d.c).

2.3 Airline terminology and definitions

Among the transportation related sectors, airlines industry measures differ from the others to a large extent. There exist some standard measures of passenger traffic and airline output in the airline industry to measure airline performance. The output of a passenger airline can be represented in several ways, including number of seats flown and number of flight departures. Since some of these performance measures may not be meaningful or even misleading on their own, the measures and their definitions are to be introduced.

"Airline traffic" is the good point to start with, which quantifies the amount of airline output that is actually consumed or sold. Cargo, which can include air freight, mail and passenger baggage, and passenger, can be jointly deemed as the "traffic" carried by airlines whereas it refers to enplaned passengers for passenger airlines. "Traffic" is different than "demand" since the latter includes both those boarded consumers and those to have a desire to travel on the flight but who could not be boarded due to capacity insufficiency, which refers to available seats. The widely used measure for airline traffic is revenue passenger kilometer (RPK) or, alternatively, revenue passenger mile (RPM) although the traffic can also be measured in terms of the number of passengers transported. Numerically, 1 RPK means 1 commercial passenger transported 1 kilometer. Accordingly, the airline traffic generated by a flight carrying 100 passengers over a distance of 500 km would be 50,000 RPK.

Another metric in airline industry is yield, which is defined as the average fare paid by all passengers per kilometer, or alternatively mile, flown. The total revenues collected from all passengers on a set of routes, or a region of operation for an airline is divided by the number of RPK carried, the result will be the yield such

that if a flight of 10,000 RPK generates the total passenger revenue of 12,000 USD, then the yield is 1.2 USD per RPK.

Available seat kilometer (ASK), or available seat mile (ASM), is another commonly used measure of airline output like RPK. In other words, 1 ASK corresponds to 1 available seat flown 1 kilometer, which is the production of an airline. A 250-seat aircraft operating a flight of 1000 km distance generates output of 250,000 ASK.

The unit cost of an airline, which is a significant measure of cost efficiency, is the average operating expense per unit of output. It is defined as the ratio of total operating expense divided by the ASK produced for a route, region or total network of an airline. As an example, the unit cost for a flight of 250,000 ASKs and 10,000-USD-total expense will be 0.04 USD. As long as the unit cost is lower than the yield, the airline will make a profit.

Another widely used measure in the airline industry is load factor, which represents the proportion of airline output sold. It can be calculated by dividing the number of the passengers by the number of seats on the flight for a non-stop operation. Average load factor defines the proportion of output consumed better than load factor due to the fact that airlines in most cases operate many flights with different distances. In this line, RPK/ASK gives the average load factor.

Similar metrics apply for cargo air transportation. Revenue freight ton kilometer (RFTK) measures cargo traffic carried and 1 RFTK defines 1 ton of cargo transported 1 kilometer. The output measure provided by cargo airlines is available freight ton kilometer (AFTK) and 1 AFTK corresponds to 1 available ton flown 1 kilometer. When mile is used instead of kilometer, then the measures will be RFTM

and AFTM. The performance measures of yield and unit cost are calculated similarly as in passenger airlines.

Apart from ASK and AFTK, there is a measure called available ton kilometer that incorporates both passenger and cargo output. It is the total number of ton of capacity available for transportation of freight, mail and passengers multiplied by the number of kilometers flown. Similarly, revenue ton kilometer is defined as the production of the kilometers flown and the number of tons of paid traffic including passengers, freight and mail.

Seat capacity is the number of people that can be seated in airplanes whereas cargo capacity is the physical amount of cargo that can be carried by air. It should also be noted that cargo and seat capacities only represent the amounts that are supplied to the market while how efficiently they are utilized is expressed in terms of load factor.

2.4 Alliances in airline industry

Alliances in airline industry are classified as major alliances, strategic alliances and minor alliances where first one refers to network-based, and second one is defined as combination of networks by partner airlines to gain access to other parts of the global markets. Minor alliances are route based alliances in which airlines, without linking their entire network, cooperate on one or more routes (as cited in Oum & Zhang, 2001, p. 291). The first international alliance was formed between Air Florida and British Island in 1986 through the code-shared British Island's flights of Air Florida on the London-Amsterdam route (Oum & Zhang, 2001).

The development of airline alliances has very significant implications for both the public and the aligned airlines managements. The managerial questions

which arise can be if the partners benefit from the alliances in terms of economic performance and if it actually creates advantages for the passengers in terms of service quality and price competition.

Oum and Zhang (2001) discuss the pros of gathering under the roof of an alliance such that each member brings substantial market coverage to the network and members will have one or more continental hubs that can be considered international gateways. Additionally, they argue that alliances provide network co-ordination of schedules, ground handling, reservation systems, in other words compatible management philosophies and corporate image. They state that most of the alliances contribute to competitive pricing and profitability gains as well as productivity enhancement, depending on the scope of cooperation where the effects can be mainly observed for strategic alliances rather than minor alliances which do not have important influence on partners' pricing, profitability or productivity.

According to Ramsay, Stamp, Regueiro, Richards, and McGilvery (2013), ongoing oil price volatility and global economic instability especially have impact on small airlines. Being under a roof alliance provides airlines international presence and strategic penetration. Strategic partnership rather than a direct investment may be more appealing to airlines for a transitional strategy to acquire a controlling stake in another airline. Alliances allow members expansion of operations through the code share arrangements, joint marketing initiatives, access to training and administrative facilities and integrated mileage programs with no need for legal change in ownership and no change in existing workforce. On the contrary, management difficulties and diverse interests of carriers have caused many alliances to break up through the history of alliances.

Today, world's major strategic alliances are Star Alliance, One World and Sky Team which together hold 63.2% of the world's overall ASK and RPK, and 70.1% of operating revenues. In other words, these three alliances capture more than 60% of the airline market as shown in Figure 10 (All Nippon Airways, n.d.).

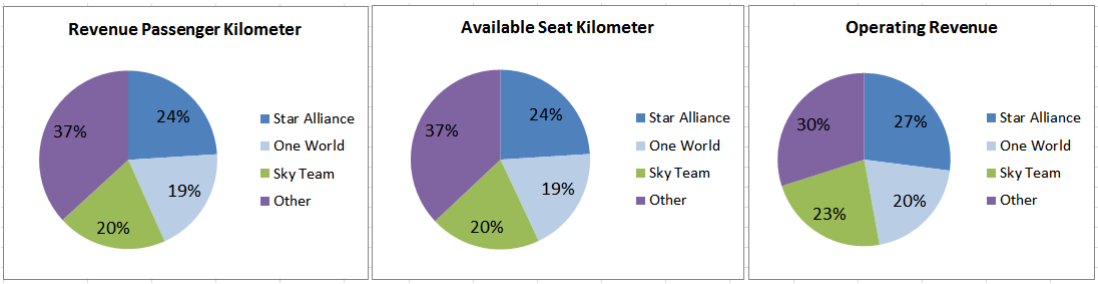

Figure 10. Alliances' market shares Adapted from "Annual Report 2015," by All Nippon Airways, p. 113

Star Alliance, established in 1997 by Lufthansa in cooperation with Air Canada, SAS, Thai Airways and United Airlines, was the first and is the world's largest airline alliance with its 28 members and 18,500 daily departures (https://portal.staralliance.com/employees/about/bottom-left/the-star-alliance-network) and according to 2014 year data it keeps 24-percent-market share as shown in Figure 10. One World, launched in 1999 by American Airlines, British Airways, Cathay Pacific and Qantas, is a 15-member alliance with more than 14,000 daily departures (https://www.oneworld.com/general/about-oneworld) and almost 20% of the market revenues today. Finally, Sky Team which has access to 1,057 destinations worldwide with its 20 members operating more than 16,200 flights was founded in 2000 by Aeromexico, Air France, Delta Air Lines and Korean Air (http://www.skyteam.com/en/about/). As demonstrated in Figure 10, Star Alliance dominates the airline market in terms of both passenger traffic and operational income. Table 2 presents the members of these three major alliances showing that the members are not from a specific region but from different regions of the entire world.

Table 2. Members of World's Leading Alliances "Source: [http://www.staralliance.com/member-airlines.; https://www.oneworld.com/general/about-oneworld; http://www.skyteam.com/en/about/]".

	Star Alliance	One World	Sky Team
1	Adria Airways	Air berlin	Aeroflot
2	Aegean Airlines	American Airlines	Aerolineas Argentinas
3	Air Canada	British Airlines	Aero Mexico
4	Air China	Cathay Pacific	Air Europa
5	Air India	Finnair	Air France
6	Air New Zealand	Iberia	Alitalia
7	ANA	Japan Airlines	China Airlines
8	Asiana Airlines	Lan	China Eastern
9	Austrian	Malaysia Airlines	China Southern
10	Avianca	Qantas	Czech Republic
11	Avianca In Brazil	Qatar Airways	Delta Airlines
12	Brussels Airlines	Royal Jordanian	Garuda Indonesia
13	Copa Airlines	S7 Airlines	Kenya Airways
14	Croatia Airlines	Srilankan Airlines	KLM
15	Egyptair Airlines	Tam Airlines	Korean Air
16	Ethiopian Airlines		Middle East Airlines
17	Eva Air		Saudia
18	Lot Polish Airlines		Tarom
19	Lufthansa		Vietnam Airlines
20	Scandinavian Airlines		Xiamenair
21	Shenzhen Airlines		
22	Singapore Airlines		
23	South African Airlines		
24	Swiss		
25	Tap Portugal		
26	Thai		
27	Turkish Airlines		
28	United		

To sum up, multilateral strategic alliances give the opportunities of achieving diverse benefits to their member airlines through the use of collaborative strategies. Alliances act as international multi-brand airlines and present gains to the members

from code share routes to strategies to generate new revenue sources and improve their profitability (Tugores-Garcia, 2012). Most of the benefits of alliances are related with reinforcement of the competitive advantages like joint marketing and code share routing. Consolidating operations with alliance peers for overlapping networks will reduce their need for fleet and aircraft size and increase load factor at the same time. Member airlines work on joint initiatives such as fleet coordination, IT projects and fuel (Star Alliance, 2015). Star Alliance, for example, is the pioneer in joint purchasing which is an effort to get greater discounts. Star Alliance, in December 2003, found Star Fuel Co, which enables the members to reduce their fuel costs (Rigas, 2006). Projects of combined seat buying and cross-utilization of ground staff can be counted joint initiatives of airlines.

CHAPTER 3

EFFICIENCY ANALYSIS

Efficiency is important in assessing managerial efficiency and devising goals for development and improvement. Efficiency analysis is used increasingly at macro as well as micro level. Increasing competition in the light of advancing technologies and globalization forces industries and economies to operate efficiently. Efficiency can be broadly defined as the comparison of what is actually produced or performed with what can ideally be achieved with the same amount of resource. Almost all business activities can be defined as inputs into outputs transforming where the objective would be to produce more outputs using less amount of inputs. In a business or economic context, various types of efficiency are utilized.

According to Bhadra (2009) efficiencies are examined in two ways: allocative and technical. When the price a company receives equals to marginal costs associated with producing an extra unit of product, that company is said to achieve the allocative efficiency. On the other hand, technical efficiencies, given the levels of inputs, evaluate that company's ability to produce maximum levels of outputs. Relatedly, the ratio of produced level of output over producible level of output gives a measure of technical efficiency. In this essence, allocative efficiency, given prices, refers to the optimal combination of outputs and inputs whereas technical efficiency is concerned with the physical input-output combination instead of prices. Koopmans states that a producer is technically efficient if a reduction in any input requires an increase in at least one other input or a reduction in at least one output, and if an increase in any output results in a reduction in at least one other output or an increase in at least one input (as cited in Inglada, Rey, Rodriguez-Alvarez, & Coto-Millan,

2006, p. 98; Semenick, 1994). So, an efficient producer is able to produce the same amount of output with less of at least one input or it is capable of producing more amount of output with the same levels of inputs. In this sense, two orientation approaches for technical efficiency analysis come to picture. One is the input orientation model that requires a projected point on the efficient frontier that enables the maximum proportional reduction in inputs where the second is the output orientation model which similarly seeks a projected point such that the proportional increase in outputs is maximized (Scherage, 2004). In other words, input-oriented technical efficiency measures the ability of decision making units to produce the same amount of output with the minimum quantity of inputs and, in contrast, output orientation model centers the possibility of producing more outputs with a given set of inputs.

CHAPTER 4

LITERATURE SURVEY

There are many studies measuring efficiency and productivity of an industry using a range of non-parametric methods such as unit cost measurement, total factor productivity (TFP) and Data Envelopment Analysis (DEA) and parametric methods such as stochastic frontier approaches that use econometric regression and traditional regression analysis (Marti, Puertas, & Calafat, 2015; Barros, Liang, & Peyboch, 2013). Non-parametric techniques create an envelope of the input and output variables corresponding to a scale yield and approximate the production frontier, and then the distance up to the frontier is measured (Lita & Stamule, 2011). Linear or non-linear mathematic programming models are used for the assessments.

Stochastic frontier model was originally developed by Aigner, Lovell, and Schmidt (1977) and then many varieties of stochastic frontier model based on different assumptions about the distribution of the inefficiency term have appeared. Estimation and specification of the parameters of the model are major steps of stochastic frontier approach. The strength of the model is that it can consider the stochastic noise in data and enable the statistical testing of hypotheses about the degree of inefficiency and production structure (Hossain, Kamil, Baten, & Mustafa, 2012).

Aviation industry, in particular, draws so much attention in terms of efficiency analysis such that many studies concern airline efficiencies in terms of operating efficiency, safety efficiency, load efficiency, environmental efficiency, fuel efficiency, cost efficiency, marketing efficiency and production efficiency (Cui & Li, 2015a, 2015b; Chao & Li, 2015; Gong & Kim, 2015; Lu, Hung, Kweh, & Lu, 2014;

Lozano & Gutierrez, 2011). The extensive literature existing in this area assesses airline industry from so diverse aspects such that there are many papers analyzing efficiency scores of samples of airlines selected with respect to their cost structures, i.e. full service or low service, fleet size, type of operations, i.e., domestic or international, and ownership types such as state-owned or private. There is also a pool of studies that analyzes the efficiencies of airlines within a specified country or region like Europe, Asia, United States, India, etc. Additionally, effects of deregulations on airline performances are of interest, as well, and many researches which mostly compare the efficiency levels after and before the deregulations (Siregar & Norsworthy, 2001; Sjögren & Söderberg, 2010).

Previous studies depict that airline research has adopted several methods to analyze airline efficiency quantitatively. There are studies using TOPSIS arguing that it is better comprehended compared to traditional two-stage approaches. TOPSIS, first developed by Hwang and Yoon in 1981 (as cited in Wanke, Barros, & Chen, 2015, p. 93), is a multi-criteria decision making method based on a principle of selecting a DMU as the best, which is as away from the negative ideal solution as possible and close to the positive ideal solution where the ideal solution is a set of the best performance values for each criterion and the set of worst performance values for each criterion constitutes the negative ideal solution (Vaidya, 2016). One advantage of TOPSIS is that it does not require a functional form of data or any distributional assumption to calculate the efficiency scores. Some researchers also argue that TOPSIS allows sensitivity analysis to assess the robustness of the results (Wanke et al., 2015).

Wanke et al. (2015) use TOPSIS in their study to compute efficiency scores of 35 selected Asian Airlines and analyze the effect of the contextual variables on the

performance. They choose Asia due to the fact that a rapid growth and bigger market share are expected in Asia's airline industry thanks to some facts such as the big population which creates a potential market demand, increasing economic welfare and growing international trade between East and West Asia. They select operational cost, depreciation, salary, employee numbers, number of planes and assets as inputs of the analysis where revenues EBIT, RPK and passenger number are the outputs. They found that efficiency levels are impacted by private ownership positively whereas jet fuel prices affect efficiency negatively. They also found that labor cost and cost of capital do not have a notable influence on efficiency levels. Similarly, Barros and Wanke (2015) use TOPSIS in their paper for efficiency assessment of 29 African airlines. They employ TOPSIS in two-stage approach along with neural networks to measure performances. Total operating cost, employees, and number of aircraft are employed as the inputs of this study where RPK, EBIT and RTK are the outputs. In this study, network size is revealed as the most important efficiency driver.

In addition, many papers employ DEA or a modification of DEA together with regression analysis, bootstrapping or super-efficiency in order to increase the explanation power of DEA to measure airline performances. This chapter provides brief information about some of the previous important studies as follows.

A study conducted by Marti, Puertas, and Calafat (2015) assesses the production efficiency of Spanish airlines comparing the effects of the operating systems hub-and-spoke with point-to-point.[3] They use the non-parametric technic, namely DEA, in their assessments for five hub-and-spoke model operating airlines

[3] In hub-and-spoke system connections, there are spokes connected to a hub at the center and traffic is directed between hub and the spokes. Point-to-point refers to the operations from one point to another without passing through a hub. In point-to-point system, each point is connected to each other directly whereas hub and spoke system does not allow direct traffic between points while each point is connected to the hub where passengers are redistributed and sent to other destinations.

and 24 point-to-point transportation providing operators. Labor costs, assets and supplies are used as input variables of this study whereas the output variable is operating income. They observe that airlines operating point-to-point flights have higher efficiency levels than those operate from hubs, which contradicts the initial reason of hub-and-spoke system for founding that carries the intention of taking the advantage of economies of scale stemmed from the use of larger airplanes, higher frequencies and greater connectivity.

Virtual frontier network slacks based measure is used by Li, Wang, and Cui (2015) to evaluate the efficiency of 22 international airlines from 2008 to 2012 within operations stage, services stage and sales stage framework. They use number of employees and aviation fuel as the input variables of operations stage of which output variables are ASK and ATK. They use the outputs of the operations stage with the addition of fleet size as inputs of services stage to get the products of RPK and RTK. In the final stage, which is sales stage, they select RPK, RTK and sales cost as inputs where total business income is the output. They build a network structure of three consecutive stages where the predecessor stages' outputs are the inputs of the successive ones. They conclude that almost all airlines' efficiency increase over time from 2008 to 2012.

Cui and Li (2015b) propose a new model called virtual frontier benevolent DEA cross efficiency model (VFB-DEA) to assess the energy efficiencies of 11 airlines with RTK, RPK, total business income and CO_2 emission decrease as the outputs and number of employees, capital stock and aviation kerosene consumption as the inputs. Their findings show that capital efficiency is a very important driver of energy efficiency and there is a remarkable influence of American debt crisis on the change in energy efficiency.

Total factor productivity (TFP) is studied together with cost competitiveness and residual average yields for 10 major North American airlines for the years 1990 and 2001 by Oum, Fu, and Yu (2005). They identify sources of the observed TFP differentials and compare the residual levels which are the productive efficiency indicators. They also compute the cost competitiveness of the airlines and explain profitability differentials in conjunction with the measured productivity. RTK and incidental services which are non-airline businesses such as catering services and aircraft maintenance are output variables of this productivity assessment and the input variables are labor, fuel, materials, flight equipment and ground property. They, additionally, perform regression on size, average stage lengths, load factor to identify the effects of these variables on productivity levels. Like Oum et al. (2005), Vaisgn and Fleming (2005) find in their analysis of the United States airways through TFP method that domestic airlines have higher TFP compared to global airlines. Their inputs are ASM, total expense, CASM, average number of employees, and fuel cost and their outputs are RPM, yield,[4] total revenue, RASM, and load factor. They state that efficiency is the transformation technique of physical inputs into physical outputs while productivity is an efficiency measure to understand how well an airline utilizes its resources.

Another study investigates the technical efficiency of US airlines applying B-convex model, combining operational and financial data, which reveals that size of the airline, mergers and acquisitions and time influence the efficiency of the sample airlines (Barros, Liang, & Peyboch, 2013). The study is the first to use B-convex model in efficiency analysis and it also provides a benchmark to upgrade the efficiency. They select total cost, number of employees and fuel consumption in

[4] Yield measures average earnings per passenger or cargo transported and calculated by dividing passenger revenue by RPK.

gallons as input varibles and total revenue, RPM and passenger load factor as the output variables.

Gong and Kim (2015) analyze operation efficiency of major 14 airlines in Asia-Pacific region from 2003 to 2011. They argue that non-radial SBM-DEA is able to capture slack values in output shortage and input excess while it provides a comprehensive efficiency of combining regional difference and economic performance. ASK, ATK and number of employees are the input variables and RPK, RTK and amount of sales are the output factors of this study. They find that Korean and Japan airlines are efficient ones whereas most of the China and ASEAN airlines are found to be inefficient. Another study measures economic and environmental efficiency of 27 global airlines in 2010 using SBM-DEA with the weak disposability assumption (Chang, Park, Jeong, & Lee, 2014). In this study, where ATK, fuel consumption and number of employees are the input variables, and RTK and carbon emissions are selected as the outputs, Asia-based airlines are observed to be generally more efficient.

Lozano and Gutierrez (2011) use fuel cost, fleet cost and operating cost as the inputs and RTK as the output of their study while they evaluate fleet, fuel and operating cost efficiencies of European airlines in 2006, employing multi-objective DEA approach. Their results reveal that about half of the airlines are technically inefficient.

The relationship between operating performance and corporate governance in 30 US airlines is explored applying a two-stage DEA to evaluate the production efficiency and marketing efficiency in a study conducted by Lu, Wang, Hung, and Lu (2012). They come up with the result that low cost carriers, on average, are more efficient than the full service airlines. In order to evaluate the impact of the

characteristics of corporate governance on airline performance, they employ truncated regression. They assess production efficiency with the input variables number of employees, fuel consumption, seating capacity, and cost of flight equipment, and the output variables ASM and ATM. Then, they use ASM and ATM as the inputs of marketing efficiency analysis with the outputs RPM and non-passenger revenue.

In another paper employing DEA as the efficiency measuring model, Zhu (2011) uses two-stage DEA instead of standard DEA. The first stage of this model so-called "centralized efficiency model" uses resources such as fuel consumption and salaries to maintain load factor and fleet size and second stage utilizes fleet size and load factor to generate revenue. This study shows that the centralized model has more discriminative power than the classical DEA model.

Wang et al. (2012) suggests that one opting for DEA analysis should choose either VRS or CRS model to analyze the performance. Lee and Worthingon (2014) choose VRS in their analysis since they argue that CRS can be appropriate when companies operate at their optimal scale which is not much possible in the very dynamic airline industry. Similarly, Siregar and Norsworthy (2001) uses VRS model based on the study which show that the airline industry is experiencing VRS.

As provided so far, efficiency in the airline industry is analyzed by different techniques. Some employ TFP models while some use neural network models; some select classical DEA while some perform integrated DEA models instead with the rationale behind. Despite the variety in the methods of assessments, the majority obviously focuses on DEA methodology whether classical or modified; input oriented or output oriented; VRS model or CRS model. Semenick (1994) states that the reasons behind the proliferation of DEA applications are due to the fact that it

does not require price information where most of the time the only data available are physical inputs and outputs, and it does not require assumption of profit maximization or cost minimization or a specified production function, and the ease of computing multiple input variables and output variables under study. On the other hand, stochastic frontier approach based on the idea that the data are contaminated with noise and measurement errors and it requires specification of a functional form to analyze the frontier production function (Michaelides, Belegri-Roboli, Karlaftis, & Marinos, 2009) as discussed in detail in the following chapter. More researches are listed in Table 3 that are studied in the efficiency analyses of airlines.

Table 3. Previous Studies in Efficiency Analyses of Airlines

Authors	Airlines	Objective	Method	Input variables	Output variables
Alzahrani (2015)	14 US airlines between 1998-2001	To investigate the economic impacts on air transportation by Leontief model and to assess company efficiencies	DEA and Leontief model	Operational expense, fuel consumed, number of employees, ATM, ASM, salaries, total fuel cost	RPM, RTM
Assaf (2011)	18 UK airlines	To measure the efficiency and productivity of UK airline sector for the period 2004-2007	Bootstrapped Malmquist index methodology[5] and second stage Tobit regression	Operational cost, labor cost, fuel expense and aircraft value	ATK and total operational revenue
Barbot, Costa, and Sochirca (2008)	49 IATA member airlines	To analyze airlines' efficiency and productivity	DEA and TFP	Number of employees, fleet size, fuel consumption	ASK, RPK, RTK
Barros and Peypoch (2009)	AEA airlines from 2000 to 2005	To evaluate operational performance and its drivers	DEA-CCR index model and a bootstrapped truncated regression	Number of employees, operational cost, number of planes	RPK, EBIT
Bhadra (2009)	14 US airlines between 1985-2008	To show that airline performance converges over time	DEA and Tobit regression	Fuel consumption, number of employees, aircraft utilization, number of seats per aircraft, number of aircraft	ASM
Ghosh and Bandyopadhyay (2014)	No-frill[6] airlines in Eastern India	To investigate the efficiencies	DEA and super-efficiency	Fleet size, number of employees, operating expense	RPK, RTK, aircraft utilization
Inglada et al. (2006)	A panel of 20 global airlines for 1996-2000	To compare the technical efficiencies of the sample	Stochastic frontier method	Number of employees, fuel consumption, capital	ATK
Jain and Natarajan (2015)	All Indian airlines	To investigate technical and scale efficiencies across service type, size and ownership	VRS model of DEA & input efficiency profiling model of DEA	ATK and operational cost	RPK, non-passenger revenue
Joo and Fowler (2014)	90 world major airlines	To measure and benchmark operating efficiencies of major airlines	DEA and Tobit regression	Operating expenses	Operating revenues, number of passengers, load factor
Michaelides et al. (2009)	24 largest network airlines	To estimate and compare efficiency scores	Stochastic frontier analysis and DEA	Number of employees, number of aircraft, fuel consumption	RPK
Wu and Liao (2014)	38 leading airlines	To evaluate the operational efficiencies	Integrated DEA-BSC model	RPK, number of passengers, fuel cost, capital cost,, material cost, labor cost, other operating expenses per employee	Operating revenue, return on investment, return on assets, net income.

[5] Malmquist index is utilized in order to compare efficiency over time. Pires and Fernandes (2012) define it as the product of the DMU's efforts to improve its efficiency and change in the efficient frontiers between the time periods.

[6] No-frill airlines are low cost carriers.

CHAPTER 5

METHODOLOGY

The methods to measure efficiency can be divided into two main groups of which one is stochastic frontier analysis that uses econometric regression and the other is linear programming model where stochastic frontier analysis is limited by its assumed functional form. In this study, input-oriented single-stage data envelopment analysis method is employed to empirically evaluate the relative input-output efficiencies of the members of the international strategic airline alliances, namely Star Alliance, One World and Sky Team, with both constant returns to scale and variable returns to scale approaches to identify the efficient frontier group and inefficient group mainly for the year 2014 and relatively limitedly for 2013. This chapter provides an explanation to the data envelopment model and the rationale behind the choice of it for efficiency measurement of airlines.

5.1 Data envelopment analysis

Farrell is the first who developed the idea of measuring efficiency and used the non-parametric frontier approach to estimate efficiency scores as relative distance from the frontier which is known as productive or technical efficiency by economists (as cited in Fethi, Jackson, & Weyman-Jones, 2000, p. 6). Operational researchers extended this measure and named the technique data envelopment analysis (DEA) (Charnes, Cooper, & Rhodes, 1978). DEA is a non-parametric technique that allows employing multiple inputs and outputs to make a relative assessment of efficiencies of homogenous units by comparing each to all the possible linear combinations of the rest of the sample which defines an empirical production frontier and measures the

distance of each unit from the frontier (Marti, Puertas, & Calafat, 2015). The production function in DEA model is generated from the actual data with no need for a priori assumption or having to specify the weights used for the inputs and outputs (Fethi et al., 2000). An empirical best practice production frontier is estimated from the observed outputs and inputs of individual decision making units (DMU) rather than the average estimate of conventional production functions (Scherage, 2004). DMUs can be divisions or organizations of the same environment and they use similar inputs in order to produce similar outputs (Alzahrani, 2015). The ability to deal with multiple inputs and outputs possessing different units is the main advantage of DEA according to Cooper, Lawrance, and Zhu (as cited in Alzahrani, 2015, p. 17). In DEA analyses, there is a rule of thumb that the number of units is to be at least twice the number of input variables and output variables selected (Golany & Roll, 1989) where Vassiloglou and Giokas (1990) mention it should be at least three times the sum of number of input variables and output variables considered. Additionally, Barros and Peypoch (2009) state that the minimum number of DMUs is to be equal to or greater than the multiplication of the number of output variables and the number of input variables. These numbers should probably be used as minimums for the basic efficiency models.

Although DEA is good at estimating relative efficiency, it cannot measure absolute efficiency (Wu & Liao, 2014). Additionally, it cannot evaluate the best performing one when the scores show more than one efficient DMUs and the result could be confusing to judge the most efficient one while there are only identical results for the efficient DMUs. The results in the study by Merkert and Hensher (2011) reveal that a traditional DEA tends to overestimate technical efficiencies unless bootstrapped on the basis that the average bias-corrected technical efficiency

scores are smaller than the average uncorrected values. In addition to the modified DEA models that make bootstrapping to identify which DMUs are extreme efficient ones, so-called super-efficiency also is capable of detecting the decision making units to study the sensitivity of the efficiency classifications.

The DEA models in which an efficient DMU under evaluation is not included in the reference set of the envelopment models are called super-efficiency DEA models (Ghosh & Bandyopadhyay, 2014). The basic idea in super-efficiency DEA is to make a comparison for the DMU with a linear combination of the rest of the DMUs under investigation, where an efficient DMU may proportionally increase its input vector in which the DMU under investigation takes the efficiency score more than one. This score indicates the radial distance of the DMU under consideration to the efficiency frontier recomputed in the absence of the DMU under assessment (Vaidya, 2016).

A DEA production frontier can be operationalized either with an input or output orientation, with the models of variables returns to scale (VRS) or constant returns to scale (CRS) (Merkert & Hensher, 2011). The input oriented technical efficiency approach investigates by how much input quantities can be decreased keeping output quantities unchanged and alternatively, output oriented approach analyzes by how much the quantity of outputs can be reduced without changing the input quantities. There is a linear relation between inputs and outputs in CRS model: outputs increase with the same percentage as inputs whereas in VRS models outputs can increase with a higher percentage, lower percentage or the same percentage (Hollanders & Esser, 2007). Figure 11 presents the difference between CRS and VRS models of input- and output-oriented approaches. The diagonal line at the left-hand side gives the CRS efficiency frontier and point C represents an inefficient unit

combining optimal levels of outputs OD and inputs OA. C could produce the same amount of output OD with just the input DE. Then, the degree of input-oriented efficiency is DE/DC, or in other words, the ratio of used inputs over the minimum amount of input needed for the same output quantity. If one looks from the output-orientation perspective, C could produce the quantity of AB outputs given its amount of input OA. Thus, the degree of output-oriented efficiency becomes AC/AB, in other words, the ratio of produced amount over the producible amount for the same input level OA. Under CRS approach, input-oriented and output-oriented efficiency are identical. However, these measures will be different under VRS approach as shown at the right-hand side of Figure 11. The degree of output-oriented efficiency is AC/AF and the degree of input-oriented efficiency equals DG/DC.

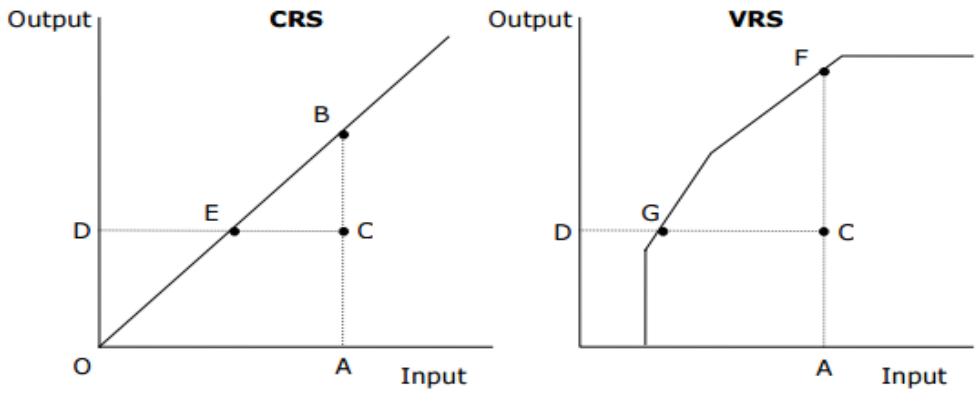

Figure 11. CRS and VRS approaches with input- and output-orientation "Source: [Hollanders & Esser, 2007]".

For technical efficiency, both CRS and VRS scores may also be calculated to see whether they are different, which would indicate scale efficiency (Merkert & Williams, 2013). CRS evaluates technical efficiency whereas VRS measures pure technical efficiency and technical efficiency computed with CRS includes pure technical efficiency together with scale efficiency and dividing technical efficiency by pure technical efficiency will give scale efficiency (Assaf, 2011; Joo & Fowler,

2014). If a DMU has a scale efficiency of 100 percent, this indicates that it is operating at its most productive scale size (Jain & Natarajan, 2015). Figure 12 shows technical and scale efficiencies for CRS and VRS approaches. The non-increasing returns to scale (NIRS) efficient frontier helps to identify whether the scale inefficiency is stemming from the fact that the DMU is too big (decreasing returns to scale) or too small (increasing returns to scale). If one looks at technical efficiencies (TE) and scale efficiency (SE) for DMU P;

TE under CRS conditions equals KG/KP;

TE under VRS conditions equals KH/KP;

SE equals KG/KH.

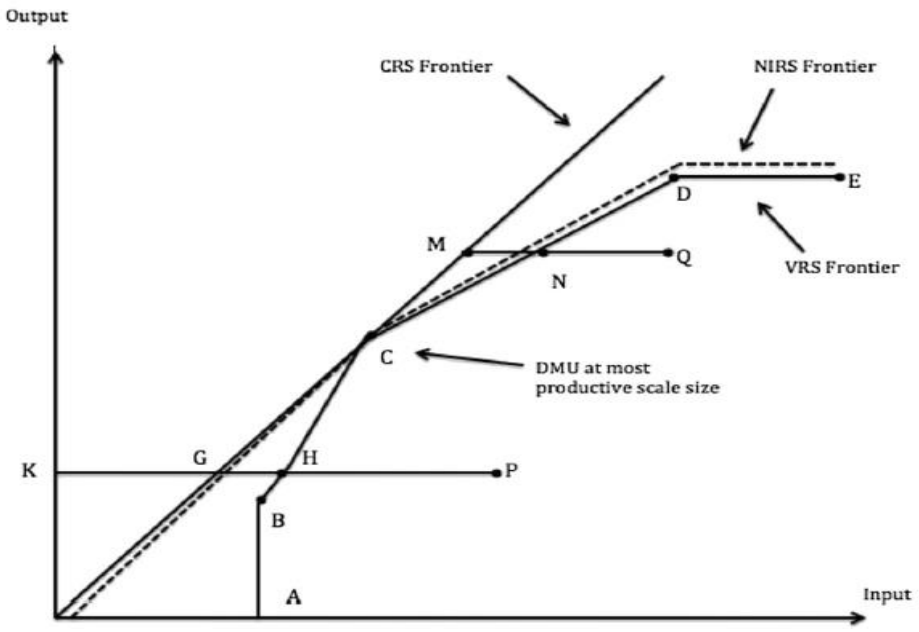

Figure 12. Technical and scale efficiencies and returns to scale "Source: [Jain & Natarajan, 2015]".

One can say from Figure 12 that DMU P is too small and operating at increasing returns to scale because its TE under VRS is greater than its TE score under NIRS condition while DMU C is at optimal size since its TEs are identical under VRS and CRS and DMU Q is operating at decreasing returns to scale because its TE under NIRS and VRS are almost same. Since DMU C is operating on both CRS and VRS

efficient frontiers, it has a scale efficiency of 100 percent meaning that it is operating at its most productive scale size.

5.2 Explanation for CCR and BCC models

The CCR model which was introduced by Charnes et al. (1978) from the theory of productivity measurement using the single output – single input ratio concept is a model to measure organizational efficiency by using multiple outputs – multiple inputs ratio concept to measure the efficiency of any DMU as the maximum of a ratio of weighted outputs to weighted inputs on the condition that the similar ratios for each DMU is less than or equal to unity. This explanation is formulated as

$$\max h_0 = \frac{\sum_{r=1}^{s}(u_r y_{r0})}{\sum_{i=1}^{m}(v_i x_{i0})}$$

subject to:

$$\frac{\sum_{r=1}^{s}(u_r y_{rj})}{\sum_{i=1}^{m}(v_i x_{ij})} \leq 1; \quad \mathrm{j} = 1, \dots, n.$$

$$u_r, v_i \geq 0; \quad r = 1, \dots, s; \quad i = i, \dots, m.$$

y_{rj}, xy_{ij} (all positive) are the outputs and inputs of the jth DMU and $u_r, v_i \geq 0$ are the variables to be determined.

In addition to output maximization, the DEA model can also be oriented as

$$\min f_0 = \frac{\sum_{i=1}^{m}(v_i x_{i0})}{\sum_{r=1}^{s}(u_r y_{r0})}$$

subject to:

$$\frac{\sum_{i=1}^{m}(v_i x_{ij})}{\sum_{r=1}^{s}(u_r y_{rj})} \leq 1; \quad \mathrm{j} = 1, \dots, n.$$

$$u_r, v_i \geq 0; \quad r = 1, \dots, s; \quad i = i, \dots, m.$$

DEA calculations generate actual observed estimates for each DMU and a DMU is considered efficient if it achieves a score of unity; otherwise it is considered inefficient.

CCR model is later modified by Banker, Charnes, and Cooper (BCC) which captures the efficiency implications under variable returns to scale whereas CCR uses the approach of constant returns to scale (as cited in Bhadra, 2009, p. 16; Siregar & Norsworthy, 2001). The BCC input oriented model measures the efficiency of DMU_0 by the following formula:

$$max \sum_{r=1}^{s} (u_r y_{rj} - u_0)$$

$$s.t. \sum_{i=1}^{m} (w_i x_{i0} = 1)$$

$$\sum_{r=1}^{s} (u_r y_{rj} - u_0) - \sum_{i=1}^{m} (w_i x_{ij}) \leq 0, \ j = 1,2, \dots, n$$

$$u_0, free$$

$$w_i \geq \varepsilon, \ i = 1, 2, \dots, m$$

$$u_r \geq \varepsilon, \ r = 1, 2, \dots, s$$

Where x_{ij} and y_{rj} are the inputs and outputs of the jth DMU, w_i and u_r are the output weights, x_{i0} and y_{r0} are the inputs and outputs of DMU_0 and ε is a non-Archimedean infinitesimal value for preventing weights from being zero (Toloo & Nalchigar, 2009).

5.3 Reasons for selecting input-oriented DEA model

The rationale behind the choice of a non-parametric method and DEA, in particular, as the method of the efficiency analysis of this study is provided in this section in the light of the discussions under chapter five so far.

Francis, Humphreys, and Fry (2005) draw attention to a very high utilization of benchmarking techniques by airlines through an international survey of the 200 largest amounts of passenger carriers such that 88% of the responding airlines use benchmarking for their performance improvement techniques. That is why an analysis providing benchmarking results will be meaningful to airline managers for policy implications. Due to the limitations of parametric techniques such that (i) they are not very useful in multi input/output environment, (ii) they require the imposition of a specific functional form on the data, (iii) the functional form also requires specific assumption about the error term, (iv) these techniques assume that the optimized regression equation applies to each unit (Rai, 2013), a non-parametric technique is preferred for the efficiency analysis for benchmarking. Since the non-parametric model DEA can provide benchmarking, it is appropriate to perform an efficiency analysis utilizing DEA. Additionally, DEA allows identifying the inefficient slacks of DMUs, in other words, DEA is also capable of quantifying the amount of improvement for each DMU to become efficient (Wu & Liao, 2014).

Additionally, since there is in airline industry a variety of inputs and outputs which have different units that cannot be converted to a common scale, DEA is suitable to employ in efficiency analysis of airline industry (Barros & Peypoch, 2009). Correspondingly, the model of this study has parameters with different units of measurement such as dollars, person, seat, and kilometer. Where DEA can be

applied to any industry, airline industry is chosen for its homogeneity of input and output. Besides, being a regulated industry, it is relatively easier to collect data from airline industry. The heuristic about the minimum number of DMUs is also obeyed in this study that total number of DMUs is more than five times greater than summation or multiplication of the number of inputs with the number of outputs.

Orientation selection carries importance since it leads to uses of different algorithms to determine the envelope surface and to measure the efficiency scores of DMUs and the results of DEA efficiency evaluation are explained according to the orientation selection. If one looks into the airline industry, it is seen that the dynamic and unpredictable changes such as 9/11, fuel prices, technological advances, epidemics, global market competition, mergers and acquisitions among competitors, entry of low-cost niche players make the industry unprecedented and cause challenging market realities for airlines. In the airline industry which is described as turbulent by the organizational theory due to these unfamiliar changes at accelerating rate, outputs are beyond the control of the companies and so airlines have bigger influence on inputs than outputs (Fethi et al., 2000; Joo & Fowler, 2014). Additionally, outputs are often predetermined by either long-term slot contract interests or through the relevant transport authority such that some governments expect their state-owned national airlines to operate scheduled services to specified domestic and international destinations in order to promote domestic, social or economic goals or merely to show the flag. Due to the preceding reasons, this study uses input orientation model.

CHAPTER 6

DEFINING THE SAMPLE AND THE INPUT – OUTPUT VARIABLES

This study covers the members of international strategic passenger alliances, namely Star Alliance, One World and Sky Team, for the years 2013 and 2014. As previously mentioned, Star Alliance has 28 members, Sky Team is a group of 20 airlines and One World is an alliance of 15 operators from all over the world. Although there are 63 aligned airlines in total, data availability is a major constraint in determining the sample size. Due to lack of data almost one fourth of the group is left out of this research and the analysis is conducted for 39 airlines for the years 2013 and 2014.

The sample of this study includes commercial airlines having different ownership structures (private or public), cost structures (FSC, LCC) in addition to being from any region of the world from Canada to Sri Lanka and from Slovenia to Australia.

Variable selection is a significant task which is to be logical and meaningful. To specify the input and output variables for the DEA model, the literature has been reviewed. Studies that analyze airline efficiency use the most common input variables fuel, labor force, capital and capacity whereas RPK, ASK, RTK and EBIT are frequently selected as output variables. There are also studies that chose some variables as the inputs that some studies chose as the outputs. For example, Wu and Liao (2014) use RPK as the input however Jain and Natarajan (2015), Barros and Peypoch (2009), and Alzahrani (2015) select RPK as the output. Furthermore, Barbot et al. (2008) defines both RPK and ASK as the outputs.

Lee and Worthington (2014) state that they do not include the variables such as revenue and profits as the output or expenditures or costs as the inputs in their

model since they employ production approach framework, with the exception of total assets as it is deemed to capture the capital stocks of airlines. They additionally argue that RPK and RTK heavily depend on demand-side conditions rather than being outputs of airlines. They also state that Coelli et al. (p. 17) mention the use of RTK, rather than airlines' actual flying operations, best reflects the marketing and ticketing aspects. Similarly, Bhadra (2009) criticizes Vasigh and Flemming (2005) for their use of RPM as output instead of ASM due to the fact that airlines typically have very little control over the demand side of the market which is usually represented by RPM. Furthermore, Lozano and Gutierrez (2014) use ASK and ATK as their production process outputs whereas they choose RPK and RTK as the outputs of the sales stage of their two-stage network model.

It should be noted that the results of the study are heavily dependent on the variables selected as well as their quality and reliability. Prior to defining the input and output variables, a discussion on the some of the variables selected in the literature sheds light to this determination process, keeping in mind the rule of thumb that the sum of input and output variables should not be less than one third of the number of DMUs.

6.1 Discussion on input variables

Fuel and labor generate the biggest two expenses for airlines such that first corresponds to 34 percent of airlines total operating cost in average while the latter has a share of 24 percent in airline cost of operation (Singh, 2014). Since airlines cannot have any influence on the fuel prices but only use hedging techniques to minimize risk exposure, the efficient use of fuel significantly contribute to their cost reductions and their profitability may increase in the end. In line with this fact,

engine producers and aircraft manufacturers are cooperating to produce more fuel efficient aircraft. Air business requires a dense workforce to sustain the operations with pilots, cabin crew, ground personnel, ticketing personnel, administrative staff, and technical staff both within the homeland and abroad for domestic and international operations. Aviation personnel have higher salaries in comparison with most of other sectors; however, labor force is to be efficiently utilized for the sake of increasing profitability. For these reasons, fuel and labor can be considered among the input variables of DEA models used in this study.

Employment, either as cost to the company or as the headcount, is one of the inputs that has been mostly considered in the researches so far. In this study, employee expense is not considered as the input variable due to data inconsistencies. Some airlines announce it as wages only, some others also include retire payments, incentives, benefits, medical insurance whereas some declare it as just labor expense (Aegean Airlines, n.d.; Garuda Indonesia, n.d.; United States Securities and Exchange Commission, 2015b). Since there is not a common definition of employee expenses, it is confusing and it will not allow a one to one comparison. Headcount does not have a common definition, either. While some simply provide it as number of employees; some give details such that the number excludes employees at third party carriers (Air Canada, n.d.); some others note that the number includes pilots, maintenance personnel and administrative staff (United States Securities and Exchange Commission, n.d.a). Besides, some share the data as year-end data; some state that it is year average number and some do not provide any such detail. In addition, some numbers are explained as FTE whereas sometimes there is no such clarification. Although, headcount, like employee expenses, does not have a unique definition in the annual reports of the airlines, headcount is chosen as the potential

input variable of this study instead of employee expenses and specifically year-end FTE headcount data are preferred in case the respective resources specify it. The first reason is that as Lee and Worthington (2014) defend cost and expense variables are to be avoided if the focus is the production approach. Second reason is that the number of employees is more frequently available rather than employee expenses, which enables to have a larger sample to analyze. Thirdly, labor cost differs very much from country to country and the sample includes DMUs from almost the entire world. A Chinese airline, for example, can produce more output with less employment expenses compared to its counterpart operating in the UK, ceteris paribus.

In selecting the appropriate variable for fuel, it would be more meaningful to use consumption in physical units such as liters or gallons, however due to limited availability of this type of data, fuel expense is chosen as another potential input of this study. The drawback in selecting expense instead of physical unit is again the variation in fuel definition as fuel and oil costs, fuel expenses, fuel cost and related taxes, fuel and emission cost (British Airways Plc, n.d.), fuel and hedging cost, fuel expenses net of hedging are some examples of how fuel expense is expressed by the airlines. These facts may be considered among the major limitations of this study. However, since fuel cost constitutes the biggest share in airlines expenses, it is meaningful to employ fuel cost, rather than the physical input, in order to observe the efficiency scores of airlines in the presence of fuel cost as the input variable. Since fuel cost numbers which are the only financial data in the study are in different currencies, World Bank purchasing power parities are used to convert all into US dollars for the corresponding years.

Number of aircraft is another variable that can be considered as input variable of the DEA model. Some studies use fleet size as the capital of the airlines; however, the entire fleet does not necessarily have to be owned by the airlines to be used in their flight operations. There are mainly two ways to operate aircraft within the fleet: (a) outright buying, and (b) lease. In outright buying, the operator straightforwardly purchases the aircraft from the aircraft manufacturer and that aircraft is its property from the beginning. However, in leases, airlines operate those leased aircraft for the contracted period with the lessors. In financial lease, which is the type of dry lease in which aircraft is leased without insurances, crew and maintenance cost, the operator has the option to or automatically purchase the aircraft at the expiration of the lease period. In operational lease, a second type of dry lease, lessee redelivers the aircraft to the leasing company at the end of the lease period. An aircraft with an operating lease does not appear on the balance sheet of the lessee. ACMI (Aircraft, Crew, Maintenance, Insurance) is where one operator provides an aircraft, complete crew, maintenance, and insurance to another operator, which pays by hours operated whereas damp lease is similar to ACMI; however, damp lease includes no cabin crew (Istanbul Technical University, n.d.). Additionally, aircraft prices differ as per various factors such as size, type and age. For example, Airbus list price for a narrow-body, single-aisle A320 aircraft is 97 million USD whereas it is 428 million USD for its two-deck A380-800 (www.airbus.com). So, number of the aircraft within a fleet alone cannot be a measure for the value although the entire fleet is in ownership of the operator since fleet mixes vary from airline to airline. In the light of the preceding explanations related to aircraft operations, fleet size cannot be deemed property for all airlines. Despite, they produce ASK and ATK which are products of airlines and that’s why aircraft size should better be utilized as input for efficiency

analysis. Since both owned and leased aircraft of an operator generate ASK and ATK, both lease and owned aircraft should be included in total for the input consideration. However, it is worth noticing that only the number of aircraft operated by the airline under assessment is used rather than aircraft of an airline operated by other airlines as in the case of Finnair (Finnair, n.d.). However, if the operator provides its ASK or RPK data including those coming from its aircraft operated by another operator, full aircraft number is chosen as in the case of Delta Airways capacity purchase agreement (United States Securities and Exchange Commission, n.d.b).

Average daily utilization is another key performance indicator for airlines since it affects airlines' success and profitability. It represents the average number of block hours flown per day per aircraft for an aircraft fleet (United States Securities and Exchange Commission, 2015a). Airlines may generate more ASK and ATK with higher utilization rates and hence aircraft utilization can be considered another input in airline efficiency input-output measures. However, due to lack of sufficient data, utilization is not taken as a variable of this study.

Seat capacity, in addition to fleet size, is another indicator that shows an operator's resource to produce ASK. Even in case where number of aircraft in the fleet is considered as capital and asset regardless of ownership or lease, it is more meaningful to use seat capacity instead of just simply the fleet size. Considering two airlines one with a fleet of 10 B737-800 and second with 10 B777-300ER, if only aircraft numbers are taken into account, they will have the same resources. However, Boeing list prices are 96 million USD and 340 million USD for B737-800 and B777-300ER, respectively (www.boeing.com). Accordingly, their lease prices are also very much different from each other depending on the type of lease and age of the aircraft.

So, it is misleading to simply consider number of aircraft in the fleet as an input variable. Instead, selecting seat capacity as input variable of an airline is more meaningful due to the fact that it can reflect the fleet size better both in terms of value and capacity to produce ASK. In the example of Boeing aircraft fleet, that with 10 B737-800 has a capacity of 1600 seats in average whereas other operator with 10 B777-300ER is a 3600-seat-capacity airline. Since seat capacity indicates the resource related to the fleet better than number of aircraft and it is used to produce ASK because airlines can only produce ASK by utilizing their aircraft, seat capacity is taken as the another potential input in this study. However, number of aircraft may also be included within this study to show its effect on the output.

In addition to seat capacity, cargo capacity is another indicator for airline performance assessment. However, the sample in this study consists of passenger airlines and cargo capacity information for most of the DMUs cannot be reached through publicly available data, which indicates that their main focus of airlines is passenger operations. If cargo capacity was selected as one of the input variables of this study, it would narrow the sample size down. Additionally, utilizing cargo capacity together with seat capacity would rationally require addition of ATK to ASK as the output variable since ASK only constitutes passenger volume; however, ATK takes into account both passenger and cargo, which is not appropriate for the reasons discussed within this chapter. So, cargo capacity is not selected as an input variable of this study.

Seat per aircraft which can be obtained dividing seat capacity by the number of aircraft operated is another parameter that can be considered within the set of input variables. Seat per aircraft shows an aircraft of an airlines has how many seats in average within each of its aircraft. This parameter is significantly related with the

fleet characteristics of an airline due to the fact that it implies how big aircraft, i.e., narrow-body or wide-body, are included in the fleet.

Number of destinations is regarded as another performance indicator of airlines since it has influence on input-output efficiency. Number of destinations is alternatively defined as number of countries or cities flown. Destinations refer to airports flown which may be more than one within a city or a country. So, the input value of an airline reporting the countries or cities flown may be lower than that of announcing the destinations flown, in fact, the reverse might be the case in reality. If a common language existed in number of destinations, it could be used as input to observe its impact on output. However, under these conditions number of destinations is not used as an input variable of this research.

6.2 Discussion on output variables

Once inputs are defined, outputs are to be identified in a consistent manner with input selection. ASK and ATK are most common output variables used by many researches. In line with many previous studies, ASK is identified as the output of this research due to the following reasons. First, by definition, ASK is mostly considered as the output of airlines, in other words airlines produce ASK by utilizing their resources. Although ATK is another output measure which is for carriage of both passenger and cargo, since ASK data can be obtained for more airlines, ASK is used as the output in this study for the sake of a big sample size. Additionally, an important portion of those reporting their ATK include only cargo load in their definitions. Furthermore, ATK could be more appropriate to use as the output if cargo capacity was also selected as the input of this research in addition to seat capacity. To support this, the biggest portion of airlines' revenues comes from

passenger operations. For example, 78% of Air France KLM group's revenue belongs to passenger business whereas only 9% is the result of cargo transportation (Air France KLM, n.d.). However, in any way, one should choose either ASK or ATK instead of using them together since ATK already incorporates passenger and cargo capacity flown even in units of tones. Otherwise, it will create double-counting as an obstacle to obtain more accurate results. ASK data sometimes are available in unit of miles, ASM, especially for airlines of the continental America, which are to be converted to ASK to obtain uniform measures.[7]

Similar to ASK, RPK is another variable worth discussing. In essence, RPK can be thought as sold ASK which is ticketed. So, although there are some who argues it is an output of an airline (Belobaba, Odoni, & Barnhart, 2015) some criticize that RPK cannot be used in production efficiency approach since it reflects the marketing efficiency. RPK was also selected as one of the outputs of this research because although it represents the demand side rather than the capacity produced, it is a measure of traffic which also includes the capacity inside. In other words, it does not show only marketing strength; however, airlines use it to demonstrate their market position together with their capacity. Due to the similar reasons discussed in ATK/ASK paragraph above, RPK is used instead of RTK[8].

Airlines have the objective to achieve the load factors to the highest extent possible in order to convert their supply, ASK, into revenue by means of RPK. Since load factor, which can be classified as passenger load factor, cargo load factor and overall load factor, is highly related with airline traffic by definition, it is considered within the output variables.

[7] In order to convert ASM into ASK, ASM numbers are multiplied by 1.852.
[8] RPMs, where available, are converted to RPKs through multiplication with 1.852 for the sake of uniform units of measure.

6.3 Data collection

All data required for the empirical analyses are publicly available and are collected through the annual reports, financial statements, business reports, web pages of the companies or respective alliances, as well as, CAPA and IATA web sites. Data for some group companies are individually available whereas only consolidated data are provided within company reports for some group companies. A Star Alliance member Air China, for example, is operating under the roof of Air China Group which also has Air China Cargo, Shenzhen Airlines, Air Macau, Dalian Airlines and Air China Inner Mongolia within the group. Due to the fact that the only data available in the report is for the group rather than Air China individually, the group data are used in the analyses. Similarly, Air New Zealand, All Nippon Airways (ANA), Avianca, Copa Airlines, Scandinavian Airlines, Singapore Airlines, British Airways, Qantas, Aero Mexico and Garuda Indonesia all provide group data so that their results are for the parent company rather than the direct member of the alliance.

On the contrary, the company data are picked instead of group data, if available, as in the case of Egypt Air, Sri Lankan Airlines, Kenya Airways, and Turkish Airlines. Egypt Air consists of Egypt Airlines, Egypt Air Cargo and Egypt Air Express in addition to its medical services and tourism divisions and Turkish Airlines has a low-cost subsidiary Anadolu Jet. Since Egypt Air and Turkish Airlines, Inc. have their mainline company data separately, namely Egypt Airlines and Turkish Airlines, the individual company data are used instead of group data. Some reports include both company data and consolidated group data for some variables as in the report of Air China where number of employees and fleet size exist both for the company and the group that consists of other subsidiary airlines. Since the output variables ASK and RPK are only provided for the group in an

aggregate form, all variables including also number of employees and fleet size are selected for these groups in order not to cause a bias due to the scale inconsistency. If the company data are used for inputs which are logically less than the group data and group data are selected for the outputs which are reasonably greater than the company data, then it could misleadingly have greater efficiency scores. Similarly, although Aero Mexico shares its company headcount, since the rest of the figures of variables are reported for the group including Aero Mexico and the regional airline Aero Mexico Connect, group headcount is selected for the analysis[9]. In contrast, Air France KLM Group announces its employee number in aggregate for Air France, KLM, Hop Airlines and Transavia Airline in its annual report (Air France KLM, n.d.) and for this reason fleet size and other operational statistics for these four airlines group are chosen. Aegean Airlines merged with Olympic Airlines in October 2013 and hence in order not to cause any distortion in the data, 2013 year data is collected for Aegean Airlines in a separate form, not consolidated manner thanks to the fact that the company report allows to reach both consolidated and separate data. However, since they operate together after October 2013, data for 2014 year analyses are selected in a consolidated form. Similarly, American Airlines merged with US Airways in December 2013 (United States Securities and Exchange Commission, n.d.a), which has lead inclusion of consolidated data for the year 2014 but individual data of American Airlines for assessment of 2013. In another case, since it was not so much possible to define what operational data belong to Garuda Indonesia or Citilink, its merger in September 2013, individually, in the annual report, consolidated data have been taken for the analysis of the year 2013.

[9] Aero Mexico company headcount is 6,133 whereas it is 12,910 for the group including Aero Mexico and Aero Mexico Connect (Grupo Aeromexico, n.d.).

Another issue arising is that although these companies' main business is air transport they may be also engaged in different areas such as travelling agencies and trading companies under their parent companies and when data for the group are shared in their reports, it may include figures for other than air business. However, there are ways to eliminate this inappropriateness as in the case of ANA that separates its air transport division data within its group statistics. Besides, some data, although titled as group data can only be air transport figures by nature. ASK, fuel expenses or number of aircraft operated, for instance, can only come from air transport business but not from a separate IT business or hotel division organized under the roof of a group. Similarly, although South African Airlines (SAA) reports its fuel cost under the title of group cost, fuel can only be used by its air business divisions like SAA, SAA Cargo and low-cost carrier Mango Airlines but not by the catering division or the travel center which are also organized under the group. Another example is Thai Airways which presents the costs and expenses for the group including the subsidiaries. However, since fuel and oil can only be used by those operating aircraft or at least the majority of it has to rationally come from jet fuel, 79,231 million Baht is totally taken as Thai Airways expense (Thai Airways International, n.d.). Finnair, as another case, states in its annual report that the data are consolidated including travel agencies. However, since other data such as ASK, fuel cost and fleet size do not include any amount from travel agencies by definition, air business personnel is selected for efficiency analysis instead of the group data, which are 3,734 and 4,461, respectively (Finnair, n.d.)[10]. Fuel costs are collected as originally announced by the airlines or obtained through aviation websites such as CAPA or IATA.

[10] Finnair's total number of employees including part-time and full time is 3,772; however, it is reported that 99 per cent is working full time. So, FTE is calculated as 99 percent of 3,772, corresponding to 3,734.

Additionally, companies' financial year dates may differ from each other and they do not have to be necessarily the same such that ANA issues reports as per its financial year statistics of March 31, however, Ethiopian Airlines provides statistics for its year-end on June 30 and Thai Airways shares its operational figures for December 31. This study aims to take calendar years as basis instead of individual financial year performances of sample airlines. So, in this regard, data are chosen according to the dates to reflect the calendar years of evaluation 2013 and 2014 to the most extent possible. For example, statistics in 31 March 2015 dated ANA report are utilized for assessment of performance in 2014 instead of 31 March 2014 dated report because the first covers the calendar year 2014 more than the latter. However, on the other hand, 30 June 2014 dated reports of Air New Zealand and Qantas are reviewed for operational figures to employ for 2014 year DEA analysis due to the fact that they are located in the Southern Hemisphere where the heavy traffic of summer time is enjoyed within the first half of the year which already captures most of the traffic in 2014. In addition, in some cases due to lack of current data, June 2014 dated report has been accepted for 2014 year data and similarly June 2013 report has been taken basis for 2013 year analyses as for Egypt Airlines and Ethiopian Airlines although they are located in Northern Hemisphere and June 2014 data cannot cover the majority of the operations in calendar year 2014. Similarly, due to lack of 31 March 2015 dated annual report, report of 31 Mar 2014 has been used for South Africa Airlines for the year 2014.

Another obstacle to tackle with during data collection phase is that sometimes the data cannot be directly reached from the report or company website. In these cases, some figures, numbers or assumptions facilitated the access to reach the missing data. For example, Ethiopian Airlines states in its 2013 year report that it has

58 aircraft (Ethiopian Airlines, n.d.a); however it does not report the fleet size for the year 2014 within its next year report. Instead, it notes the phased-in and phased-out aircraft with their type and quantity information (Ethiopian Airlines, n.d.b). One can reach from this information that within 2014 year 11 passenger aircraft and one freighter, in total, are phased-in. So, fleet size of Ethiopian for the year 2014 is obtained by adding 12 aircraft to its 2013 year fleet which gives 70 aircraft in the end. Again for Ethiopian airlines, the only employee figures are about recurrent trainee and new basic trainee rather than total number of employees. Since most of the time an employee does not take the same type recurrent training within the same year and new basic trainings are held for fresh members of the company, they are summed to reach the total number of employees, with an assumption that one employee takes only one type of recurrent training and new basic training. This assumption can be validated such that the total number becomes 9,166 where Star Alliance reports the employee number of Ethiopian Airlines in its website updated as of August 2015 as 8,678 (www.staralliance.com). This corresponds to 5 percent difference and shows that the real number does not so much deviate from estimated 9,166. Another missing datum is again the number of employees but this time of Egypt Airlines. Only the employee expenses are available in Egypt Airlines report whereas the study utilizes headcount. Star Airlines gives the information in its website updated as of December 2014 that Egyptair is a 9,000-employee company (www.staralliance.com). However, in 2014 year annual report, Egyptair salary figures are provided for Egyptair and Egyptair Airlines separately (Egyptair Airlines, n.d.). The ratio between the salary expenses is assumed to give the ratio of employee numbers of Egypt Air and Egypt Airlines and the figure 3,443 is reached for Egypt Airlines 2014 year headcount. Another calculation is made for Cathay Pacific to

reach its 2014 year RPK value while Cathay Pacific only shares ASK and load factor information in its report. Since RPK is the product of ASK and load factor, once these two variables are already available, RPK is estimated multiplying these figures with each other[11]. A Lufthansa Group airline, Austrian Airlines, does not share its fuel cost in its annual report. However, Lufthansa states in its 2014 year report that 21.5% of its total operating cost corresponds to fuel cost (Lufthansa Group, n.d.). This ratio is taken basis for Austrian, as well, with the assumption that it conducts the operations at the same cost structure and hence Austrian's 2014 year fuel cost is calculated as 465.3 million EUR given that its total operating expense is 2,164 million EUR (Austrian Airlines, n.d.). ASK and RPK values for Royal Jordanian are determined from the graph presented in its 2014 year annual report while there are no numbers provided (Royal Jordanian Airlines, n.d.).

Another point of attention is that the homogeneity is to be achieved to the highest degree possible. Although Duygun, Prior, Shaban, and Tortosa-Ausina (2016) use another method for utilization of data such that they take the average of the number of aircraft at the beginning and at the end of the year to calculate their input variable flight asset instead of taking year-end data. On the contrary, most studies in literature have used these year-end data for efficiency analyses. In this sense, year-end data are used in this search. However, sometimes companies announce their average year data. In such cases, since the remarkable quantity of the data belongs to the year-end statistics, numbers for the end of the year are selected in these cases, if possible. For example, 30,191 is taken as the headcount for efficiency measures while KLM shares its average-year headcount together with year-end numbers which are 30,711 and 30,191, respectively (KLM, n.d.). However, although

[11] 2014 year ASK for Cathay Pacific is 134,711 million and the corresponding load factor is 83.3 percent (Cathay Pacific Annual Report 2014, p. 2) where RPK equals to 134,711 x 83,3% which gives 112,214 million.

average numbers are avoided for the sake of data collection for the end of the year, since the date of the data published depends on the fiscal year periods of the respective companies which may be any date within the year as per the company policy, it does not mean that the figures collected always represent numbers belonging to 31 December.

Another notable issue is that some of the alliance members are subsidiaries of other members such that Xiamen Airlines within China Southern, Austrian and Swiss airlines within Lufthansa Group, KLM and Air France under the roof of Air France KLM and LAN Airlines exist within LATAM Airlines. Therefore, if there are not enough separate data for these airlines to conduct the efficiency analysis, they are not individually included in the measurement phase as Xiamen Airlines, Air France, LAN and Swiss Airlines. However, KLM and Austrian can be individually included in the analyses although they also exist in the measurements within the groups of Air France KLM and Lufthansa Passenger Airline Group. Delta Airlines, as another case, issues the operational numbers such as ASK, RPK, fleet size and fuel expenses for consolidated results including mainline airline and regional airlines under capacity purchase agreements whereas its headcount does only include mainline airline but not those regional airlines. Delta makes capacity purchase agreements at least for 10-year periods with regional carriers under which Delta controls the scheduling, pricing, ticketing, reservations and seat inventories for their flights operating on behalf of Delta under DL designator code, which Delta is entitled to cargo, mail, ticket and in-flight revenues associated with these flights in expense of some amount to pay as per the agreement (United States Securities and Exchange Commission, n.d.b). Since the focus in this study is not financial efficiency, Delta's data are considered appropriate for the analyses despite the fact that Delta does not count the

number of employees of those regional airlines, because Delta already pays for these capacity purchase agreements which affect its financial figures rather than input-output efficiency analyzed here.

The explanations about data selection so far are for 2014 year data. Similar assumptions and calculations are also valid for 2013 year data in cases where data cannot be reached directly through annual or financial reports or the websites. The data characteristics of the airlines for the year 2014 are also summarized, it is shown whether they are individual company data or the group statistics and the dates they are reported for are provided (see Appendix A).

The analysis of year 2013 is included separately since the year of data change and companies under the some airlines may differ as in the case of American Airlines which merged with US Airways in December 2013. Another point to note is that although Sri Lankan and Tam Airlines joined Sky Team in 2014, they are included in 2013 year evaluation to compare their efficiency scores just before and after entry into an alliance despite DEA provides relative efficiency measures rather than absolute efficiency scores (see Appendix A).

Data for seat capacity which shows an airline resource to for their production are collected through the annual reports, financial reports, websites of the respective companies or other aviation websites such as CAPA, IATA or newspapers for the relevant date. Likewise the path taken for headcount, year-end data are chosen instead of year-average data, where possible. Some operators like Turkish Airlines (Turkish Airlines, n.d.c) and Aegean Airlines (Aegean Airlines, n.d.) report their seat capacities as Arabic numbers in their annual reports. For such airlines, it is easier since seat capacity is simply the figure reported. However, for those who do not share such data, which is generally the case, seat capacities are calculated with the

help of their fleet mix information. The initial discussion of seat capacity calculations is about Finnair. It includes its fleet size and fleet mix data together with average seat capacities for each type of aircraft in its annual report (Finnair, n.d.). Since it does not share the total seat capacity, it is calculated as total sum of multiplications of the number of aircraft with its seating capacity. For example, Finnair has 10 A320 with a seating capacity of 165 per each. Then, Finnair's seating capacity for A320 fleet is 1,650. Similarly, it has 9 A319 with average seating capacity 138 which gives 1,242 seats in total. However, depending on the configuration, sometimes airlines share more than one figure as seating capacities such that Finnair gives 297, 271 and 263 as its seating capacities for its A330 aircraft. In such case, the arithmetic average has been taken as the valid seat capacity which equals 277. Then, the number of that type of aircraft is multiplied with this estimated average seat capacity, i.e., 277 is multiplied by 8, to get 2,216 seats for Finnair's A330 fleet. The overall fleet's seating capacity is calculated in this way and the number 9,222 is reached in the end. Another example is faced for airlines which only publish their fleet mix without seat capacity data in its annual reports. Ethiopian Airlines, for instance, only shares the numbers for each type of aircraft in its fleet. In order to calculate seat capacity of Ethiopian airlines, in addition to its annual report, its website has been visited because airlines generally publish their fleet information in their websites with the seat configurations and capacities. Ethiopian has, for example, 13 Q400 aircraft according to its annual report 2013 and in its website Q400 has 71 seating capacity. So, the multiplication of 13 and 71 is to give the seat capacity for Ethiopian's Q400 fleet. The overall seat capacity of Ethiopian Airlines is the summation of each sub-fleet's capacity calculated in the same way.

There exist also airlines with missing seat capacity information either for the entire fleet or for each aircraft type. For these cases, first a matrix for each aircraft type and operator is prepared as an Excel sheet which designates which aircraft type has what real seating capacities and the arithmetic average is taken for each type. For example, average seating capacity for A320 aircraft is 158, which is estimated as the average of seat capacity information collected through the annual reports of airlines such as Air New Zealand, Avianca, Croatia, Scandinavian, United, American, Finnair, Latam, Aeroflot, Air France, Alitalia, China Southern, Garuda Indonesia and Air Canada. Then, these average numbers for each type of aircraft is used as the seating capacity of airlines such as Thai Airways for A320, Kenya Airways for E170 and for the whole fleet seating capacity of Air China. Instead of taking the sample average with the existing data in the beginning to compensate the missing seat capacity data of the rest of the sample, data of aircraft manufacturers such as Airbus, Boeing, Bombardier or Embraer might be used. However, since these numbers designate maximum capacity, it cannot not reflect the real situation since seating capacity for a type changes from airline to airline according to the configuration although it is hard to mention very high deviation. However, where an average number cannot be reached due to lack of data, the manufacturer's number is used as for MD-11 aircraft of Aeroflot and KLM, which are 323 (Boeing Commercial Airplanes, 2011). An assumption utilized through seat capacity calculation is that if only the model of aircraft can be known for an airline instead of the type, then it is assumed that airline has equal quantities of each type. For example, Air China reports that it has 40 A319 in its fleet. Since the Excel sheet created has two types of A319, namely A319-200 and A319-100, it is assumed that Air China has 20 A319-200 and 20 A319-100 while seat capacity estimations are performed. Lufthansa

(LH), conversely, informs in its website that seat capacities for A340-400 and A340-600 are 221 and 306, respectively. However, there is quantity information for only its A340 model without designating the type, which is 42 for 2014. Then, it is assumed that LH has 21 A340-400 and 21 A340-600 to determine the total seat capacity. Same similar assumptions and calculations for 2013 and 2014 are also made for other airlines, where necessary.

CHAPTER 7

EMPIRICAL RESULTS

In this study, efficiencies of the international passenger airlines are measured using data envelopment analysis for the years 2013 and 2014, which are two successive years when declines in world oil prices started and deepened after the peak in 2012, with two different assumptions (CRS and VRS) and one orientation (input oriented) through utilization of Banxia Frontier Analyst 4. The analysis is not performed for the year 2015 due to the fact that companies' fiscal years differ and most of the airlines under consideration have not shared their financial and operational data for 2015 with the public during the course of this study.

In addition to standard efficiency analyses, super-efficiency model is also applied in order to be able to increase the discriminative power of DEA to rank the airlines as per their efficiency scores and determine the best performing one(s) while, otherwise, DEA results would simply show the efficient ones without analyzing the efficient ones in further detail. Application of super-efficiency removes the need for bootstrapping because it allows identifying the best performing airlines.

Previously determined input and output variables are used within various combinations in order to differentiate between efficient and inefficient airlines; to interpret the sensitivity of the results to different variables, to assess the impact of variables on the efficiency results; to detect the improvement opportunities for airlines. Results are analyzed using six different models of DEA where in each model a variable changed, ceteris paribus.

The sample in this study consists of passenger airlines and their main business areas are passenger transportation although a majority deals with cargo

operations as well in relatively smaller volumes. Since air cargo companies such as DHL or Fedex are not included in this study, negligence of cargo capacities does not create under- or overestimation of efficiencies. Additionally, as previously emphasized in this research, the sample which is large enough is essential to reach accurate results. Cargo related parameters for most of the DMUs cannot be reached through publicly available data, which proves that their main focus is passenger operations, and so if any cargo related parameter, cargo capacity for example, was selected as one of the input variables of this study; it would narrow the sample size down.

The data sample consists of 39 DMUs which is used for all combinations for 2014 (see Appendix B). Although Sri Lankan Airlines and Tam Airlines have joined One World in 2014, they are included in 2013 year measures in order to observe their relative efficiency scores and ranks just after the joining.

Table 4 provides descriptive statistics of the variables that are intended to be used in the DEA model for the sample of 39 DMUs relative to the year 2014, including average, maximum and minimum values. According to Table 4, the sample has an average fuel expense of almost 4 billion USD for 2014 with an average headcount of about thirty thousand employees where more than 119 billion ASK and 102 billion RPK are produced.

Table 4. Descriptive Statistics of the Sample of 39 DMUs as per the Year 2014

Variable	Max	Min	Average
Number of Employees	94,666	421	27,391
Fuel Cost (mUSD)	13,512	74	3,880
Seat Capacities	168,474	1,380	47,003
Number of Operative Aircraft	1,271	12	274
Number of Operative PAX Aircraft	1,271	12	270
ASK (m)	455,630	1,938	115,816
RPK (m)	439,890	1,342	99,692
Load Factor (%)	86.50	63.00	77.84
PAX Volume (m)	145.57	1.82	40.92
Number of Seats per Aircraft	310.28	112.71	176.41
Number of Seats per PAX Aircraft	310.28	115.00	181.26

Prior to proceeding with the efficiency analysis, it is vital to understand whether the inputs and the outputs are the right variables for the analysis performed and whether they really have impact on efficiency scores and hence to distinguish those to be removed from the analysis. Although there have been numerous researches on the technical efficiency of airlines so far; they do not include any discussion on the correlation among variables. If the inputs are highly correlated with each other, this implies that they may represent the same basic data, and as a result, one of these variables can potentially be removed from the assessment to increase the discrimination in the analysis. The remaining variables can be used in the DEA model to assess the impact of this action on efficiency score. An acceptable level of correlation can be defined heuristically. Generally, correlation above 0.80 is accepted as high correlation. The closer the correlation is to 1.00 the more likely it is that a change in the value of one variable has impact on the other variable either positively

or negatively. A high correlation between a variable and efficiency reveals that the variable is a key driver of efficiency and it carries significance.

Variables that have been used commonly in airline efficiency analyses in the literature are headcount, fuel, seat capacity, seat per aircraft, passenger volume, ASK and RPK. Similarly these variables are considered as the potential indicators for this study. Headcount, fuel cost, seat capacity, seat per aircraft, seat per passenger aircraft, total number of operative aircraft, total number of passenger aircraft are defined to be the potential inputs and ASK, RPK, passenger volume carried, and load factor are selected as the potential outputs. Results of the correlation analyses conducted for this study shows that most of the inputs are highly correlated as shown in Table 5. The correlation analysis results imply that if there is high correlation between two variables then they reflect the same phenomena. So, on contrary to many previous studies using at least two of fuel, headcount, seat capacity and number of aircraft in the fleet for their analysis, using any two of these variables simultaneously may have the effect of double-counting and decrease the reliability of the results. The correlation results of number of operative aircraft or number of operative passenger aircraft, specifically, are observed to be the same likewise seat per aircraft and seat per passenger aircraft. Although the main focus of the DMUs is most of the time passenger business, there are some operators having cargo aircraft. Therefore, total number of aircraft and total number of passenger aircraft like seat per aircraft and seat per passenger aircraft have been deemed separate variables, however, the correlation results reveal that selecting total number of aircraft or total number of passenger aircraft, and seat per aircraft or seat per passenger aircraft are expected to give similar results. Besides, since the focus of the assessment is passenger business, seat per passenger aircraft is selected as the input.

Table 5. Correlation Matrix for Input Variables

	Headcount	Fuel Cost	Seat Capacity	Number of AC	Number of PAX AC	Seat per AC	Seat per PAX AC
Headcount	1.00	0.90	0.93	0.88	0.88	-0.08	-0.08
Fuel Cost	0.90	1.00	0.93	0.90	0.90	0.05	0.05
Seat Capacity	0.93	0.93	1.00	0.97	0.97	-0.06	-0.08
Number of AC	0.89	0.90	0.97	1.00	1.00	-0.21	-0.23
NR of PAX AC	0.88	0.90	0.97	1.00	1.00	-0.22	-0.23
Seat per AC	-0.08	0.05	-0.06	-0.21	-0.22	1.00	0.98
Seat per PAX AC	-0.08	0.05	-0.08	-0.23	-0.23	0.98	1.00

Table 6 provides correlation results for the variables considered best appropriate to be output variables ASK, RPK, load factor and passenger volume. It is observed that passenger volume, ASK and RPK are highly correlated with each other and one should choose only one of these variables as the output of the efficiency analysis. However, passenger load factor is not highly correlated with other variables.

Table 6. Correlation Matrix for Output Variables

Variable	ASK	RPK	PAX Load Factor	Passenger Volume
ASK	1.00	0.99	0.46	0.95
RPK	0.99	1.00	0.46	0.94
PAX Load Factor	0.46	0.46	1.00	0.43
Passenger Volume	0.95	0.94	0.43	1.00

The analysis hereinafter is designed as per the correlation results for six different combinations of variables. Seat per passenger aircraft is used as an input in all models along with either passenger seat capacity or fuel cost. However, in model 5 and model 6, fuel cost and passenger seat capacity are used together as the input variables in order to observe how employing two highly correlated variables affect the results. Table 7 demonstrates the inputs and outputs for each of six models.

Table 7. Input and Output Combinations for the DEA

Model	Inputs	Outputs
Model 1	Fuel cost, seat per PAX aircraft	RPK
Model 2	Fuel cost, seat per PAX aircraft	ASK, PAX load factor
Model 3	Seat capacity, seat per PAX aircraft	RPK
Model 4	Seat capacity, seat per PAX aircraft	ASK, PAX load factor
Model 5	Fuel cost, seat capacity, seat per PAX aircraft	RPK
Model 6	Fuel cost, seat capacity, seat per PAX aircraft	ASK, PAX load factor

In order to present a sample process diagram for these six models, model 4 was selected and reflected in Figure 13 with its inputs and outputs. Accordingly, model 4 is a process that converts seat capacity and seat per passenger aircraft into passenger load factor and ASK.

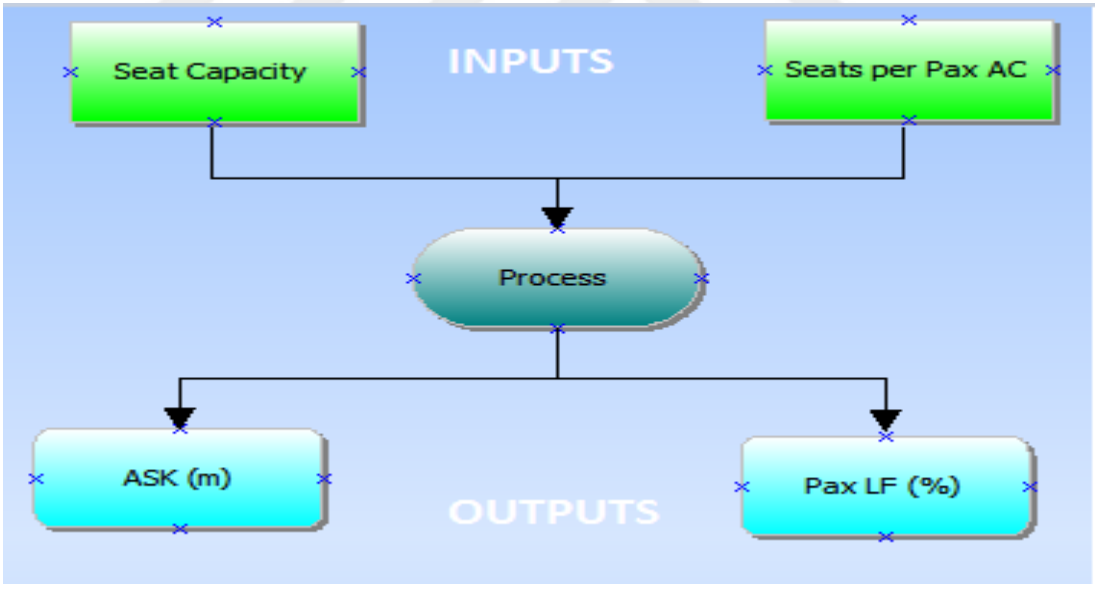

Figure 13. Process diagram for model 4

Efficiency analysis for the sample of 39 aligned airlines is performed for both BCC and CCR models in order to be able to compare the results with each other under variable returns (VRS) and constant returns (CRS) to scale conditions, respectively. Standard efficiency and super efficiency results are separately monitored. The

models are set to demonstrate those below the efficiency score of 90 as inefficient DMUs and those between 90 and 100 are called near-efficient DMUs. Efficiency analysis results for CCR specification generated according to the standard efficiency calculations are presented in Table 8.

Table 8. Standard Efficiency Scores for Six Models under CCR conditions

Alliance	Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Average
OW	Air berlin	95,70	97,63	49,76	49,39	95,70	97,63	80,97
	American	100,00	100,00	100,00	92,60	100,00	100,00	98,77
	British	80,97	79,65	95,49	85,64	97,19	85,91	87,48
	Cathay Pacific	45,62	44,36	100,00	87,63	100,00	87,63	77,54
	Finnair	95,45	100,00	100,00	95,91	100,00	100,00	98,56
	Japan	68,80	70,21	72,81	67,18	75,97	70,88	70,98
	Qantas	100,00	100,00	93,69	84,31	100,00	100,00	96,33
	Royal Jordanian	31,06	69,69	80,08	90,48	80,08	90,55	73,66
	SriLankan	29,24	57,54	100,00	100,00	100,00	100,00	81,13
	Tam	67,24	66,24	80,42	72,72	81,51	72,72	73,48
	OW AVG	71,41	78,53	87,23	82,59	93,05	90,53	83,89
SA	Aegean	58,35	90,19	41,61	89,22	58,35	90,19	71,32
	Air Canada	86,10	100,00	92,22	100,00	93,76	100,00	95,35
	Air China	40,17	68,48	63,32	72,47	63,32	72,47	63,37
	Air New Zealand	79,33	100,00	66,95	98,58	79,33	100,00	87,37
	Ana	46,71	69,16	51,01	67,15	52,79	71,21	59,67
	Austrian	69,45	94,65	56,01	89,03	69,45	94,65	78,87
	Avianca	49,13	98,15	50,36	96,80	53,16	98,15	74,29
	Copa	72,82	98,70	72,34	95,76	75,98	100,00	85,93
	Croatia	36,63	100,00	27,31	100,00	36,68	100,00	66,77
	Egypt Airlines	22,00	49,31	70,86	53,25	70,86	53,25	53,26
	Ethiopian	19,15	71,18	79,28	100,00	79,28	100,00	74,82
	Lufthansa PAX Group	65,39	80,85	73,42	84,13	73,55	84,13	76,91
	Scandinavian	73,43	98,25	52,42	73,70	73,43	98,25	78,25
	Singapore	50,65	64,68	94,99	100,00	95,45	100,00	84,30
	South African	26,70	58,76	68,70	85,28	68,70	85,54	65,61
	Thai	20,06	34,90	64,42	78,76	64,42	78,76	56,89
	Turkish	41,01	60,48	77,84	88,15	77,84	88,15	72,25
	United	100,00	100,00	100,00	100,00	100,00	100,00	100,00
	SA AVG	53,17	79,87	66,84	87,35	71,46	89,71	74,73
ST	Aeroflot	37,90	62,05	78,47	91,28	78,83	91,28	73,30
	Aeromexico	38,58	100,00	63,42	100,00	64,45	100,00	77,74
	Air Europa	65,23	83,81	81,60	99,66	81,60	100,00	85,32
	Air France-KLM Group	75,66	87,82	87,76	94,38	87,96	94,38	87,99
	China Eastern	37,55	70,52	57,89	70,52	57,89	70,52	60,82
	China Southern	39,96	70,21	60,89	70,35	60,89	70,35	62,11
	Delta	93,58	95,90	93,58	95,90	93,58	95,90	94,74
	Garuda Indonesia	46,79	67,57	42,17	63,07	46,87	67,57	55,67
	Kenya	20,74	58,17	35,17	64,01	35,17	64,01	46,21
	KLM	57,76	68,77	87,05	91,52	88,82	91,63	80,93
	Korean Air	37,69	51,46	72,09	83,78	72,60	83,81	66,91
	ST AVG	50,13	74,21	69,10	84,04	69,88	84,50	71,98
	Overall AVG	58,24	77,54	74,39	84,66	78,13	88,25	76,87

The results of four models are first discussed prior to the last two models through which the effects of adding a correlated input on the efficiency results will be analyzed. It is observed from the results that average efficiency scores are lowest for all alliances for model 1 where fuel cost and seat per passenger aircraft are used as the inputs and RPK is the output. However, while fuel cost is replaced by passenger seat capacity in model 3, the efficiency scores get higher such that it goes up to 87.23 for One World from 71.41 and 66.84 for Star Alliance from 53.17. This result might reveal the fact that airlines pay notable amounts of fuel cost for their operations. Amount of fuel cost, apart from the external factors as global fuel prices, is significantly related to the frequency of flights, fleet mix, age of fleet, and local prices of fuel due to taxes. When number of efficient DMUs is compared for the two aforementioned models, it is also seen from Table 9 and Table 10 that the number of efficient DMUs is greater in model 3 than that in model 1 and using fuel in place of seat capacity increases total number of inefficient DMUs. The total efficient number of DMUs is three in model 1 while it becomes 5 in model 4 and it is 33 for the first model whereas it decreases to 29 for the latter. This also shows that One World is the alliance that is affected most in terms of efficient-inefficient DMU distribution, which may imply that One World pays higher for fuel in production of RPK compared to its competitors Star Alliance and Sky Team for the same seat capacity. Cathay Pacific, Finnair and SriLankan Airlines from One World becomes efficient in the use of seat capacity despite they are found inefficient in the presence of fuel. In contrast, Qantas is measured inefficient in model 2 while it scores efficient if fuel cost is employed as the input variable. The same phenomena shows up comparing the results of model 2 and model 4 that average scores for model 4 that use seat capacity instead of fuel to produce ASK and load factor are higher than model 2

where fuel cost is used. The overall average of model 2 is 77.54 whereas it is 84.66 for model 4. However, in this comparison, no DMU is observed to upgrade to efficient status from non-efficient status. On contrast to increasing average efficiency scores, total number of efficient DMUs decrease by one, from eight to seven. On the other hand, number of inefficient DMUs decrease and become near-efficient, but not efficient. Results after addition of third inputs, to have three input-models, are discussed for models 2, 4 and 6, and for models 1, 3 and 5. It is observed that adding the third input, namely fuel, which is highly correlated with seat capacity increases the average efficiency scores. All alliances' average efficiency scores are higher for three-input models. Number of efficient DMUs increases from model 2 to model 6 while number of inefficient DMUs decreases at the same time.

Table 9. Number of DMUs with Respect to Their Standard Efficiency Scores under CCR Conditions

Result	Alliance	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	2	3	4	1	5	4
	SA	1	4	1	5	1	7
	ST	0	1	0	1	0	2
Near-Efficient	OW	2	1	2	3	2	2
	SA	0	5	2	3	2	4
	ST	1	1	1	5	1	4
Inefficient	OW	6	6	4	6	3	4
	SA	17	9	15	10	15	7
	ST	10	9	10	5	10	5

.

Table 10. Percentage of DMUs with Respect to Their Standard Efficiency Scores under CCR Conditions

Result	Alliance	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	20	30	40	10	50	40
	SA	6	22	6	28	6	39
	ST	0	9	0	9	0	18
Near-Efficient	OW	20	10	20	30	20	20
	SA	0	28	11	17	11	22
	ST	9	9	9	45	9	36
Inefficient	OW	60	60	40	60	30	40
	SA	94	50	83	56	83	39
	ST	91	82	91	45	91	45

Since super efficiency further compares efficient DMUs in order to determine the most efficient one, average efficiency scores are higher in super efficiency analysis. However, as shown in Tables 11, 12 and 13 super efficiency analysis does not change the scores of non-efficient DMUs and accordingly it does not change efficiency status of any DMU with respect to standard efficiency calculations as expected. American Airways for model 1, Croatia Airlines for models 2, 4 and 6, United Airlines for model 3 and Finnair for model 5 and SriLankan Airlines for model 6 are identified as the super-efficient airlines of the analysis under CRS conditions.

Table 11. Super Efficiency Scores for Six Models under CCR conditions

Alliance	Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Average
OW	Air berlin	95.70	97.63	49.76	49.39	95.70	97.63	80.97
	American	121.25	102.89	110.62	92.60	121.25	102.89	108.58
	British	80.97	79.65	95.49	85.64	97.19	85.91	87.48
	Cathay Pacific	45.62	44.36	103.92	87.63	103.92	87.63	78.85
	Finnair	95.45	100.40	104.84	95.91	123.02	109.89	104.92
	Japan	68.80	70.21	72.81	67.18	75.97	70.88	70.98
	Qantas	118.73	103.46	93.69	84.31	116.37	103.46	103.34
	Royal Jordanian	31.06	69.69	80.08	90.48	80.08	90.55	73.66
	Srilankan	29.24	57.54	106.32	115.92	106.32	115.92	88.54
	Tam	67.24	66.24	80.42	72.72	81.51	72.72	73.48
	OW AVG	75.41	79.21	89.80	84.18	100.13	93.75	87.08
SA	Aegean	58.35	90.19	41.61	89.22	58.35	90.19	71.32
	Air Canada	86.10	113.01	92.22	108.59	93.76	113.57	101.21
	Air China	40.17	68.48	63.32	72.47	63.32	72.47	63.37
	Air New Zealand	79.33	104.36	66.95	98.58	79.33	104.36	88.82
	Ana	46.71	69.16	51.01	67.15	52.79	71.21	59.67
	Austrian	69.45	94.65	56.01	89.03	69.45	94.65	78.87
	Avianca	49.13	98.15	50.36	96.80	53.16	98.15	74.29
	Copa	72.82	98.70	72.34	95.76	75.98	100.44	86.01
	Croatia	36.63	708.85	27.31	284.37	36.68	708.85	300.45
	Egyptair Airlines	22.00	49.31	70.86	53.25	70.86	53.25	53.26
	Ethiopian	19.15	71.18	79.28	102.42	79.28	102.42	75.62
	LH PAX Group	65.39	80.85	73.42	84.13	73.55	84.13	76.91
	Scandinavian	73.43	98.25	52.42	73.70	73.43	98.25	78.25
	Singapore	50.65	64.68	94.99	113.36	95.45	114.79	88.99
	South African	26.70	58.76	68.70	85.28	68.70	85.54	65.61
	Thai	20.06	34.90	64.42	78.76	64.42	78.76	56.89
	Turkish	41.01	60.48	77.84	88.15	77.84	88.15	72.25
	United	114.51	113.92	114.51	109.41	114.51	113.92	113.46
	SA AVG	53.98	115.44	67.64	99.47	72.27	126.28	89.18
ST	Aeroflot	37.90	62.05	78.47	91.28	78.83	91.28	73.30
	Aero Mexico	38.58	101.22	63.42	106.54	64.45	103.01	79.54
	Air Europa	65.23	83.81	81.60	99.66	81.60	103.11	85.84
	Air France-KLM	75.66	87.82	87.76	94.38	87.96	94.38	87.99
	China Eastern	37.55	70.52	57.89	70.52	57.89	70.52	60.82
	China Southern	39.96	70.21	60.89	70.35	60.89	70.35	62.11
	Delta	93.58	95.90	93.58	95.90	93.58	95.90	94.74
	Garuda Indonesia	46.79	67.57	42.17	63.07	46.87	67.57	55.67
	Kenya	20.74	58.17	35.17	64.01	35.17	64.01	46.21
	KLM	57.76	68.77	87.05	91.52	88.82	91.63	80.93
	Korean Air	37.69	51.46	72.09	83.78	72.60	83.81	66.91
	ST AVG	50.13	74.32	69.10	84.64	69.88	85.05	72.19
	Overall AVG	59.84	89.65	75.51	89.43	80.76	101.69	82.81

Table 12. Number of DMUs with Respect to Their Super Efficiency Scores under CCR Conditions

Alliance	Unit name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	2	3	4	1	5	4
	SA	1	4	1	5	1	7
	ST	0	1	0	1	0	2
Near-Efficient	OW	2	1	2	3	2	2
	SA	0	5	2	3	2	4
	ST	1	1	1	5	1	4
Inefficient	OW	6	6	4	6	3	4
	SA	17	9	15	10	15	7
	ST	10	9	10	5	10	5

Table 13. Super Efficiency Scores for Six Models under CCR conditions

Alliance	Unit name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	20	30	40	10	50	40
	SA	6	22	6	28	6	39
	ST	0	9	0	9	0	18
Near-Efficient	OW	20	10	20	30	20	20
	SA	0	28	11	17	11	22
	ST	9	9	9	45	9	36
Inefficient	OW	60	60	40	60	30	40
	SA	94	50	83	56	83	39
	ST	91	82	91	45	91	45

Table 14 provides the standard efficiency results for BCC specification. In average, the efficiency scores are higher in VRS conditions with respect to those presented under CRS assumptions. Since using the VRS option provides more room to the analysis to find optimal solutions, it is expected that no DMU receives a lower efficiency score using BCC method than it has had with CCR estimations (Hussein & Jones, 2010). Correspondingly, number of efficient DMUs increases in VRS case for all six models and number of inefficient DMUs decreases with respect to CCR method. A Sky Team member Garuda Indonesia is not observed efficient in CRS

circumstances, however, it is found efficient for models 1, 3, and 5 in BCC assessment as Croatia is noted fully efficient in BCC measurement while it has only efficiency score of 100 for models 2 and 4 in CCR model. KLM also is another airline that is shown to perform efficiently in VRS environment for some models as its group company Air France KLM; however they are measured inefficient in CRS conditions. KLM's scores are found higher when it is evaluated individually rather than acting within the group of Air France KLM, which may show that KLM is performing better than its group in transforming its inputs into outputs.

The similar result is observed for Austrian as well when its efficiency scores are separately measured rather than existing in its Lufthansa Passenger Airlines.

Table 14. Standard Efficiency Scores for Six Models under BCC conditions

Alliance	Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Average
OW	Airberlin	97.48	99.42	56.32	55.47	97.48	99.42	84.27
	American	100.00	100.00	100.00	93.05	100.00	100.00	98.84
	British	81.94	83.37	96.48	85.83	97.58	88.62	88.97
	Cathay P.	53.24	44.37	100.00	94.43	100.00	94.43	81.08
	Finnair	100.00	100.00	100.00	96.14	100.00	100.00	99.36
	Japan	84.62	71.10	80.98	68.38	84.62	71.18	76.81
	Qantas	100.00	100.00	96.74	84.34	100.00	100.00	96.85
	Royal Jordanian	100.00	74.59	100.00	92.19	100.00	92.19	93.16
	Srilankan	73.03	57.93	100.00	100.00	100.00	100.00	88.49
	Tam	79.57	66.27	85.33	73.06	85.33	73.06	77.10
	OW AVG	86.99	79.71	91.59	84.29	96.50	91.89	88.49
SA	Aegean	82.67	100.00	82.31	97.23	82.67	100.00	90.81
	Air Canada	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Air China	69.46	70.57	71.04	72.48	71.04	72.48	71.18
	Air New Zealand	93.45	100.00	89.17	100.00	93.45	100.00	96.01
	Ana	56.50	69.78	56.22	68.38	56.50	71.21	63.10
	Austrian	85.07	94.96	82.54	95.16	85.07	94.96	89.63
	Avianca	94.94	98.78	94.94	97.70	94.94	98.78	96.68
	Copa	88.41	98.78	88.08	96.64	88.53	100.00	93.41
	Croatia	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Egypt Airlines	62.60	60.51	82.17	60.51	82.17	60.51	68.08
	Ethiopian	77.07	75.74	97.57	100.00	97.57	100.00	91.33
	LH PAX Group	76.24	81.05	77.21	84.23	77.21	85.01	80.16
	Scandinavian	100.00	98.36	76.14	73.77	100.00	98.36	91.11
	Singapore	54.35	64.72	96.16	100.00	97.45	100.00	85.45
	South African	67.15	60.84	80.60	85.28	80.60	85.75	76.70
	Thai	41.25	40.23	67.00	79.95	67.00	79.95	62.56
	Turkish	63.46	62.88	82.15	88.17	82.15	88.17	77.83
	United	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	SA AVG	78.48	82.07	84.63	88.86	86.46	90.84	85.22
ST	Aeroflot	65.78	64.27	87.82	91.31	87.82	91.31	81.39
	Aeromexico	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Air Europa	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	AFI-KLM Group	82.87	100.00	90.91	99.22	89.63	100.00	93.77
	China Eastern	88.31	72.88	93.49	72.88	93.49	72.88	82.32
	China Southern	84.14	72.69	89.70	72.71	89.70	72.71	80.28
	Delta	94.79	100.00	94.79	100.00	94.79	100.00	97.40
	Garuda Indonesia	100.00	68.81	100.00	68.12	100.00	68.81	84.29
	Kenya	100.00	68.24	100.00	68.41	100.00	68.41	84.18
	KLM	91.08	100.00	99.62	100.00	97.86	100.00	98.09
	Korean Air	78.61	51.80	77.00	84.20	76.21	84.24	75.34
	ST AVG	89.60	81.70	93.94	86.99	93.59	87.12	88.82
	Overall AVG	85.02	81.16	90.05	86.71	92.19	89.95	87.51

Although the scores may vary with respect to the models, as per the results of six models, Sky Team ranks first with 88.82 average efficiency score, One World becomes second with the score of 88.49 and Star Alliance ranks third with its 88.82 point. In addition, if the efficiency scores are discussed according to the efficient, near-efficient and inefficient findings with the help of Table 15 and Table 16, it is seen that 39.4% of Sky Team's DMUs are found efficient in general and this number is 38.3% for One World and 27.3% for Star Alliance. If the general numbers for the inefficient DMUs for each alliance is mentioned, 53.7% of Star Alliance's members, 42.4% of Sky Team group and 40% of One World alliance are found inefficient, which reveals that all the three alliances have more inefficient DMUs than efficient units. Since DEA gives relative efficiency scores rather than absolute situation, the results could be observed different and it would be more reliable if all members of the alliances could be included in the analysis.

Table 15. Number of DMUs with Respect to Standard Efficiency Scores under BCC Conditions

Alliance	Unit name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	4	3	5	1	6	4
	SA	4	5	3	6	4	8
	ST	4	5	4	4	4	5
Near-Efficient	OW	1	1	2	4	2	3
	SA	2	4	3	4	4	3
	ST	2	0	4	2	3	1
Inefficient	OW	5	6	3	5	2	3
	SA	12	9	12	8	10	7
	ST	5	6	3	5	4	5

Table 16. Percentage of DMUs with Respect to Standard Efficiency Scores under BCC Conditions

Alliance	Unit name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Efficient	OW	40	30	50	10	60	40
	SA	22	28	17	33	22	44
	ST	36	45	36	36	36	45
Near-Efficient	OW	10	10	20	40	20	30
	SA	11	22	17	22	22	17
	ST	18	0	36	18	27	9
Inefficient	OW	50	60	30	50	20	30
	SA	67	50	67	44	56	39
	ST	45	55	27	45	36	45

Replacing fuel cost with seat capacity increases the average efficiency scores when model 1 and model 3, and model 2 and model 4 are compared with each other as in CRS calculations. If the efficient scores for model 1 and model 3 are compared where fuel cost is the input of first one and seat capacity is the input variable of the latter, SriLankan Airlines changes to efficient from inefficient, Qantas falls to near-efficient although it has been efficient and Scandinavian becomes inefficient although it is efficient in model 1 and the rest remains unchanged with respect to their efficient / inefficient status. It again shows that fuel cost has greater excess amount than seat capacity when the output is RPK since when fuel cost comes into picture the overall efficiency scores decline, however, with very small shifts from efficient to inefficient status. This fact is proved by model 5 results by its improvement summary. As shown in Figure 14, model 5 requires 45.9% reduction in fuel cost and 27.52% in seat capacity when they are used together as the input variables. Similar results are observed when the output is ASK and load factor instead of RPK. However, less fuel reduction is required when the output variables are ASK and load factor than it is RPK while improvement results in seat capacity are almost same, 28.88% and 27.52%, respectively. The reason lies in the definitions

of RPK and ASK. The supply of airlines are ASK, which has been already produced before it is transformed into sales, which represent RPK. Since ASK is theoretically greater than RPK, load factor may have more influence on efficiency than ASK. So, airlines need higher load factors to incorporate with ASK to produce RPK. Airlines need fuel in order to produce ASK, however, once ASK is produced they need highest load factors to maximize their RPK. Correspondingly, although the model is input oriented, model 6 requires increase in its load factor, which is the output variable. Seat per aircraft is also recommended in model 6 to be decreased which is expected to result in favor of higher load factors since smaller aircraft have higher load factors. Similar conclusions are derived for models 2, 4 and 6. Discussions about input improvement are provided in more detail in the following paragraphs.

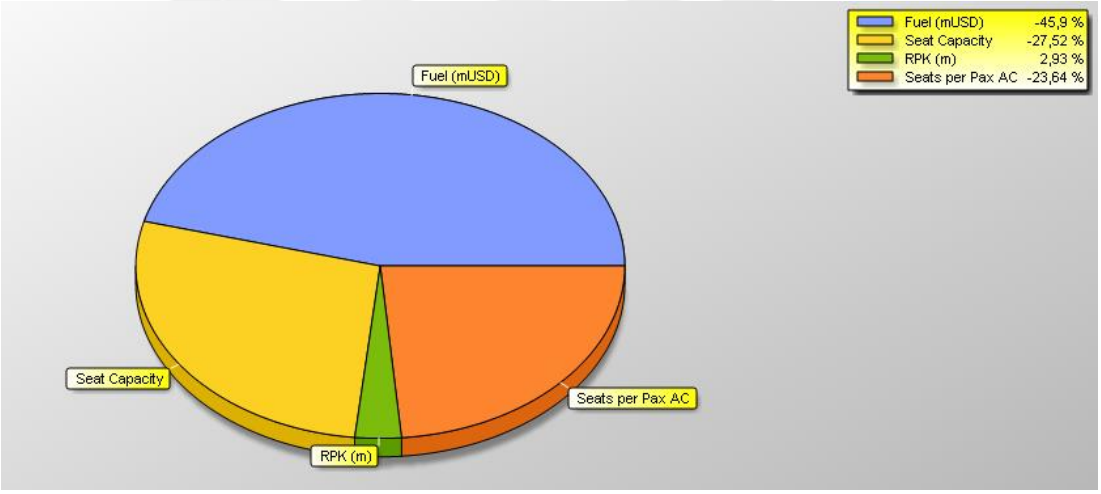

Figure 14. Overall improvement summary for model 5

As discussed for Figure 14, it is demonstrated in Figure 15 that fuel cost needs more reduction proportion that seat capacity, which are 37.75% and 28.88%, respectively. The model 6 also requires load factor to increase.

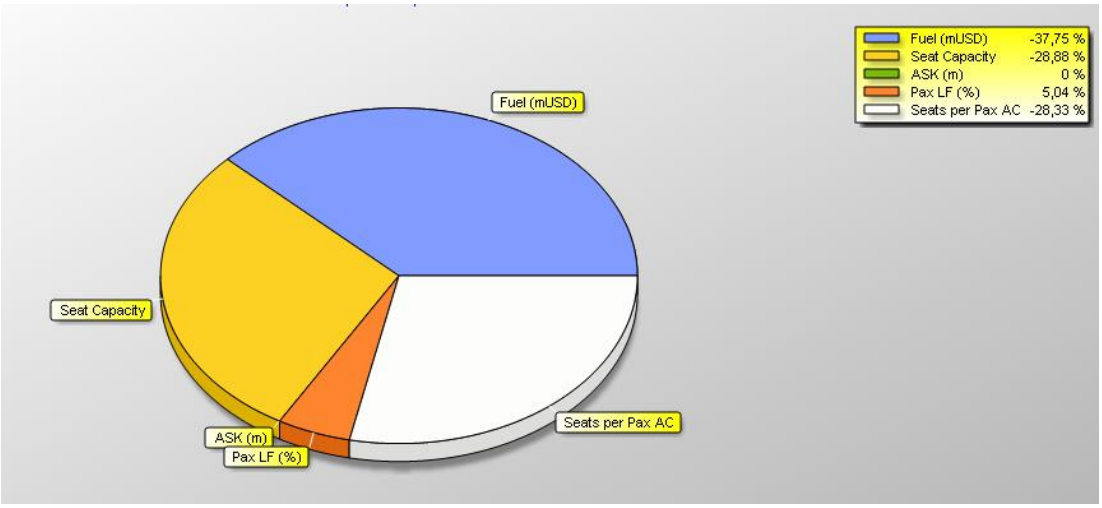

Figure 15. Overall improvement summary for model 6

After providing a general expression about the input variables and their relations with the output and hence impact on the efficiency scores, in order to be able to rank the best efficient ones among the efficient DMUs with 100 efficiency score, same analysis is performed for super-efficiency option. As represented in Table 17, American Airlines is the global efficient in models 1, 3 and 5 with one thousand efficiency score, United Airlines, Delta Airlines and KLM apart from its Air France-KLM group are the best performing operators in models 2, 4 and 6, which also shows that they are not affected by inclusion or removal of fuel in their efficiency results. This fact provides the result that the super-efficient airlines do not lose their efficiency scores according to the input variables either it is fuel cost or seat capacity, in other words they are not sensitive to the variables. Another result is that under super-efficiency calculations, the scores of efficient DMUs change in order to detect the best one but the non-efficient ones have the same scores as they do under standard efficiency estimations.

Table 17. Super Efficiency Scores for Six Models under VRS conditions

Alliance	Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Average
OW	Air berlin	97.48	99.42	56.32	55.47	97.48	99.42	84.27
OW	American	1000.00	106.07	1000.00	93.05	1000.00	106.07	550.87
OW	British	81.94	83.37	96.48	85.83	97.58	88.62	88.97
OW	Cathay Pacific	53.24	44.37	106.34	94.43	106.34	94.43	83.19
OW	Finnair	126.34	101.13	105.90	96.14	126.34	110.04	110.98
OW	Japan	84.62	71.10	80.98	68.38	84.62	71.18	76.81
OW	Qantas	122.29	104.23	96.74	84.34	116.51	104.23	104.72
OW	Royal Jordanian	103.59	74.59	130.60	92.19	130.60	92.19	103.96
OW	Srilankan	73.03	57.93	165.10	131.14	165.10	131.14	120.57
OW	Tam	79.57	66.27	85.33	73.06	85.33	73.06	77.10
	OW Avg	182.21	80.85	192.38	87.40	200.99	97.04	140.14
SA	Aegean	82.67	124.06	82.31	97.23	82.67	124.06	98.83
SA	Air Canada	102.99	113.12	101.47	109.31	102.99	114.02	107.32
SA	Air China	69.46	70.57	71.04	72.48	71.04	72.48	71.18
SA	Air New Zealand	93.45	131.34	89.17	126.15	93.45	131.34	110.82
SA	Ana	56.50	69.78	56.22	68.38	56.50	71.21	63.10
SA	Austrian	85.07	94.96	82.54	95.16	85.07	94.96	89.63
SA	Avianca	94.94	98.78	94.94	97.70	94.94	98.78	96.68
SA	Copa	88.41	98.78	88.08	96.64	88.53	100.47	93.49
SA	Croatia	858.41	858.41	302.25	302.73	858.41	858.41	673.10
SA	Egypt Airlines	62.60	60.51	82.17	60.51	82.17	60.51	68.08
SA	Ethiopian	77.07	75.74	97.57	103.00	97.57	103.00	92.33
SA	Lufthansa PAX Group	76.24	81.05	77.21	84.23	77.21	85.01	80.16
SA	Scandinavian	102.02	98.36	76.14	73.77	102.02	98.36	91.78
SA	Singapore	54.35	64.72	96.16	119.12	97.45	119.12	91.82
SA	South African	67.15	60.84	80.60	85.28	80.60	85.75	76.70
SA	Thai	41.25	40.23	67.00	79.95	67.00	79.95	62.56
SA	Turkish	63.46	62.88	82.15	88.17	82.15	88.17	77.83
SA	United	126.95	1000.00	126.95	1000.00	126.95	1000.00	563.48
	SA Avg	122.39	178.01	97.44	153.32	130.37	188.09	144.94
ST	Aeroflot	65.78	64.27	87.82	91.31	87.82	91.31	81.39
ST	Aero Mexico	136.70	102.58	138.14	117.24	138.14	104.32	122.85
ST	Air Europa	244.63	110.51	121.71	302.39	121.71	174.51	179.24
ST	Air France KLM Group	82.87	104.97	90.91	99.22	89.63	104.97	95.43
ST	China Eastern	88.31	72.88	93.49	72.88	93.49	72.88	82.32
ST	China Southern	84.14	72.69	89.70	72.71	89.70	72.71	80.28
ST	Delta	94.79	1000.00	94.79	1000.00	94.79	1000.00	547.40
ST	Garuda Indonesia	184.19	68.81	112.49	68.12	111.18	68.81	102.27
ST	Kenya	300.06	68.24	120.96	68.41	120.88	68.41	124.49
ST	KLM	91.08	1000.00	99.62	1000.00	97.86	1000.00	548.09
ST	Korean Air	78.61	51.80	77.00	84.20	76.21	84.24	75.34
	ST Avg	131.92	246.98	102.42	270.59	101.95	258.38	185.37
	Overall Avg	145.51	168.61	130.75	170.44	144.44	181.17	156.82

Six separate assessments are performed so far under both variable and constant returns to scale assumptions and the results are discussed in detail. However, it is important to detect where to put the emphasis and which results to take reference for the following discussions such as improvement suggestions. Junior, Rubem, Soares de Mello, and Meza (2015) apply BCC in their analysis for Brazilian airlines arguing that there is no presumption of proportionality between inputs and outputs due to the scale size disparity. Lee and Worthington (2014) use VRS model, as well, stating that a CRS assumption is only suitable if firms are operating at their optimal scale, which is not possible for airline industry of ongoing structural changes. In contrast, Jang, Choi, and Lee (2011) use CCR model on the basis that many prior studies indicate that airline industry has CRS production. In this study, airline industry is found to exhibit variable returns to scale characteristics as discussed before.

Table 18 demonstrates the returns to scale ratio characteristics of each DMU for the all six models analyzed. Accordingly, -1 in Table 18 represents that the company is operating under decreasing returns to scale, 0 stands for constant returns to scale whereas 1 symbolizes increasing returns to scale. It varies from model to model whether 1s or -1s are the most abundant in the groups but 0s never constitute the majority of the results. Since these three alliances are the major players in the industry and holds more than 60% share in airline business, the results reached here can easily be generalized for the industry. Based on the minority of 0s, it can be concluded that the airline industry, specifically passenger airline industry, is operating under variable returns to scale. Another result driven from Table 18 is that the industry shows decreasing returns to scale production for models 4 and 6 while increasing returns to scale production features are observed mostly in models 1, 3, and 5. The numbers of DMUs designating increasing or decreasing returns to scale

are almost same for model 2. These varying results can be explained with the definition of load factor which is the output of model 4 and its relation between seat per aircraft and seat capacity. Passenger load factor designates the ratio the seats in the aircraft of a specific flight is ticketed. If the inputs seat capacity and seat per aircraft increase simultaneously, then it implies that the airline is operating a fleet of mostly or entirely wide-body aircraft which is hard to have a proportionally high load factor. However, the returns to scale results do not show decreasing returns to scale for model 3 which employs the same inputs. Although RPK is the multiplication of ASK and load factor, when they are separately employed as the outputs of the processes with the same inputs, then different results are observed. The reason behind may be that there is a high correlation between ASK and RPK; however, load factor is not highly correlated with ASK, and when ASK and load factor are used together load factor dominates in the analysis and pulls the scores down. This case can be easily seen by the overall efficiency scores between model 1 and model 2, model 3 and model 4, and model 5 and model 6, where RPK is replaced by ASK and load factor. If the results in terms of returns to scale of model 2 and model 4 are compared, existence of fuel cost as the input variable prevent the model to become decreasing returns to scale due to the fact that if fuel is increasing it shows the operations are increasing for most of the DMUs which produces more ASK and higher load factors.

Another result retrieved from Table 18 is that the sample includes efficient DMUs which are operating at decreasing returns to scale (DRS) or increasing returns to scale (IRS). In BCC model, if an efficient DMU exhibits DRS, it means that it is located on the DRS efficient frontier and if it is found IRS, then it is said that it is located on the IRS efficient frontier of the model (Seiford & Zhu, 1999).

Table 18. Returns to Scale Results for Standard Efficiency Analysis

Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Aeroflot	1	1	1	1	1	1
Aero Mexico	1	0	1	0	1	0
Aegean	1	-1	1	-1	1	-1
Air Canada	1	0	1	0	1	0
Air China	1	1	1	-1	1	-1
Air Europa	1	-1	1	-1	1	0
Air France-KLM Group	1	-1	1	-1	1	-1
Air New Zealand	1	0	1	-1	1	0
Air berlin	1	-1	1	-1	1	-1
American	0	0	0	-1	0	0
Ana	1	1	1	1	1	-1
Austrian	1	-1	1	-1	1	-1
Avianca	1	1	1	1	1	1
British	-1	-1	1	-1	-1	-1
Cathay Pacific	1	-1	0	-1	0	-1
China Eastern	1	1	1	1	1	1
China Southern	1	1	1	1	1	1
Copa	1	-1	1	-1	1	0
Croatia	1	0	1	0	1	0
Delta	1	-1	1	-1	1	-1
Egypt Airlines	1	1	1	1	1	1
Ethiopian	1	1	1	0	1	0
Finnair	1	0	0	-1	0	0
Garuda Indonesia	1	1	1	1	1	1
Japan	1	1	1	1	1	1
Kenya	1	1	1	1	1	1
KLM	1	-1	1	-1	1	-1
Korean Air	1	1	1	1	1	1
Lufthansa PAX Group	1	-1	1	-1	1	-1
Qantas	0	0	1	-1	0	0
Royal Jordanian	1	1	1	1	1	1
Scandinavian	1	-1	1	1	1	-1
Singapore	1	-1	-1	0	-1	0
South African	1	1	1	-1	1	1
Srilankan	1	1	0	0	0	0
Tam	1	-1	1	-1	1	-1
Thai	1	1	1	1	1	1
Turkish	1	1	1	-1	1	-1
United	0	0	0	0	0	0

Table 19 presents super efficiency results for returns to scale analysis which are exactly the same as standard efficiency results. Due to the fact that the industry resembles variable returns to scale, the results for standard efficiency BCC model assessments only are broadly discussed hereinafter.

Table 19. Returns to Scale Results for Super Efficiency Analysis

Unit Name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Aeroflot	1	1	1	1	1	1
Aero Mexico	1	0	1	0	1	0
Aegean	1	-1	1	-1	1	-1
Air Canada	1	0	1	0	1	0
Air China	1	1	1	-1	1	-1
Air Europa	1	-1	1	-1	1	0
Air France-KLM Group	1	-1	1	-1	1	-1
Air New Zealand	1	0	1	-1	1	0
Air berlin	1	-1	1	-1	1	-1
American	0	0	0	-1	0	0
Ana	1	1	1	1	1	-1
Austrian	1	-1	1	-1	1	-1
Avianca	1	1	1	1	1	1
British	-1	-1	1	-1	-1	-1
Cathay Pacific	1	-1	0	-1	0	-1
China Eastern	1	1	1	1	1	1
China Southern	1	1	1	1	1	1
Copa	1	-1	1	-1	1	0
Croatia	1	0	1	0	1	0
Delta	1	-1	1	-1	1	-1
Egyptair Airlines	1	1	1	1	1	1
Ethiopian	1	1	1	0	1	0
Finnair	1	0	0	-1	0	0
Garuda Indonesia	1	1	1	1	1	1
Japan	1	1	1	1	1	1
Kenya	1	1	1	1	1	1
KLM	1	-1	1	-1	1	-1
Korean Air	1	1	1	1	1	1
Lufthansa PAX Group	1	-1	1	-1	1	-1
Qantas	0	0	1	-1	0	0
Royal Jordanian	1	1	1	1	1	1
Scandinavian	1	-1	1	1	1	-1
Singapore	1	-1	-1	0	-1	0
South African	1	1	1	-1	1	1
Srilankan	1	1	0	0	0	0
Tam	1	-1	1	-1	1	-1
Thai	1	1	1	1	1	1
Turkish	1	1	1	-1	1	-1
United	0	0	0	0	0	0

Table 20 is related to improvement analyses of DEA models. In other words, it shows the improvements that should be made to become efficient. It is shown in the table which airline and which alliance in total use what quantities of inputs, what quantities of outputs they produce and what the target levels for those inputs are. Accordingly, One World has an expense of almost 35 million USD fuel, Star Alliance makes more or less 62 million USD fuel payments and Sky Team has about 55 million USD spend on jet fuel. The target level of fuel spend for One World is about 29 million USD with a of 15.40% reduction while Star Alliance is targeted to make 30.04% less fuel cost and Sky Team requires 14.73% decrease in the fuel expenses to attain the target level of about 46 million USD. Similarly, all alliances should decrease their seats per aircraft figure to become efficient. Star Alliance needs most percentage reductions in both inputs than One World and Sky Team needs to achieve its actual operational figures and conversely Sky Team requires less reductions in both input variables to operate efficiently. However, Sky Team is also found to increase its RPK. These results, which are consistent with the average efficiency scores, show that Star Alliance has more excess amount of its inputs to produce RPK than its competitors have. Reductions in seat per aircraft variable indicates that the alliance or the DMUs are operating wider aircraft than needed to act efficiently, in other words, they can achieve their actual RPKs with smaller aircraft.

Table 20. Input and Output Quantities for Model 1: Standard Efficiency BCC Results

Alliance	Unit Name	Actual Fuel (mUSD)	Target Fuel (mUSD)	Actual Seats per Pax AC	Target Seats per Pax AC	Actual RPK (m)	Target RPK (m)	Percent Fuel (mUSD)	Percent Seats per Pax AC	Percent RPK (m)
OW	Air berlin	1,251	1,219	267	197	59,030	59,030	-2.50	-26.20	0.00
	American	10,592	10,592	166	166	439,891	439,891	0.00	0.00	0.00
	British	4,430	3,630	227	174	170,917	170,917	-18.10	-23.30	0.00
	Cathay Pacific	6,368	3,390	279	149	134,711	134,711	-46.80	-46.80	0.00
	Finnair	656	656	205	205	30,889	30,889	0.00	0.00	0.00
	Japan	2,476	2,095	179	152	84,003	84,003	-15.40	-15.40	0.00
	Qantas	2,874	2,874	175	175	141,715	141,715	0.00	0.00	0.00
	Royal J.	757	757	154	154	11,600	11,600	0.00	0.00	0.00
	SriLankan	1,122	819	216	158	16,180	22,174	-27.00	-27.00	37.00
	Tam	4,167	3,316	185	147	130,201	130,201	-20.40	-20.40	0.00
	OW Total	34,693	29,350	205	168	1,219,137	1,225,131	-15.40	-18.36	0.49
SA	Aegean	334	276	140	116	9,600	9,600	-17.30	-17.30	0.00
	Air Canada	2,871	2,871	122	122	114,113	114,113	0.00	0.00	0.00
	Air China	9,156	4,764	172	119	154,684	154,684	-48.00	-30.50	0.00
	Air New Zealand	718	671	130	122	28,078	28,078	-6.60	-6.60	0.00
	Ana	3,222	1,821	219	124	74,221	74,221	-43.50	-43.50	0.00
	Austrian	538	458	140	119	18,428	18,428	-14.90	-14.90	0.00
	Avianca	1,346	1,030	122	116	32,602	32,602	-23.40	-5.10	0.00
	Copa	821	726	136	120	29,471	29,471	-11.60	-11.60	0.00
	Croatia	74	74	115	115	1,342	1,342	0.00	0.00	0.00
	Egyptair Airlines	2,578	1,485	191	119	27,971	28,245	-42.40	-37.40	1.00
	Ethiopian	2,639	1,485	155	119	24,726	28,245	-43.70	-22.90	14.20
	Lufthansa PAX Group	7,655	5,836	180	137	214,641	214,641	-23.80	-23.80	0.00
	Scandinavian	959	959	161	161	34,714	34,714	0.00	0.00	0.00
	Singapore	3,772	2,050	310	169	94,209	94,209	-45.70	-45.70	0.00
	South African	1,945	1,306	193	130	25,606	26,617	-32.80	-32.80	3.90
	Thai	6,053	2,322	291	120	57,194	57,194	-61.60	-58.70	0.00
	Turkish	5,858	3,717	191	121	106,787	106,787	-36.50	-36.50	0.00
	United	11,676	11,676	126	126	380,695	380,695	0.00	0.00	0.00
	SA Total	62,213	43,525	172	126	1,429,082	1,433,886	-30.04	-26.47	0.34
ST	Aeroflot	3,735	2,457	186	122	67,100	67,100	-34.20	-34.20	0.00
	Aero Mexico	1,485	1,485	119	119	28,245	28,245	0.00	0.00	0.00
	Air Europa	638	638	169	169	20,515	20,515	0.00	0.00	0.00
	Air France-KLM	7,595	6,294	194	161	248,483	248,483	-17.10	-17.10	0.00
	China Eastern	8,027	7,089	166	146	127,750	224,387	-11.70	-11.70	75.60
	China Southern	10,000	8,414	167	140	166,629	269,544	-15.90	-15.90	61.80
	Delta	13,512	11,676	133	126	375,817	380,695	-13.60	-5.20	1.30
	Garuda Indonesia	1,560	1,560	171	171	35,997	35,997	0.00	0.00	0.00
	Kenya	958	958	169	169	9,793	9,793	0.00	0.00	0.00
	KLM	3,229	2,941	191	174	91,477	143,542	-8.90	-8.90	56.90
	Korean Air	3,656	2,874	258	175	67,948	141,715	-21.40	-32.40	108.60
	ST Total	54,395	46,386	175	152	1,239,755	1,570,016	-14.73	-13.02	26.64

Super-efficiency analysis results for model 1 are provided in Table 21. Relative to standard efficiency results, One World and Sky Team have lower target fuel cost level in super-efficiency analysis whereas it is higher for Star Alliance. However, in regards with seat per aircraft, One World has higher target level while Star Alliance and Sky Team have lower targets. The differences are coming from the efficient units while target numbers are the same as standard efficiency results for non-efficient DMUs. These results stem from the fact that the efficient airlines in each group have different ratios for fuel cost with respect to seat per aircraft. Finnair and Qantas from One World, Air Canada and Croatia Airlines from Star Alliance, and Aero Mexico and Air Europa from Sky Team, for example, have higher target levels of fuel expenses than they have in standard efficiency assessment while United Airlines is advised to decrease its fuel cost compared to standard efficiency results. Since super efficiency only sets targets for the efficient airlines to take them higher in efficiency score to be the super-efficient one, super efficiency results are not discussed further for improvement numbers in this study.

Table 21. Input and Output Quantities for Model 1: Super Efficiency BCC Results

Alliance	Unit Name	Actual Fuel (m USD)	Target Fuel (m USD)	Act. Seats per Pax AC	Target Seats per Pax AC	Actual RPK (m)	Target RPK (m)	Percent Fuel (m USD)	Percent Seats per Pax AC	Percent RPK (m)
OW	Air berlin	1,251	1,219	267	197	59,030	59,030	-2.50	-26.20	0.00
	American	10,592	10,592	166	166	439,891	439,891	0.00	0.00	0.00
	British	4,430	3,630	227	174	170,917	170,917	-18.10	-23.30	0.00
	Cathay Pacific	6,368	3,390	279	149	134,711	134,711	-46.80	-46.80	0.00
	Finnair	656	829	205	169	30,889	30,889	26.30	-17.50	0.00
	Japan	2,476	2,095	179	152	84,003	84,003	-15.40	-15.40	0.00
	Qantas	2,874	3,515	175	168	141,715	141,715	22.30	-3.90	0.00
	Royal Jordanian	757	785	154	160	11,600	21,856	3.60	3.60	88.40
	Srilankan	1,122	819	216	158	16,180	22,174	-27.00	-27.00	37.00
	Tam	4,167	3,316	185	147	130,201	130,201	-20.40	-20.40	0.00
	OW	34,693	30,191	205	164	1,219,137	1,235,386	-12.98	-20.17	1.33
SA	Aegean	334	276	140	116	9,600	9,600	-17.30	-17.30	0.00
	Air Canada	2,871	2,957	122	126	114,113	114,113	3.00	3.00	0.00
	Air China	9,156	4,764	172	119	154,684	154,684	-48.00	-30.50	0.00
	Air N. Zlnd.	718	671	130	122	28,078	28,078	-6.60	-6.60	0.00
	Ana	3,222	1,821	219	124	74,221	74,221	-43.50	-43.50	0.00
	Austrian	538	458	140	119	18,428	18,428	-14.90	-14.90	0.00
	Avianca	1,346	1,030	122	116	32,602	32,602	-23.40	-5.10	0.00
	Copa	821	726	136	120	29,471	29,471	-11.60	-11.60	0.00
	Croatia	74	638	115	169	1,342	20,515	758.40	46.60	1,428.70
	Egypt Airlines	2,578	1,485	191	119	27,971	28,245	-42.40	-37.40	1.00
	Ethiopian	2,639	1,485	155	119	24,726	28,245	-43.70	-22.90	14.20
	Lufthansa Pax. Airl.	7,655	5,836	180	137	214,641	214,641	-23.80	-23.80	0.00
	Scandinavian	959	978	161	164	34,714	34,714	2.00	2.00	0.00
	Singapore	3,772	2,050	310	169	94,209	94,209	-45.70	-45.70	0.00
	South African	1,945	1,306	193	130	25,606	26,617	-32.80	-32.80	3.90
	Thai	6,053	2,322	291	120	57,194	57,194	-61.60	-58.70	0.00
	Turkish	5,858	3,717	191	121	106,787	106,787	-36.50	-36.50	0.00
	United	11,676	9,282	126	159	380,695	380,695	-20.50	26.90	0.00
	SA	62,213	41,800	172	132	1,429,082	1,453,059	-32.81	-23.42	1.68
ST	Aeroflot	3,735	2,457	186	122	67,100	67,100	-34.20	-34.20	0.00
	Aero Mexico	1,485	2,030	119	163	28,245	65,929	36.70	36.70	133.40
	Air Europa	638	1,560	169	171	20,515	35,997	144.60	1.50	75.50
	Air France-KLM	7,595	6,294	194	161	248,483	248,483	-17.10	-17.10	0.00
	China Eastern	8,027	7,089	166	146	127,750	224,387	-11.70	-11.70	75.60
	China Sothern	10,000	8,414	167	140	166,629	269,544	-15.90	-15.90	61.80
	Delta	13,512	11,676	133	126	375,817	380,695	-13.60	-5.20	1.30
	Garuda Indonesia	1,560	2,874	171	175	35,997	141,715	84.20	2.10	293.70
	Kenya	958	2,874	169	175	9,793	141,715	200.10	3.40	1.347.10
	KLM	3,229	2,941	191	174	91,477	143,542	-8.90	-8.90	56.90
	Korean Air	3,656	2,874	258	175	67,948	141,715	-21.40	-32.40	108.60
	ST	54,395	51,083	175	157	1,239,755	1,860,822	-6.09	-10.12	50.10

Overall improvement for model 1 is shown in Figure 16. Accordingly, for efficient operations total fuel cost of the sample regardless of the alliance is to be reduced by 40.57%, seat per passenger aircraft is to be decreased by 38.68% and RPK is to increase by 20.75%.

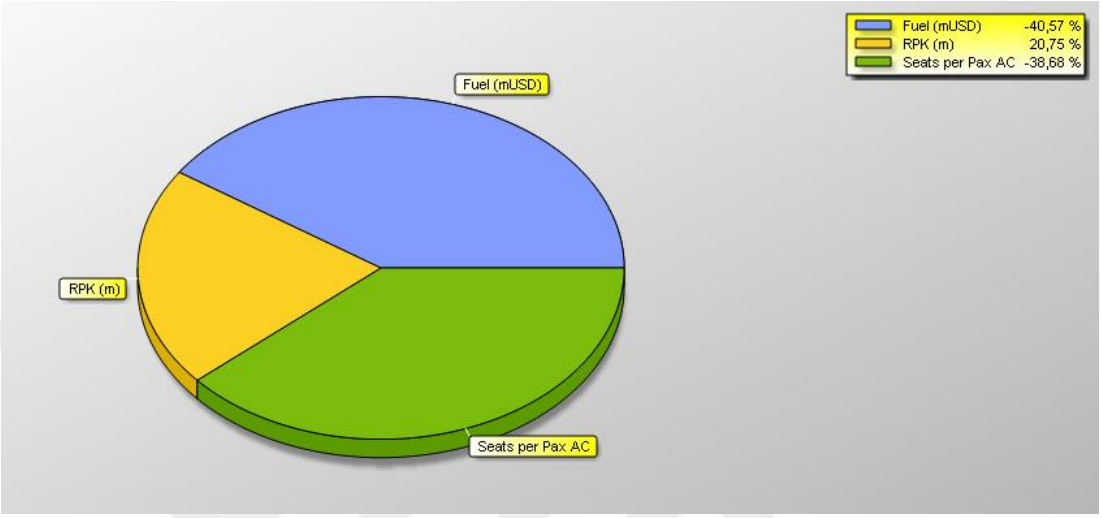

Figure 16. Overall improvement summary for model 1

Improvement results for model 2 are included in Table 22. Model 2, where RPK is employed as the output instead of ASK and LF in model 1, needs different targets changing in both directions, up or down relative to model 1. Star Alliance is still advised to have lower fuel costs as other two alliances; however its target, 43,969 million USD, is slightly higher than that in model 1, which is 43,525million USD, whereas One World and Sky Team have relatively lower targets of fuel costs compared to the numbers in model 2. The analysis also requires some increase in load factors although load factor is the output variable of this input-oriented analysis. Therefore, the results reveal that if the outputs are load factor and ASK rather than their multiplication, RPK, and then alliances are to decrease their fuel costs further and increase their load factors at the same time in order to efficiently operate. One World and Sky Team is targeted to further reduce their inputs compared to model 1 whereas Star Alliance needs less reductions its inputs. This implies that Star Alliance

will be operating efficiently with less reductions but higher load factors. One World is to decrease its seat per aircraft input by 29.95%, Star Alliance by 23.82% and Sky Team by 20.20%. Sky Team and One World can operate with less seat per aircraft input with respect to model 1, where RPK is the output, due to the fact that once ASK is produced it is load factor that leads higher RPKs. Accordingly, the analysis recommends improving load factors rather than using bigger aircraft.

Table 22. Input and Output Quantities for Model 2: Standard Efficiency BCC Results

Alliance	Unit Name	Act. Fuel (mUSD)	Tgt. Fuel (mUSD)	Act. Seat per Pax AC	Tgt. Seat per Pax AC	Act. ASK (m)	Tgt. ASK (m)	Act. Pax LF (%)	Tgt. Pax LF (%)	% Fuel (m USD)	% Seat per Pax AC	% ASK (m)	% Pax LF (%)
OW	Air berlin	1,251	1,244	267	132	59,030	59,030	83	83	-0.60	-50.60	0.00	0.00
	American	10,592	10,592	166	166	439,891	439,891	82	82	0.00	0.00	0.00	0.00
	British	4,430	3,693	227	147	170,917	170,917	81	81	-16.60	-35.20	0.00	0.00
	Cathay Pacific	6,368	2,825	279	123	134,711	134,711	83	83	-55.60	-55.80	0.00	0.00
	Finnair	656	656	205	205	30,889	30,889	80	80	0.00	0.00	0.00	0.00
	Japan	2,476	1,761	179	127	84,003	84,003	72	77	-28.90	-28.90	0.00	7.50
	Qantas	2,874	2,874	175	175	141,715	141,715	77	77	0.00	0.00	0.00	0.00
	Royal J.	757	321	154	115	11,600	11,600	69	70	-57.60	-25.40	0.00	0.70
	SriLankan	1,122	650	216	125	16,180	26,294	80	80	-42.10	-42.10	62.50	0.00
	Tam	4,167	2,761	185	122	130,201	131,261	83	83	-33.70	-33.70	0.80	0.00
	OW	34,693	27,377	205	144	1,219,137	1,230,311	79	80	-21.09	-29.95	0.92	0.74
SA	Aegean	334	334	140	140	12,194	12,194	78	78	0.00	0.00	0.00	0.00
	Air Canada	2,871	2,871	122	122	136,842	136,842	83	83	0.00	0.00	0.00	0.00
	Air China	9,156	5,235	172	121	193,631	193,631	80	80	-42.80	-29.40	0.00	0.00
	Air New Zealand	718	718	130	130	33,396	33,396	84	84	0.00	0.00	0.00	0.00
	Ana	3,222	2,248	219	153	109,700	109,700	68	77	-30.20	-30.20	0.00	13.20
	Austrian	538	511	140	133	23,343	23,343	79	79	-5.00	-5.00	0.00	0.00
	Avianca	1,346	1,329	122	121	41,052	41,052	79	79	-1.20	-1.20	0.00	0.00
	Copa	821	811	136	134	38,442	38,442	77	77	-1.20	-1.20	0.00	0.00
	Croatia	74	74	115	115	1,938	1,938	69	69	0.00	0.00	0.00	0.00
	Egypt Airlines	2,578	473	191	115	17,544	17,544	63	70	-81.60	-39.50	0.00	10.60
	Ethiopian	2,639	1,108	155	117	33,257	33,257	74	74	-58.00	-24.30	0.00	0.00
	Lufthansa Pax Gr.	7,655	6,204	180	146	268,105	268,105	80	82	-18.90	-18.90	0.00	2.90
	Scandinavian	959	943	161	158	45,158	45,158	77	77	-1.60	-1.60	0.00	0.00
	Singapore	3,772	2,441	310	170	120,001	120,001	79	79	-35.30	-45.10	0.00	0.00
	South African	1,945	1,163	193	118	33,999	33,999	75	75	-40.20	-39.20	0.00	0.00
	Thai	6,053	2,146	291	117	82,969	82,969	69	72	-64.50	-59.80	0.00	4.20
	Turkish	5,858	3,683	191	120	135,330	135,330	79	79	-37.10	-37.10	0.00	0.00
	United	11,676	11,676	126	126	455,631	455,631	84	84	0.00	0.00	0.00	0.00
	SA	62,213	43,969	172	131	1,782,533	1,782,533	76	78	-29.32	-23.82	0.00	1.51
ST	Aeroflot	3,735	2,400	186	119	85,800	85,800	78	78	-35.70	-35.70	0.00	0.00
	Aero Mexico	1,485	1,485	119	119	36,217	36,217	80	80	0.00	0.00	0.00	0.00
	Air Europa	638	638	169	169	24,486	24,486	84	84	0.00	0.00	0.00	0.00
	Air France-KLM	7,595	7,595	194	194	292,088	292,088	85	85	0.00	0.00	0.00	0.00
	China Eastern	8,027	4,429	166	121	160,585	160,585	80	80	-44.80	-27.10	0.00	0.00
	China Southern	10,000	5,592	167	121	209,807	209,807	79	79	-44.10	-27.30	0.00	0.00
	Delta	13,512	13,512	133	133	443,880	443,880	85	85	0.00	0.00	0.00	0.00
	Garuda Indonesia	1,560	1,074	171	118	50,155	50,155	72	74	-31.20	-31.20	0.00	3.30
	Kenya	958	419	169	115	15,406	15,406	64	70	-56.30	-31.80	0.00	9.50
	KLM	3,229	3,229	191	191	105,755	105,755	87	87	0.00	0.00	0.00	0.00
	Korean Air	3,656	1,894	258	134	90,979	90,979	75	77	-48.20	-48.20	0.00	2.40
	ST	54,395	42,267	175	139	1,515,158	1,515,158	79	80	-22.30	-20.20	0.00	1.17

The sample wide improvement is presented in Figure 17. Fuel cost is to be reduced by 49.73% and seat per aircraft requires decrease by 43.87% whereas the output variables ASK and load factor are to be increased by 3.45% and 2.95%, respectively.

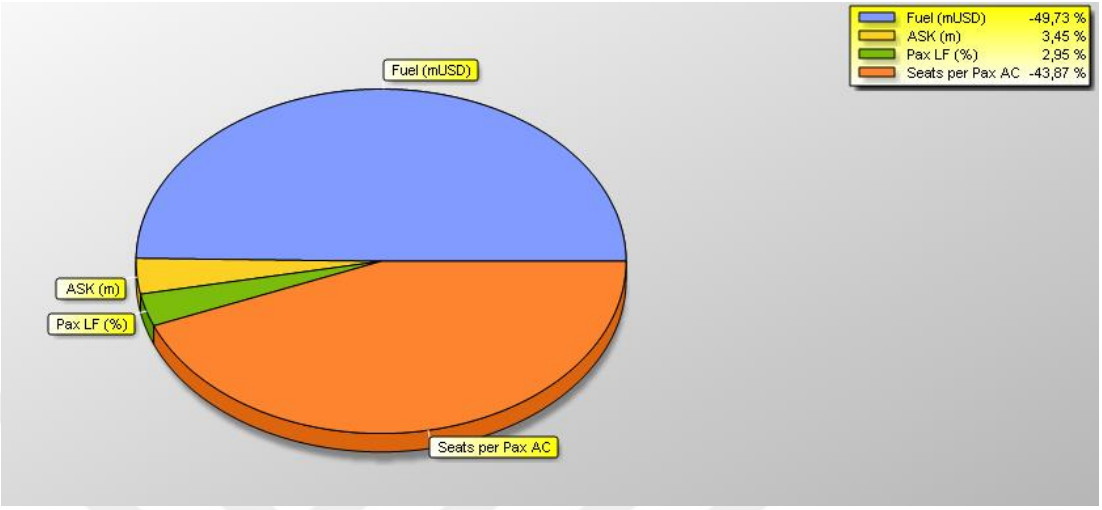

Figure 17. Overall improvement summary for model 2

Target results for model 3 that incorporates both seat capacity and seat per aircraft as the inputs and RPK for the output are provided in Table 23. Accordingly, all alliances are given targets of lower seat capacity and seat per aircraft, implying that they can produce almost the same amount of RPK, which is defined as the traffic, with smaller fleets of smaller aircraft. Although the largest seat per aircraft input belongs to One World, Star Alliance is advised to reduce its average seat per capacity the most, which are 9.33% for One World and 18.63% for the latter.

Table 23. Input and Output Quantities for Model 3: Standard Efficiency BCC Results

Alliance	Unit Name	Actual Seat Capacity	Target Seat Capacity	Actual Seats per Pax AC	Target Seats per Pax AC	Actual RPK (m)	Target RPK (m)	Percent Seat Capacity	Percent Seats per Pax AC	Percent RPK (m)
OW	Airberlin	39.850	22.444	267	151	59.030	59.030	-43,70	-43,70	0,00
	American	163.372	163.372	166	166	439.891	439.891	0,00	0,00	0,00
	British	63.288	61.062	227	219	170.917	170.917	-3,50	-3,50	0,00
	Cathay Pacific	45.467	45.467	279	279	134.711	134.711	0,00	0,00	0,00
	Finnair	9.222	9.222	205	205	30.889	30.889	0,00	0,00	0,00
	Japan	40.138	32.502	179	145	84.003	84.003	-19,00	-19,00	0,00
	Qantas	53.823	52.069	175	169	141.715	141.715	-3,30	-3,30	0,00
	Royal Jordanian	4.171	4.171	154	154	11.600	11.600	0,00	0,00	0,00
	Srilankan	4.544	4.544	216	216	16.180	16.180	0,00	0,00	0,00
	Tam	57.653	49.193	185	158	130.201	130.201	-14,70	-14,70	0,00
	OW AVG	481.527	444.045	205	186	1.219.137	1.219.137	-7,78	-9,33	0,00
SA	Aegean	7.000	4.787	140	115	9.600	9.600	-31,60	-17,70	0,00
	Air Canada	44.450	44.450	122	122	114.113	114.113	0,00	0,00	0,00
	Air China	89.130	63.322	172	122	154.684	154.684	-29,00	-29,00	0,00
	Air New Zealand	13.787	12.295	130	116	28.078	28.078	-10,80	-10,80	0,00
	Ana	50.764	28.540	219	123	74.221	74.221	-43,80	-43,80	0,00
	Austrian	10.493	8.429	140	115	18.428	18.428	-19,70	-17,50	0,00
	Avianca	22.092	14.277	122	116	32.602	32.602	-35,40	-5,10	0,00
	Copa	13.310	11.723	136	120	29.471	29.471	-11,90	-11,90	0,00
	Croatia	1.380	1.380	115	115	1.342	1.342	0,00	0,00	0,00
	Egypt Airlines	12.393	10.183	191	157	27.971	27.971	-17,80	-17,80	0,00
	Ethiopian	9.755	9.518	155	151	24.726	24.726	-2,40	-2,40	0,00
	Lufthansa Pax Airline	107.188	82.762	180	139	214.641	214.641	-22,80	-22,80	0,00
	Scandinavian	22.153	16.867	161	122	34.714	34.714	-23,90	-23,90	0,00
	Singapore	32.579	31.328	310	250	94.209	94.209	-3,80	-19,40	0,00
	South African	11.590	9.342	193	156	25.606	25.606	-19,40	-19,40	0,00
	Thai	29.056	19.466	291	195	57.194	57.194	-33,00	-33,00	0,00
	Turkish	48.163	39.564	191	157	106.787	106.787	-17,90	-17,90	0,00
	United	157.892	157.892	126	126	380.695	380.695	0,00	0,00	0,00
	SA AVG	683.174	566.123	172	140	1.429.082	1.429.082	-17,13	-18,63	0,00
ST	Aeroflot	28.788	25.282	186	163	67.100	67.100	-12,20	-12,20	0,00
	Aero Mexico	14.799	14.799	119	119	28.245	28.245	0,00	0,00	0,00
	Air Europa	7.501	7.501	169	169	20.515	20.515	0,00	0,00	0,00
	Air France-Klm Group	103.407	94.008	194	177	248.483	248.483	-9,10	-9,10	0,00
	China Eastern	80.317	75.092	166	155	127.750	159.401	-6,50	-6,50	24,80
	China Southern	100.374	90.033	167	150	166.629	199.333	-10,30	-10,30	19,60
	Delta	168.424	157.892	133	126	375.817	380.695	-6,30	-5,20	1,30
	Garuda Indonesia	28.920	28.920	171	171	35.997	35.997	0,00	0,00	0,00
	Kenya	8.449	8.449	169	169	9.793	9.793	0,00	0,00	0,00
	Klm	35.992	35.856	191	191	91.477	93.556	-0,40	-0,40	2,30
	Korean Air	31.271	24.077	258	199	67.948	67.948	-23,00	-23,00	0,00
	ST AVG	608.242	561.910	175	163	1.239.755	1.311.067	-7,62	-7,04	5,75

Overall improvement numbers for model 3 can be reached by Figure 18. Total seat capacity of the sample is to be reduced by 49.17%, seat per passenger aircraft is to be decreased by 45.87% and RPK is to increase by 4.97% for efficient operations.

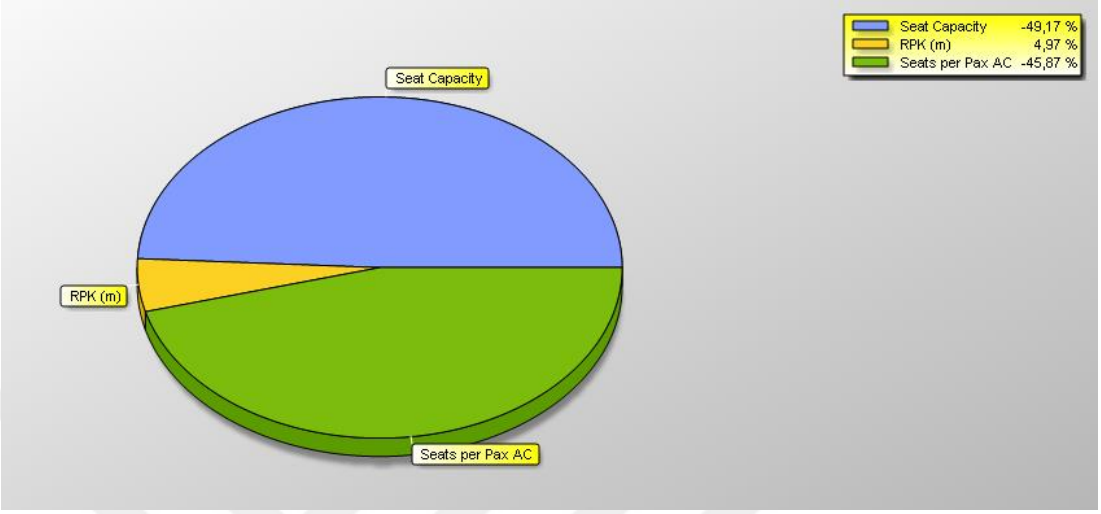

Figure 18. Overall improvement summary for model 3

Table 24 includes the improvement results for model 4 with seat capacity and seat per aircraft input variables and ASK and load factor output variables. As in model 3, it is again targeted here to have less seat capacity and lower seat per aircraft average. Sky Team and One World are targeted fewer amounts of inputs in model 4 than the results in model 3; however Star Alliance can make less reduction. Star Alliance is found to reduce its inputs by less portions when load factor becomes the output. This may be due to the fact that Star Alliance has the lowest average load factor for the sample considered. While target seat capacity for Star Alliance is 566,123 for model 3, it is 594,151 in model 4 over 683,174 seat capacity this is due to lower load factor of Star Alliance within the sample.

Table 24. Input and Output Quantities for Model 4: Standard Efficiency BCC Results

Alliance	Unit Name	Act. Seat Capacity	Tgt. Seat Capacity	Act.Seat per pax AC	Target Seats per Pax AC	Act. ASK (m)	Target ASK (m)	Act.Pax LF (%)	Target Pax LF (%)	Percent Seat Capacity	Percent Seats per Pax AC	Percent ASK (m)	Percent Pax LF (%)
OW	Air berlin	39.850	22.104	267	148	59.030	68.406	83	83	-44,50	-44,50	15,90	0,00
	American	163.372	152.015	166	134	439.891	439.891	82	83	-7,00	-19,20	0,00	1,20
	British	63.288	54.322	227	195	170.917	170.917	81	82	-14,20	-14,20	0,00	0,70
	Cathay Pacific	45.467	42.935	279	232	134.711	134.711	83	83	-5,60	-17,00	0,00	0,00
	Finnair	9.222	8.866	205	197	30.889	30.889	80	80	-3,90	-3,90	0,00	0,00
	Japan	40.138	27.444	179	123	84.003	84.003	72	78	-31,60	-31,60	0,00	9,10
	Qantas	53.823	45.396	175	147	141.715	141.715	77	83	-15,70	-15,70	0,00	6,90
	Royal J.	4.171	3.845	154	142	11.600	11.600	69	71	-7,80	-7,80	0,00	3,50
	Srilankan	4.544	4.544	216	216	16.180	16.180	80	80	0,00	0,00	0,00	0,00
	Tam	57.653	42.120	185	135	130.201	130.201	83	83	-26,90	-26,90	0,00	0,00
	OW AVG	481.527	403.591	205	167	1.219.137	1.228.514	79	81	-16,19	-18,71	0,77	1,99
SA	Aegean	7.000	6.806	140	136	12.194	17.910	78	78	-2,80	-2,80	46,90	0,00
	Air Canada	44.450	44.450	122	122	136.842	136.842	83	83	0,00	0,00	0,00	0,00
	Air China	89.130	64.604	172	124	193.631	193.631	80	83	-27,50	-27,50	0,00	4,40
	Air New Zealand	13.787	13.787	130	130	33.396	33.396	84	84	0,00	0,00	0,00	0,00
	Ana	50.764	34.713	219	150	109.700	109.700	68	81	-31,60	-31,60	0,00	19,20
	Austrian	10.493	9.984	140	133	23.343	25.973	79	79	-4,80	-4,80	11,30	0,00
	Avianca	22.092	16.374	122	119	41.052	41.052	79	79	-25,90	-2,30	0,00	0,00
	Copa	13.310	12.863	136	131	38.442	38.442	77	77	-3,40	-3,40	0,00	0,00
	Croatia	1.380	1.380	115	115	1.938	1.938	69	69	0,00	0,00	0,00	0,00
	Egypt Airlines	12.393	6.764	191	115	17.544	17.544	63	70	-45,40	-39,50	0,00	10,60
	Ethiopian	9.755	9.755	155	155	33.257	33.257	74	74	0,00	0,00	0,00	0,00
	Lufthansa Pax Group	107.188	90.280	180	152	268.105	268.105	80	83	-15,80	-15,80	0,00	3,30
	Scandinavian	22.153	16.342	161	118	45.158	45.158	77	77	-26,20	-26,20	0,00	0,00
	Singapore	32.579	32.579	310	310	120.001	120.001	79	79	0,00	0,00	0,00	0,00
	South African	11.590	9.884	193	165	33.999	33.999	75	75	-14,70	-14,70	0,00	0,00
	Thai	29.056	23.231	291	232	82.969	82.969	69	77	-20,00	-20,00	0,00	11,70
	Turkish	48.163	42.463	191	169	135.330	135.330	79	82	-11,80	-11,80	0,00	4,20
	United	157.892	157.892	126	126	455.631	455.631	84	84	0,00	0,00	0,00	0,00
	SA AVG	683.174	594.151	172	150	1.782.533	1.790.878	76	79	-13,03	-12,60	0,47	2,70
ST	Aeroflot	28.788	26.286	186	170	85.800	85.800	78	78	-8,70	-8,70	0,00	0,20
	Aero Mexico	14.799	14.799	119	119	36.217	36.217	80	80	0,00	0,00	0,00	0,00
	Air Europa	7.501	7.501	169	169	24.486	24.486	84	84	0,00	0,00	0,00	0,00
	Air France KLM	103.407	102.600	194	157	292.088	292.088	85	85	-0,80	-19,30	0,00	0,00
	China Eastern	80.317	56.999	166	121	160.585	160.585	80	80	-29,00	-27,10	0,00	0,00
	China Southern	100.374	72.986	167	121	209.807	209.807	79	79	-27,30	-27,30	0,00	0,00
	Delta	168.424	168.424	133	133	443.880	443.880	85	85	0,00	0,00	0,00	0,00
	Garuda Indonesia	28.920	18.209	171	117	50.155	50.155	72	72	-37,00	-31,90	0,00	0,00
	Kenya	8.449	5.780	169	116	15.406	15.406	64	70	-31,60	-31,60	0,00	10,60
	KLM	35.992	35.992	191	191	105.755	105.755	87	87	0,00	0,00	0,00	0,00
	Korean Air	31.271	26.329	258	218	90.979	90.979	75	78	-15,80	-15,80	0,00	3,80
	ST AVG	608.242	535.905	175	148	1.515.158	1.515.158	79	80	-11,89	-15,23	0,00	1,12

When model 5 is considered, its results show that fuel cost is to be reduced by 45.9%, seat capacity is to be decreased by 27.52%, seat per passenger aircraft needs improvement of -23.84% and RPK is required to increase by 2.93%. If the target results of model 6 are examined, it indicates that 37.75% reduction is targeted in fuel cost, 28.88% decrease in seat capacity is required, seat per passenger aircraft is to be 28.32% less whereas load factor is to increase 5.04% and ASK is to remain same. If these results of the same input variables are detected it means that model 6 requires more fuel than model 5; however, less seat per aircraft relative to model 6 is ideal for DMUs to efficiently operate according to model 6. Reversely, model 5 requires less fuel and more seats per aircraft compared to model 6. Since they have almost same seat capacity target, it is neglected in comparison of model 5 and model 6. If less seats per aircraft but more fuel is used to produce the same amount of ASK but with the higher output variable of load factor, its interpretation is that it refers to more frequencies for model 6 than model 5. However, if the result requires less fuel cost but more seats per aircraft, it may point out increase in average stage length, which is the average distance flown by the aircraft of an airline, for model 5 with respect to model 6. In order to obtain precise conclusion, regression analysis against stage length and frequency can be performed in order to identify their relations with the models.

Table 25 provides the average percentage of improvements for each alliance according to models 1, 2, 3 and 4 with standard efficiency calculations of BCC method. Accordingly, all alliances are observed to reduce their seat capacity around 10%. Sky Team is found to be the alliance with less excess amount of input compared to the other two alliances; however, it is also found to increase its output RPK. Star Alliance is observed as the alliance with more excess amount of input with

respect to its competitors. The results imply that airlines need to operate narrower fleets of smaller aircraft with lower fuel costs in order to operate efficiently. It is also found that the industry which is represented by 60% with the sample under consideration has an excess amount of 23.04% fuel cost, 12.41% seat capacity and 18.32% seat per aircraft.

Table 25. Average improvements for alliances

Alliance	% Fuel	% Seat Capacity	% Seats per Pax AC	% RPK	% ASK	% LF
OW	-18.24	-11.98	-19.09	0.25	0.84	1.36
SA	-29.68	-15.08	-20.38	0.17	0.23	2.11
ST	-18.51	-9.76	-13.87	16.20	0.00	1.15
AVG	-23.04	-12.41	-18.23	5.30	0.32	1.64

In addition to average improvement proportions are demonstrated in Table 26 prepared according to standard efficiency results of models 1, 2, 3 and 4. It is seen that most of the airlines need reductions in their inputs in varying proportions. Air berlin, for example, needs to reduce its fuel cost by 1.55%, seat capacity by 44.11% and seats per aircraft by 41.25% in order to be able operate efficiently.

Table 26. Average improvements for airlines

Unit Name	% Fuel	% Seat Capacity	% Seats per Pax AC	% RPK	% ASK	% LF
Aegean	-8.67	-17.19	-9.45	0.00	23.44	0.00
Aeroflot	-34.98	-10.44	-22.71	0.00	0.00	0.10
Aero Mexico	0.00	0.00	0.00	0.00	0.00	0.00
Air Canada	0.00	0.00	0.00	0.00	0.00	0.00
Air China	-45.40	-28.24	-29.11	0.00	0.00	2.19
Air Europa	0.00	0.00	0.00	0.00	0.00	0.00
Air France-KLM Group	-8.57	-4.93	-11.37	0.00	0.00	0.00
Air New Zealand	-3.28	-5.41	-4.35	0.00	0.00	0.00
Air berlin	-1.55	-44.11	-41.25	0.00	7.94	0.00
American	0.00	-3.48	-4.80	0.00	0.00	0.58
Ana	-36.86	-37.70	-37.28	0.00	0.00	16.19
Austrian	-9.99	-12.25	-10.57	0.00	5.63	0.00
Avianca	-12.33	-30.63	-3.42	0.00	0.00	0.00
British	-17.34	-8.84	-19.06	0.00	0.00	0.34
Cathay Pacific	-51.20	-2.78	-29.88	0.00	0.00	0.00
China Eastern	-28.25	-17.77	-18.11	50.21	0.00	0.00
China Southern	-29.97	-18.79	-20.19	40.69	0.00	0.00
Copa	-6.41	-7.64	-7.03	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00
Delta	-6.79	-3.13	-2.60	1.30	0.00	0.00
Egypt Airlines	-62.03	-31.63	-33.56	0.49	0.00	10.63
Ethiopian	-50.86	-1.21	-12.40	7.12	0.00	0.00
Finnair	0.00	-1.93	-0.96	0.00	0.00	0.00
Garuda Indonesia	-15.60	-18.52	-15.77	0.00	0.00	1.63
Japan	-22.14	-25.32	-23.73	0.00	0.00	8.27
Kenya	-28.14	-15.80	-15.84	0.00	0.00	10.03
KLM	-4.46	-0.19	-2.32	29.59	0.00	0.00
Korean Air	-34.80	-19.40	-29.85	54.28	0.00	3.12
Lufthansa Pax Airlines Group	-21.35	-19.28	-20.32	0.00	0.00	3.10
Qantas	0.00	-9.46	-4.73	0.00	0.00	3.46
Royal Jordanian	-28.79	-3.91	-8.31	0.00	0.00	2.11
Scandinavian	-0.82	-25.05	-12.94	0.00	0.00	0.00
Singapore	-40.47	-1.92	-27.54	0.00	0.00	0.00
South African	-36.54	-17.06	-26.53	1.97	0.00	0.00
SriLankan	-34.52	0.00	-17.26	18.52	31.25	0.00
Tam	-27.08	-20.81	-23.95	0.00	0.41	0.00
Thai	-63.09	-26.53	-42.89	0.00	0.00	7.92
Turkish	-36.83	-14.84	-25.84	0.00	0.00	2.08
United	0.00	0.00	0.00	0.00	0.00	0.00

DEA is not only capable of providing relative efficiency scores and improvement figures, but it also provides benchmarking (see Appendix C). In this regard, for model 1, Japan of One World takes its alliance-mate Qantas as reference; however, it also learns from Aeromexico and Air Europa from Sky Team while Turkish Airlines of Star Alliance has American Airlines, United Airlines and Aero Mexico as the benchmarking peers. One World's benchmarking peer is again One World with 13 peers and Sky Team with its six peers. Like One World, Star Alliance and Sky Team member airlines are taking their own alliance members as reference the most. However, for super-efficiency calculations where even efficient DMUs take references to become super-efficient, Star Alliance becomes benchmarking peers for Star Alliance 24 times, One World has a 12 benchmarking frequency for its own and Sky Team takes Star Alliance reference with a frequency of eight times.

Star Alliance becomes the reference alliance for all three alliances for model 2 (see Appendix C). Members of Star Alliance are met 13 times with One World, 31 times with Star Alliance and 13 times with Sky Team. However, in super-efficiency calculations, these frequencies become 17, 32 and 19, respectively.

One World becomes leader in benchmarking matching although Sky Team peers become those from its own alliance most for model 3 (see Appendix C). One World is observed as the reference alliance for Star Alliance with a reference number of 23, which implies that One World is utilizing seat capacity for its production better than Star Alliance, which is also proved by the improvement rates of seat capacity as -7.73% for One World and -17.13% for Star Alliance. The benchmarking frequencies led by One World are observed to be 17 for One World, 34 for Star Alliance and 20 for Sky Team for super-efficiency calculations.

Star Alliance becomes leader in benchmarking for efficiency for model 4 such that it is referenced by One World, Star Alliance and Sky Team 20 times, 35 times and 17 times, respectively (see Appendix C). Super efficiency results for Star Alliance are 21 times for One World, 38 times Star Alliance and 19 times for Sky Team.

Table 27 summarizes the benchmarking peer results for all models and for all the three alliances. Besides, super efficiency results are also included in the table due to the fact that even efficient airlines with scores of 100 and above have benchmarking peers to become super-efficient results depict that Star Alliance, with an overall frequency average of 48, is the alliance of which members are taken reference by the members of other two alliances most.

Table 27. Reference Frequencies for Each Alliance as per the Results of BCC Approach

	Model 1			Model 2			Model 3			Model 4			Overall AVG
Reference Frequency	STE	SPE	AVG	STE	SPE	AVG	STE	SPE	AVG	STE	SPE	AVG	
OW	30	34	32	21	22	22	45	54	50	4	5	5	27
SA	23	37	30	57	68	63	23	25	24	72	78	75	48
ST	22	13	18	15	18	17	16	16	16	23	28	26	19

In addition to alliance reference frequency performances, airlines performances are also provided in Table 28. Accordingly, totally 351 and 398 reference frequencies for efficiency are observed for standard efficiency and super efficiency results for models 1, 2, 3 and 4. Among the reference units, United Airways ranks first with its 58 average reference frequency.

Table 28. Reference Units and Their Frequencies for Model 1, 2, 3 and 4 as per the Results of BCC Approach for Super- and Standard Efficiency Results

Reference Unit	STE Reference Frequency	SPE Reference Frequency	Average
United	54	62	58
Croatia	50	56	53
Aero Mexico	42	42	42
American	36	43	40
Air Canada	33	36	35
Qantas	27	31	29
Finnair	18	19	19
Singapore	16	16	16
Air New Zealand	12	15	14
Royal Jordanian	11	11	11
Air Europa	17	30	24
Ethiopian	8	8	8
Garuda Indonesia	6	5	6
SriLankan	5	8	7
KLM	5	9	7
Cathay Pacific	3	3	3
Delta	3	4	4
Kenya	2		2
Aegean	1		1
Air France KLM	1		1
Scandinavian	1		1
Total	351	398	375

The overall reference frequencies of DMUs are also found consistent with their ranks in efficiency scores as provided in Table 29, where Croatia has the highest score and followed by United Airlines and American Airlines.

Table 29. Overall Efficiency Scores of DMUs for Models 1, 2, 3 and 4 as per the Results of BCC Approach for Super- and Standard Efficiency Results

Unit Name	STE Average	SPE Average	Overall Average
Croatia	100	580	340
United	100	563	332
American	98	550	324
KLM	98	548	323
Delta	97	547	322
Air Europa	100	195	147
Kenya	84	139	112
Aero Mexico	100	124	112
Air New Zealand	96	110	103
Garuda Indonesia	84	108	96
Finnair	99	107	103
Srilankan	83	107	95
Air Canada	100	107	103
Qantas	95	102	99
Royal Jordanian	92	100	96
Avianca	97	97	97
Aegean	91	97	94
Air France-KLM Group	93	94	94
Copa	93	93	93
Austrian	89	89	89
Ethiopian	88	88	88
Scandinavian	87	88	87
British	87	87	87
Singapore	79	84	81
China Eastern	82	82	82
China Southern	80	80	80
Lufthansa Pax Airline Group	80	80	80
Aeroflot	77	77	77
Air berlin	77	77	77
Japan	76	76	76
Tam	76	76	76
Cathay Pacific	73	75	74
Turkish	74	74	74
South African	73	73	73
Korean Air	73	73	73
Air China	71	71	71
Egypt Airlines	66	66	66
Ana	63	63	63
Thai	57	57	57

To sum up, the efficiency scores of both the airlines and alliances differ from model to model. Although somewhere in this study model 5 and model 6 are also used in order to detect the effects of the input variables seat capacity and fuel on the efficiency scores, overall assessment is achieved through the models 1, 2, 3 and 4. According to these results, in overall, airlines need improvement in their inputs and outputs such that they are found to decrease fuel cost, seat capacity, seat per aircraft; however, they need to perform higher load factors. It cannot be stated that any alliance is operating efficiently; rather, they have efficient and non-efficient airlines. One World has an average standard efficiency score of 85.64; it is 83.51 for Star Alliance and 88.06 for Sky Team. Average super efficiency results are 135.71, 137.79 and 187.98, respectively, for these three alliances. If the improvement proportions are discussed, it is observed that Sky Team needs less reduction in its inputs such that it is to reduce its fuel cost by 18.51%, seat capacity by 9.76% and seat per aircraft by 13.87% whereas these numbers are 29.68%, 15.08% and 20.38% for Star Alliance, which is found to make most reductions in its inputs. The efficiency analysis is performed for 10 DMUs out of 15 members of One World, 18 DMUs among 28 of Star Alliance and 11 DMUs from 20 members of Sky Team. The efficiency scores find that 32.5% of One World, 25.0% of Star Alliance and 38.6% of Sky Team are relatively efficient. It is also found that Star Alliance has more reference units in average for the whole sample. The assessment also reveals that United Airlines, Croatia Airlines, Air Europa, Aero Mexico, and SriLankan Airlines are the units that found relatively efficient for the all four models.

In order to compare the relative efficiency results between the years 2014 and 2013, model 2 is selected and DEA analysis is performed for the same 39-unit sample in order to observe the fuel cost on relative efficiency results. Since the focus

here is to measure the effect of fuel cost, a model with fuel cost as the input variable is to be chosen. Additionally, since 2014-year results are found to put emphasis on load factor, it carries importance to have load factor as the output variable. Therefore, the analysis for model 2 is performed for the year 2013 and the results are presented in Table 30. When these results are compared with the scores of 2014, it is found that overall average relative efficiency scores increases from 78 to 81 in 2014. Average efficiency score of One World is observed to increase from 74 in 2013 to 80 in 2014. Similarly, relative efficiency score of Star Alliance increases from 77 in 2013 to 82 in 2014. In contrast, efficiency score of Sky Team decreases from 85 in 2013 to 82 in 2014.

Table 30. Efficiency Scores for the Year 2013 for Model 2 Employing BCC Method

Alliance	Unit Name	STE Score	SPE Score	Average
OW	Air berlin	100	129	115
	American	93	93	93
	British	74	74	74
	Cathay Pacific	44	44	44
	Finnair	68	68	68
	Japan	68	68	68
	Qantas	100	110	105
	Royal Jordanian	71	71	71
	SriLankan	57	57	57
	Tam	65	65	65
	OW Average	74	78	76
SA	Aegean	65	65	65
	Air Canada	100	115	107
	Air China	68	68	68
	Air New Zealand	100	122	111
	Ana	63	63	63
	Austrian	91	91	91
	Avianca	97	97	97
	Copa	91	91	91
	Croatia	100	146	123
	Egypt Airlines	59	59	59
	Ethiopian	65	65	65
	Lufthansa Pax Airline Group	82	82	82
	Scandinavian	81	81	81
	Singapore	55	55	55
	South African	59	59	59
	Thai	39	39	39
	Turkish	62	62	62
	United	100	1000	550
	SA Average	77	131	104
ST	Aeroflot	61	61	61
	Aero Mexico	99	99	99
	Air Europa	100	314	207
	Air France-KLM Group	100	101	100
	China Eastern	72	72	72
	China Southern	74	74	74
	Delta	100	1000	550
	Garuda Indonesia	100	1000	550
	Kenya	76	76	76
	KLM	100	1000	550
	Korean Air	47	47	47
	ST Average	85	349	217
	Overall Total	78	186	132

The overall improvement numbers are seen in the Figure 19. If these numbers are compared with the results of the year 2014, it is found that 35.42% reduction in fuel cost is required in 2013 whereas it is 24.91% in 2014 for model 2. The analysis also requires a notable increase in the output variable ASK as presented in Figure 19.

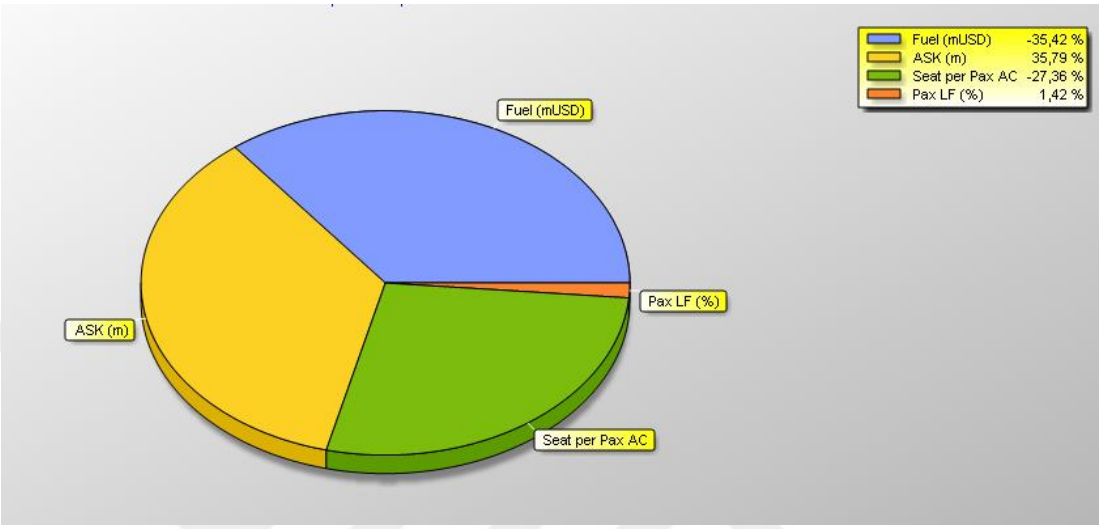

Figure 19. Improvement ratios for model 2 for the year 2013 under VRS conditions

However, if model 6 is performed in order to increase discriminative power of the results, improvement numbers in Figure 20 are observed. Accordingly, when 2014 year results are compared with the percentages in Figure 20, it is found that 46.33% reduction in fuel cost is required for the year 2013 whereas it is 37.75% for 2014 for model 6. Seat capacity is also to decrease by 22.26% and seat per aircraft is to reduce by 24.88%. The overall average efficiency score for 2013 under VRS conditions is found to be 89.01 which is slightly different from the average score of 2014 which is 89.95.

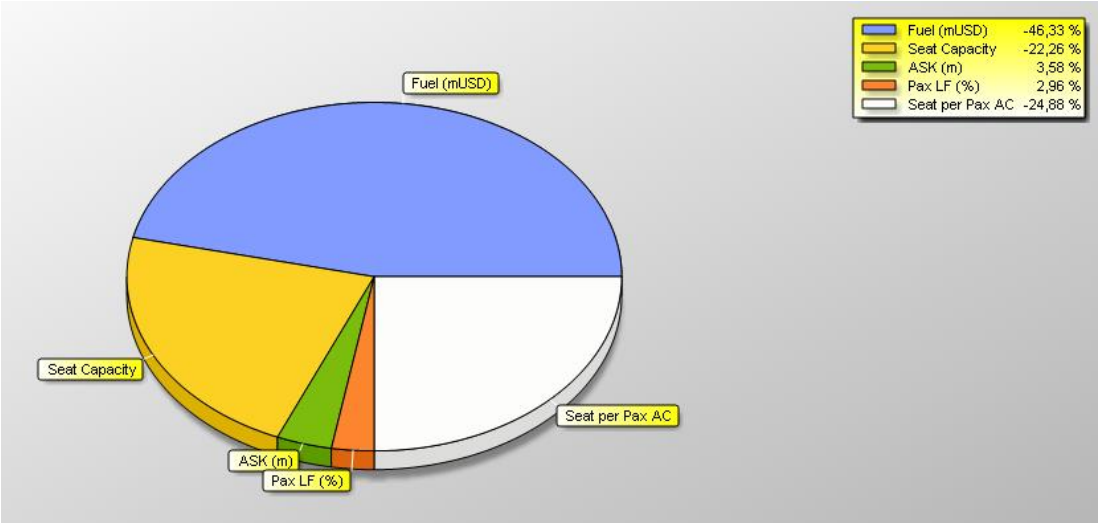

Figure 20. Improvement ratios for model 6 for the year 2013 under VRS conditions

SriLankan and Tam airlines are also included in 2013-year analyses in order to be able to compare their efficiency scores with 2014-year scores. SriLankan's efficiency score is 58 and Tam has an efficiency score of 66 for 2014. These results do not significantly differ from the results of the year 2013, which are 57 and 65, respectively. Since, it has been only one year in 2014 that these airlines join in the alliance; an observable impact of joining might be expected for the incoming years.

Since DEA measures relative efficiencies rather than absolute efficiencies, the comparison of the results of years 2013 and 2014 is not a one-to-one comparison. Additionally, these figures are calculated under the assumption of all-other-things-being-equal, which is not possible for the airline industry which is affected by so many factors from terrorism to growth rates and from rise of low cost carriers to currency fluctuations.

CHAPTER 8

EFFICIENCY ANALYSIS OF TURKISH FLAG CARRIER IN THE PRESENCE OF ITS LOW COST AIRLINE

Turkish flag carrier Turkish Airlines (TA) is found to have an average efficiency score of 74 for the main four models at the global scale and TA is not observed efficient for any model. The overall improvement portions TA needs to have as reductions in its inputs to be efficient are 36.83% in fuel cost, 14.84% in seat capacity and 25.84% in seat per aircraft. The scope of this study is the direct members of any three alliances under consideration. Therefore, subsidiary alliances or other subsidiaries under the parent company are not included in this study to the most extent possible where the limit is data availability. Since Turkish Airlines is the direct member of Star Alliance regardless of its subsidiaries, the analyses are performed for the full service carrier Turkish Airlines. This chapter detects the efficiency score of Turkish Airlines in detail for the year 2014 and aims to observe its efficiency status under the presence of its low cost carrier Anadolu Jet.

The analyses in this chapter are conducted for the models 3 and 4 due to the fact that fuel cost cannot be used as the input variable since the data are not available separately. Even if it was available, TA's data would include fuel cost of Turkish Cargo since Turkish Cargo is not a separate entity and the fuel cost announced is in consolidated form. In order to reach more accurate and neat results, models employing seat capacity and seat per aircraft as the input variables are analyzed. Table 31 presents the efficiency scores of the whole sample including Turkish Airlines Inc., the parent company with figures of Anadolu Jet[12]. The assessment

[12] Anadolu Jet December 31, 2014, figures are 27 AC, 4905-seat capacity, ASK of 7814, RPK of 6519, LF of 84% and seat per passenger AC of 182 (Turkish Airlines, 2014).

shows that Turkish Airlines, Inc. has lower efficiency scores with respect to its full cost carrier. Previous scores are 88.17 and 82.15 for models 5 and 6; however, they are 80 and 86, respectively, with the aggregate data including TA and Anadolu Jet.

Table 31. Efficiency Score and Rating of Turkish Airlines at the Global Scale

Unit Name	Model 3	Model 4
Aeroflot	88	91
Aero Mexico	100	100
Aegean	82	97
Air Canada	100	100
Air China	71	72
Air Europa	100	100
Air France-KLM Group	91	99
Air New Zealand	89	100
Air berlin	56	55
American	100	93
Ana	56	68
Austrian	83	95
Avianca	95	98
British	96	86
Cathay Pacific	100	94
China Eastern	93	73
China Southern	90	73
Copa	88	97
Croatia	100	100
Delta	95	100
Egypt Airlines	82	61
Ethiopian	98	100
Finnair	100	96
Garuda Indonesia	100	68
Japan	81	68
Kenya	100	68
KLM	100	100
Korean Air	77	84
Lufthansa Pax Airline Group	77	84
Qantas	97	84
Royal Jordanian	100	92
Scandinavian	76	74
Singapore	96	100
South African	81	85
Srilankan	100	100
Tam	85	73
Thai	67	80
Turkish Inc.	80	86
United	100	100

Including Anadolu Jet data and Turkish Airlines under the roof of one airline and employing the analyses do not change the efficiency scores significantly. If Anadolu Jet and the full cost carrier are included in the sample separately, how will be the results? What will be the rank of Anadolu Jet within other airlines?

Table 32 presents the efficiency scores at the global scale under the presence of Anadolu Jet. Anadolu Jet has an efficiency score of 85 for the third model and it is efficient as per the results of model 4, which has ASK and load factor as the output variables. In order to be able to observe the ranks as well, super-efficiency analysis is conducted. Anadolu Jet ranks sixth out of 12 efficient DMUs. The reason to why Anadolu Jet is found relatively efficient for model 4 rather than model 3 may lie in its high load factor, 84%.

Table 32. Efficiency Scores of the Global Sample under the Presence of Anadolu Jet

Unit Name	Model 3	Model 4
Aeroflot	88	91
Aero Mexico	138	117
Aegean	82	97
Air Canada	101	109
Air China	71	72
Air Europa	122	302
Air France-KLM Group	91	99
Air New Zealand	89	126
Air berlin	56	55
American	1000	93
Ana	56	68
Anadolu Jet	85	148
Austrian	83	95
Avianca	95	98
British	96	86
Cathay Pacific	106	94
China Eastern	93	73
China Southern	90	73
Copa	88	97
Croatia	302	303
Delta	95	1000
Egypt Airlines	82	61
Ethiopian	98	103
Finnair	106	96
Garuda Indonesia	112	68
Japan	81	68
Kenya	121	68
KLM	100	1000
Korean Air	77	84
Lufthansa Pax Airline Group	77	84
Qantas	97	84
Royal Jordanian	131	92
Scandinavian	76	74
Singapore	96	119
South African	81	85
Srilankan	165	131
Tam	85	73
Thai	67	80
Turkish	82	88
United	127	1000

In addition to global scale, position of Anadolu Jet in Star Alliance is also investigated. Table 33 provides the super-efficiency results. Accordingly, Anadolu Jet has scores of 664 and 271 for model 3 and model 4, respectively. Anadolu Jet ranks second within six efficient airlines for model 3 and fourth within eight efficient Star Alliance airlines. Additionally, Anadolu Jet is found to be reference for Croatia Airlines, Ethiopian Airlines, Scandinavian Airlines, South African Airlines, Thai Airways and Turkish Airlines for model 3, and Aegean Airlines, Austrian Airlines, Croatia Airlines, Ethiopian Airlines, and South African Airlines for model 4.

Table 33. Efficiency Scores of Members of Star Alliance in the Presence of Anadolu Jet

Unit Name	Model 3	Model 4
Aegean	82	97
Air Canada	107	110
Air China	71	72
Air New Zealand	89	1000
Ana	57	68
Anadolu Jet	664	271
Austrian	83	91
Avianca	95	100
Copa	90	98
Croatia	355	355
Egypt Airlines	87	61
Ethiopian	117	106
Lufthansa Pax Airline Group	81	84
Scandinavian	98	75
Singapore	114	119
South African	99	87
Thai	75	80
Turkish	85	88
United	1000	1000

To sum up, the low cost carrier subsidiary of Turkish Airlines, namely Anadolu Jet, is observed efficient both at the global scale and alliance scale. This result is in line with the visions of a full cost carrier and its low cost airline. Turkish Airlines has targets for sustained growth and most envied service level along with its cost reduction goals (investor.turkishairlines.com) and it is selected as the best airlines in

service quality by the passengers according to the surveys conducted by different organizations. High service quality including in-flight and ground services, many international destinations to operate flights to, and sustainable growth may make it hard for airlines to operate efficiently. However, low cost carriers, although providing satisfactory service level with respect to industry standards, may have the room to operate more efficiently. The result of this analysis also proves that airlines with smaller aircraft and smaller fleet may operate efficiently as in the case of Anadolu Jet with smaller fleet of narrower aircraft with respect to its parent company Turkish Airlines.

CHAPTER 9

CONCLUSION

The aim of this study is to measure relative efficiencies of three international airline alliances, namely Star Alliance, One World and Sky Team, which capture together more than 60 percent of airline industry. The main year of analysis is 2014, when jet fuel prices deepen in line with oil prices after its peak in 2012. 2014 is also the year of political crisis in the Middle East and Ukraine and Ebola epidemic in West Africa and aircraft crashes. The analysis is also performed in a limited framework for the year 2013 in order to compare the results of two years. Since availability of data is a major constraint in empirical analyses, some airlines are not included in the sample due to lack of sufficient data. The study has a sample of 39 DMUs, which is composed of both airline groups and individual airlines, out of totally 63 members, corresponding to more than 90 % of total ASK and RPK results of the alliances, and 57 percent and 61 percent of world's total ASK and RPK, respectively[13].

The method used in this study is data envelopment analysis with input-oriented method both under VRS and CRS conditions with standard efficiency and super-efficiency calculations. In efficiency measurements, variable selection is very important task in order to obtain reliable results. In this study, six different models are performed in order to observe the efficiency scores with different combinations of input and output variables. Input variables are fuel cost, seat per aircraft and seat capacity, and the output variables are RPK, ASK and load factor. Overall average efficiency scores, improvement proportions and benchmarking peers are assessed for both individual DMUs and the alliances correlation. Although there are six models in

[13] According to ICAO results, 7,713,768 million ASK is produced while RPK amount is 6,144,510 million.

the study, the fifth and sixth models are used in order to identify the effects of the input variables seat capacity and fuel on the efficiency scores when they exist together. The overall assessment is made according to the results of the four main models using either seat capacity or fuel cost as the input variable. The efficiency scores of both alliances and airlines vary from model to model. The first result derived from the analysis is that airline industry exhibits variable returns to scale rather than constant returns to scale which have been very much discussed in the literature by other researches so far. Due to the VRS nature of the industry, only of BCC method are analyzed in further detail. This study also reveals that airlines need improvements in their inputs and outputs. Generally, they are found to decrease their fuel costs, seats per aircraft and seat capacities; and, to achieve higher load factors in order to locate at the efficient frontier. Decreasing seat capacity and seats per aircraft implies that airlines are to operate smaller fleets with smaller aircraft. A policy implication may be a joint action of alliance partners in fleet planning along with network planning and to purchase or lease aircraft collaboratively. It is also derived from the analysis that efficiency scores of airlines decline when seat capacity is replaced by fuel cost, keeping the other variables. This might reflect more excess amount of fuel cost. Jet fuels constitute a high portion of airlines operational expenses with varying shares. Although fuel costs are determined globally and airlines can have impact to a limited degree, reduction can be achieved through several ways such as successful hedging and purchases in higher volumes. If the airlines gather and purchase the jet fuel needed for their operations collaboratively, then this might increase their bargaining power and result in lower prices. Joint purchasing can create a negotiating power through better deals with suppliers, not only for fuel or aircraft, but also for spare-parts, maintenance, airport charges, and

catering. Members enjoy the benefits of economies of scale as a result of bulk purchasing and sharing of resources. Such further joint efforts would increase the advantages of being an alliance member.

No alliance is found to be operating efficiently with an overall average of 100 score according to the main four models; rather, they have both efficient and non-efficient airlines. One World has an average standard efficiency score of 85.64, and it is 83.51 for Star Alliance and 88.06 for Sky Team. Regarding alliances' improvement proportions, all of them are observed to reduce their seat capacities by around 10%. Star Alliance is found to be the alliance which needs more reduction portions in its inputs compared to other two alliances. It is also found that the industry, which is represented by 60% with the sample under consideration, has an excess amount of 23.04% fuel cost, 12.41% seat capacity and 18.32% seat per aircraft. Additionally, average overall improvement results are also presented for each airline.

Results underline that 32.5% of the members of One World, 25.0% of Star Alliance and 38.6% of Sky Team are relatively efficient. It is also found that Star Alliance has more reference units in average as benchmarking peers for the whole sample, which is mostly due to the fact that most efficient airlines are found to be the members of Star Alliance which are referenced by the inefficient ones and even by efficient DMUs under super-efficiency calculations. However, it is to be noted that the weights of reference units in benchmarking carry significance as well as their frequencies, which is not reflected in the results of this study. The assessment also reveals that United Airlines, Croatia Airlines, Air Europa, Aero Mexico, and SriLankan Airlines are the airlines that found relatively efficient for all the four models. Another result found is that super-efficient airlines secure their super-

efficient positions in the presence of same output variables regardless of the input variables. American Airlines, United Airlines, Delta Airlines and KLM are found to be super-efficient airlines for different models under VRS conditions. However, results of some airlines are more sensitive to the variable selection and their efficient/inefficient positions may differ from model to model. While KLM and Austrian are examined separately from their group, Air France KLM and Lufthansa Passenger Airlines Group, it is observed that they perform with higher efficiency scores individually than their groups do.

The relative efficiency scores for the year 2013 are also observed for two models employing fuel cost as the input variable. Based on the model, airlines have lower overall efficiency scores in average in 2013 compared to 2014. Regarding improvements in fuel cost, it is 35.42% for 2013 and 21.64% for 2014, for model 2. Since DEA measures relative efficiency rather than absolute efficiency, it is hard to argue that alliances perform more efficiently in the year 2013 relative to 2014. However, the results reveal the decrease in jet fuel prices and airlines need less reduction in order to reach efficiency level.

A separate analysis is conducted for Turkish Airlines and its low cost subsidiary Anadolu Jet for models 3 and 4 to identify the efficiency status of Anadolu Jet within the sample. Another analysis is also conducted for the same two models for Star Alliance only to observe both Turkish Airlines and Anadolu Jet within the alliance. Although the full service carrier Turkish Airlines has lower efficiency scores than 100, Anadolu Jet is shown to be efficient for model 4 within the global sample and for both models within the alliance. Anadolu Jet has narrower fleet with smaller aircraft compared to its parent airline, Turkish Airlines. This result fits Turkish Airlines company strategy; (i) to provide highest quality service with

Turkish Airlines, and (ii) to achieve efficiency with its low cost carrier. The result also proves one of the findings of this study: Reduction in fleet and aircraft size required in order to operate efficiently.

Although there are numerous studies analyzing efficiency of airlines in the literature, these studies are airline specific and do not include alliance-specific analyses. Furthermore, the benchmarking peer analyses are generally neglected or discussed limitedly.

The contribution of this study to the literature is represented in various aspects. This research enables both airlines and the alliances to identify their relative positions in the industry, benchmarking partners and targets for potential improvement. The sample includes low cost carriers as well as 5-star full service carriers, state ownerships and fully privatized airlines from various regions of the world. Thus, it provides real-life conditions and a wide range of benchmarking peers from different geographical regions for comparison. Airline managers can utilize the results of DEA models and create solutions and investigate the ways to improve their efficiencies. By comparing the relative efficiency values and slacks with other DMUs, managers can set certain strategies to catch up, to increase operational performance and to become more competitive in the end. It is important to detect the inputs causing inefficiency as well as their level of impact. The results are expected to shed light for managers in line with their corporate policies and strategies. The slacks required to improve efficiency can be used as a roadmap for relocation of resources.

Choice of the input and output variables may affect the efficiency scores. Financial data such as EBIT or operating cost, for example, which are not variables of this study, may result in different scores and interpretations. Turkish Airlines,

Lufthansa, British Airways, for example, are found efficient in a study with input variables of fuel cost, flight and ground asset, and operating cost and output variable of RTK (Lozano & Gutierrez, 2011). Since the sample has various airlines with different priorities, a full cost carrier for example focuses on service quality; however a low cost carrier is mostly interested in its cost, a privatized airline takes expenses into consideration more than a state owned airline since it is subsidized by the state, efficiency measures may gain interest according to the airlines' strategies.

There could be other factors that affect the efficiencies of airlines such as local crisis or local regulations. Airline industry may face different subsidized policies and taxation rules, which may seriously influence the financial performance and efficiency of the airlines. Further studies can investigate these discrepancies and make appropriate adjustments. Additionally, drivers of inefficiency can be determined utilizing regression analysis with the variables which are relevant but not directly included in the analyses of this study such as growth rate, age of company, year of joining, state ownership, and fleet age.

APPENDIX A

DATA CHARACTERISTICS OF THE AIRLINES

Only the legally independent entities within the companies are designated in Table 34. For example, Turkish Airlines has also cargo operations; however, since Turkish Cargo is not a legally independent airline, it is not separately noted.

Table 34. Data Characteristics of the DMUs for the year 2014

Airline	Consolidated or Company Data	Date of Data	Alliance and Year of Entry	Country
Aegean	Aegean Airlines and Olympic Air	31 Dec 2014	SA / 2010	Greece
Air Canada	Air Canada	31 Dec 2014	SA / 1997	Canada
Air China	Air China Cargo, Shenzhen Airlines, Air Macau,	31 Dec 2014	SA / 2007	China
Air New	Air New Zealand Ltd. and its subsidiaries	30 Jun 2014	SA / 1999	New Zealand
ANA	ANA	31 Mar 2015	SA / 1999	Japan
Austrian	Austrian Airlines	31 Dec 2014	SA / 2000	Austria
Avianca	Avianca Passenger and Avianca Cargo	31 Dec 2014	SA / 2012	Panama
Copa Airlines	Copa Airlines and Copa Colombia	31 Dec 2014	SA / 2012	Panama
Croatia	Company data	31 Dec 2014	SA / 2004	Croatia
Egyptair	Egyptair Airlines	30 Jun 2014	SA / 2008	Egypt
Ethiopian	Company data	30 Jun 2014	SA / 2011	Ethiopia
Lufthansa	Lufthansa Passenger Airlines, Swiss and Austrian	31 Dec 2014	SA / 1997	Germany
Scandinavian	Blue 1, SAS Cargo, SAS Denmark-Norway-	31 Oct 2014	SA / 1997	Sweden
Singapore	Singapore Airlines, Tigerair, Scoot Air, Silkair	31 Mar 2015	SA / 2000	Singapore
Singapore	Singapore Airlines and Singapore Cargo	31 Mar 2015	SA / 2000	Singapore
South African	South African Airlines and Mango Airways	31 Mar 2014	SA / 2006	South Africa
Thai Airways	Thai Airways and Thai Smile	31 Dec 2014	SA / 1997	Thailand
Turkish	Turkish Airlines	31 Dec 2014	SA / 2008	Turkey
United Airlines	United Airlines and regional carriers	31 Dec 2014	SA / 1997	USA
Air berlin	Air berlin and Leisure Cargo	31 Dec 2014	OW / 2012	Germany
American	American Airlines and US Airways	31 Dec 2014	OW / 1999	USA
British	British Airways	31 Dec 2014	OW / 1999	UK
Cathay Pacific	Cathay Pacific +Dragon Air	31 Dec 2014	OW / 1999	Hong Kong
Finnair	Finnair	31 Dec 2014	OW / 1999	Finland
Japan Airlines	Japan Airlines	31 Mar 2015	OW / 2007	Japan
Qantas	Qantas Domestic, Qantas International, Qantas	30 Jun 2014	OW / 1999	Australia
Royal	Royal Jordanian	31 Dec 2014	OW / 2007	Jordan
Sri Lankan	Sri Lankan Airlines	31 Mar 2015	OW / 2014	Sri Lanka
Tam Airlines	Latam Airlines Group	31 Dec 2014	OW / 2014	Brazil
Aeroflot	Aeroflot	31 Dec 2014	ST / 2006	Russia
Aero Mexico	Aero Mexico Airlines and Aero Mexico Connect	31 Dec 2014	ST / 2000	Mexico
Air Europa	Air Europa	31 Dec 2014	ST / 2007	Spain
Air France	Air France, KLM, Hop Airlines and Transavia	31 Dec 2014	ST / 2004	France
China Eastern	China Eastern	31 Dec 2014	ST / 2011	China
China Southern	China Southern, Xiamen Airlines, Shantou	31 Dec 2014	ST / 2007	China
Delta Airlines	Delta Airlines[14]	31 Dec 2014	ST / 2000	USA
Garuda	Garuda Indonesia and Citilink	31 Dec 2014	ST / 2014	Indonesia
Kenya Airways	Kenya Airways	31 Mar 2015	ST / 2007	Kenya
KLM	KLM	31 Dec 2014	ST / 2004	Netherlands
Korean Air	Korean Air	31 Dec 2014	ST / 2000	South Korea

[14] Operational data include also from those regional carriers as per capacity purchase agreements.

Table 35. Data Characteristics of the DMUs for the year 2013

Airline	Consolidated or Company Data	Date of Data
Aegean Airlines	Aegean Airlines	31 Dec 2013
Air Canada	Air Canada	31 Dec 2013
Air China	Air China Cargo, Shenzhen Airlines, Air Macau, Dalian Airlines and Air China	31 Dec 2013
Air New Zealand	Air New Zealand Ltd. and its subsidiaries	30 Jun 2013
ANA	ANA	31 Mar 2014
Austrian Airlines	Austrian Airlines	31 Dec 2013
Avianca	Avianca Passenger and Avianca Cargo	31 Dec 2013
Copa Airlines	Copa Airlines and Copa Colombia	31 Dec 2013
Croatia Airlines	Company data	31 Dec 2013
Egyptair Airlines	Egypt Airlines	30 Jun 2013
Ethiopian Airlines	Company data	30 Jun 2013
Lufthansa Passenger	Lufthansa Passenger Airlines, Swiss and Austrian Airlines	31 Dec 2013
Scandinavian	Blue 1, SAS Cargo, SAS Denmark-Norway-Sweden	31 Oct 2013
Singapore Airlines	Singapore Airlines, Tigerair, Scoot Air, Silkair	31 Mar 2014
Singapore Group	Singapore Airlines and Singapore Cargo	31 Mar 2014
South African	South African Airlines and Mango Airways	31 Mar 2013
Thai Airways	Thai Airways and Thai Smile	31 Dec 2013
Turkish Airlines	Turkish Airlines	31 Dec 2013
United Airlines	United Airlines and regional carriers	31 Dec 2013
Air berlin	Air berlin and Leisure Cargo	31 Dec 2013
American Airlines	American Airlines	31 Dec 2013
British Airways	British Airways	31 Dec 2013
Cathay Pacific	Cathay Pacific +Dragon Air	31 Dec 2013
Finnair	Finnair	31 Dec 2013
Japan Airlines	Japan Airlines	31 Mar 2014
Qantas	Qantas Domestic, Qantas International, Qantas Freight, Jetstar, Qantas Loyalty	30 Jun 2013
Royal Jordanian	Royal Jordanian	31 Dec 2013
Sri Lankan Airlines	Sri Lankan Airlines	31 Mar 2014
Tam Airlines	Latam Airlines Group	31 Dec 2013
Aeroflot	Aeroflot	31 Dec 2013
Aero Mexico	Aero Mexico Airlines and Aero Mexico Connect	31 Dec 2013
Air Europa	Air Europa	31 Dec 2013
Air France KLM	Air France, KLM, Hop Airlines and Transavia Airlines	31 Dec 2013
China Eastern	China Eastern	31 Dec 2014
China Southern	China Southern, Xiamen Airlines, Shantou Airlines, Zhuhai Airlines, Guizhou	31 Dec 2013
Delta Airlines	Delta Airlines[15]	31 Dec 2013
Garuda Indonesia	Garuda Indonesia and Citilink	31 Dec 2013
Kenya Airways	Kenya Airways	31 Mar 2014
KLM	KLM	31 Dec 2013
Korean Air	Korean Air	31 Dec 2013

[15] As previously explained within this chapter, operational data of Delta include also from those regional carriers as per capacity purchase agreements.

APPENDIX B

OPERATIONAL DATA FOR THE AIRLINES

Table 36. 2014 Year Operational Data

Airline	NR of Staff	Fuel Cost, m USD	NR of OPR AC	NR of OPR Pax AC	Seat Capacity	ASK, m	RPK, m	LF, %	Pax TRF, m	Seat per AC	Seat per Pax AC
Aegean	1988	334	50	50	7000	12194	9600	78	10	140	140
Air Canada	24400	2871	364	364	44450	136842	114113	83	39	122	122
Air China	68553	9156	531	519	89130	193631	154684	80	83	168	172
Air New Zealand	10546	718	106	106	13787	33396	28078	84	14	130	130
Ana	14314	3222	242	232	50764	109700	74221	68	50	210	219
Austrian	6067	538	75	75	10493	23343	18428	79	11	140	140
Avianca	20545	1346	196	181	22092	41052	32602	79	26	113	122
Copa	9267	821	98	98	13310	38442	29471	77	12	136	136
Croatia	967	74	12	12	1380	1938	1342	69	2	115	115
Egypt Arl	3443	2578	65	65	12393	17544	27971	63	7	191	191
Ethiopian	9166	2639	70	63	9755	33257	24726	74	7	139	155
Lufthansa Pax Arl Gr	54960	7655	595	595	107188	268105	214641	80	106	180	180
Scandinavian	12329	959	138	138	22153	45158	34714	77	29	161	161
Singapore	13920	3772	105	105	32579	120001	94209	79	19	310	310
South African	11491	1945	63	60	11590	33999	25606	75	9	184	193
Thai	24952	6053	102	100	29056	82969	57194	69	19	285	291
Turkish	19902	5858	261	252	48163	135330	106787	79	55	185	191
United	84000	11676	1257	1257	157892	455631	380695	84	138	126	126
Air berlin	8440	1251	149	149	39850	59030	59030	83	32	267	267
American	94400	10592	983	983	163372	439891	439891	82	146	166	166
British	39868	4430	279	279	63288	170917	170917	81	42	227	227
Cathay Pacific	25800	6368	188	163	45467	134711	134711	83	32	242	279
Finnair	3734	656	45	45	9222	30889	30889	80	10	205	205

Japan	31534	2476	224	224	40138	84003	84003	72	39	179	179
Qantas	30751	2874	308	308	53823	141715	141715	77	49	175	175
Royal Jordanian	4424	757	29	27	4171	11600	11600	69	3	144	154
Srilankan	6987	1122	21	21	4544	16180	16180	80	4	216	216
Tam	53072	4167	327	312	57653	130201	130201	83	68	176	185
Aeroflot	18981	3735	155	155	28788	85800	67100	78	24	186	186
Aero Mexico	12910	1485	124	124	14799	36217	28245	80	17	119	119
Air Europa	3068	638	45	45	7501	24486	20515	84	10	169	169
Air France-KLM Gr.	94666	7595	546	532	103407	292088	248483	85	87	189	194
China Eastern	43960	8027	497	485	80317	160585	127750	80	84	162	166
China Southern	82132	10000	612	602	100374	209807	166629	79	101	164	167
Delta	79655	13512	1271	1271	168424	443880	375817	85	129	133	133
Garuda Indonesia	8488	1560	169	169	28920	50155	35997	72	29	171	171
Kenya	3973	958	52	50	8449	15406	9793	64	4	162	169
KLM	30191	3229	198	188	35992	105755	91477	87	28	182	191
Korean Air	20543	3656	147	121	31271	90979	67948	75	23	213	258

Table 37. 2013 Year Operational Data

Airline	NR of Staff	Fuel Cost, m USD	NR of OPR AC	NR of OPR Pax AC	Seat Capacity	ASK, m	RPK, m	LF, %	Pax TRF, m	Seat per AC
Aegean	1459	26997	30	30	5348	9873	7800	79	7	178
Air Canada	24500	2733	352	352	41145	126997	105177	83	36	117
Air China	25830	8972	488	479	82261	175677	141968	81	78	172
Air New Zealand	10336	769	104	104	12958	33167	27733	84	13	125
Ana	14196	2991	231	222	48433	102497	68474	67	49	218
Austrian	6208	544	74	74	10318	22528	17709	79	11	139
Avianca	19153	1326	155	150	18529	38762	31200	81	25	124
Copa	8644	783	90	90	12054	35095	26915	77	11	134
Croatia	1076	79	12	12	1356	1922	1323	69	2	113
Egyptair ARL.	3141	2597	65	65	12393	18579	27685	67	8	191
Ethiopian	8000	2389	58	52	9172	30170	21358	72	6	176
Lufthansa Pax ARL GR.	55272	7940	602	602	105655	262682	209652	80	105	176
Scandinavian	14127	981	139	139	21980	44629	33451	75	30	158
Singapore	14160	4003	103	103	32087	120503	95064	79	19	312
South African	11462	1761	61	58	11314	33441	24880	74	9	195
Thai	25323	6168	100	98	28733	85655	63479	74	22	293
Turkish	18882	4947	233	224	42236	116433	91997	79	48	189
United	87000	12354	1265	1265	155673	454396	379969	84	139	123
Air berlin	8905	1288	140	140	38894	57250	48570	85	32	278
American	59550	7839	627	627	105556	286132	237821	83	87	168
British	38476	4763	278	278	62945	161444	131333	81	40	226
Cathay Pacific	24500	6177	181	155	43464	127215	104571	82	30	280
Finnair	3619	691	45	45	9204	31162	24776	80	9	205
Japan	31472	2528	220	220	39421	83319	59136	71	39	179
Qantas	33265	2702	312	312	54988	139909	110905	79	48	176
Royal Jordanian	4643	833	32	32	5081	12000	8400	70	3	159
Srilankan	6578	1279	21	21	4493	15781	12811	81	4	214
Tam	52997	4414	339	323	58943	131691	106466	81	67	182
Aeroflot	17890	3306	143	143	26998	76500	60200	79	21	189
Aero Mexico	13652	1380	117	117	13688	32496	24474	77	15	117

Air Europa	2746	570	41	41	6777	20945	17700	85	9	165
Air France- KLM	96417	7752	583	569	104893	292091	246029	84	86	184
China Eastern	42747	8162	465	451	73545	152075	120461	79	79	163
China Southern	80175	9455	561	551	87493	186800	148417	79	92	159
Delta	77755	11464	1275	1275	166752	431035	361118	84	120	131
Garuda Indonesia	7861	0	140	140	24068	43133	31950	74	25	172
Kenya	4003	1046	47	45	6711	14188	9309	66	4	149
KLM	30235	3267	202	192	36804	103793	89039	86	27	192
Korean Air	19470	3946	147	121	30914	89110	68361	77	24	255

APPENDIX C

BENCHMARKING PEERS

Table 38. Benchmarking Peers for Model 1: Standard Efficiency BCC Results

		Reference											
		OW				SA				ST			
Alliance	Referencing Units	American	Finnair	Qantas	Royal J.	Air	Croatia	Scandinavian	United	Aero Mexico	Air	Garuda I.	Kenya
OW	Air berlin		X	X									
	American	X											
	British	X		X									
	Cathay Pacific	X		X						X			
	Finnair		X										
	Japan			X						X	X		
	Qantas			X									
	Royal Jordanian				X								
	Srilankan									X	X		
	Tam	X		X						X			
OW Sum Per Reference Unit		4	2	6	1	0	0	0	0	4	2	0	0
OW Sum Per Alliance		13				0				6			
SA	Aegean	X				X	X						
	Air Canada					X							
	Air China						X		X				
	Air New Zealand	X		X			X						
	Ana	X		X			X						
	Austrian	X		X			X						
	Avianca						X		X				
	Copa	X		X			X						
	Croatia						X						
	Egyptair Arl.									X			
	Ethiopian									X			
	LH Pax Gr.	X							X	X			
	Scandinavian							X					
	Singapore			X						X	X		
	South African									X	X		
	Thai								X	X			
	Turkish	X							X	X			
	United								X				
SA Sum Per Reference Unit		7	0	5	0	2	8	1	6	7	2	0	0
SA Sum Per Alliance		12				17				9			

ST	Aeroflot	X							X	X					
	Aero Mexico									X					
	Air Europa										X				
	Air France-KLM Group	X		X					X						
	China Eastern								X				X		
	China Southern								X				X		
	Delta								X						
	Garuda Indonesia												X		
	Kenya														X
	KLM			X					X						
	Korean Air			X											
ST Sum Per Reference Unit		2	0	3	0	0	0	0	6	2	1	3	1		
ST Sum Per Alliance		5				6				7					

Table 39. Benchmarking Peers for Model 2: Standard Efficiency BCC Results

		Reference												
		OW			SA					ST				
Alliance	Referencing Unit	American	Finnair	Qantas	Aegean	United	Air	Air New	Croatia	Delta	KLM	Aeromexico	Air	AFL
OW	Air berlin			X			X	X						
	American	X												
	British	X		X			X							
	Cathay Pacific			X			X	X						
	Finnair		X											
	Japan			X			X		X					
	Qantas			X										
	Royal Jordanian					X			X					
	Srilankan							X	X			X		
	Tam						X	X				X		
		2	1	5	0	1	5	4	3	0	0	2	0	0
			8				13					2		
SA	Aegean				X									
	Air Canada						X							
	Air China					X			X			X		
	Air New Zealand							X						
	Ana			X			X		X					
	Austrian		X	X				X	X					
	Avianca						X	X	X			X		
	Copa		X	X				X	X					
	Croatia								X					
	Egyptair Arl.					X			X					
	Ethiopian					X			X			X		
	Lufthansa Pax Airline Group	X		X			X							
	Scandinavian		X	X				X	X					
	Singapore		X	X				X						
	South African					X			X			X		
	Thai					X			X					
	Turkish					X	X		X			X		
	United					X								
		1	4	6	1	7	5	6	12	0	0	5	0	0
			11				31					5		
ST	Aeroflot					X	X		X			X		
	Aero Mexico											X		
	Air Europa												X	
	Air France-KLM Group													X
	China Eastern					X			X			X		
	China Southern					X			X			X		
	Delta									X				
	Garuda Indonesia			X			X		X					
	Kenya					X			X					
	KLM										X			
	Korean Air			X			X		X					
		0	0	2	0	4	3	0	6	1	1	4	1	1
			2				13					8		

Table 40. Benchmarking Peers for Model 3: Standard Efficiency BCC Results

		Reference											
		OW					SA			ST			
Alliance	Referencing Unit	American	Cathay	Finnair	Royal	SriLankan	Air	Croatia	United	Aeromexico	Air	Garuda	Kenya
OW	Air berlin	X			X					X			
	American	X											
	British	X	X	X									
	Cathay Pacific		X										
	Finnair			X									
	Japan	X			X					X			
	Qantas	X		X	X								
	Royal Jordanian				X								
	Srilankan					X							
	Tam	X								X	X		
		6	2	3	4	1	0	0	0	3	1	0	0
				16				0			4		
SA	Aegean							X	X				
	Air Canada						X						
	Air China	X						X	X				
	Air New Zealand	X						X	X				
	Ana	X						X	X				
	Austrian							X	X				
	Avianca							X	X				
	Copa	X		X				X					
	Croatia							X					
	Egypt Arl.	X		X	X								
	Ethiopian	X			X					X			
	Lufthansa Pax Airline	X							X	X			
	Scandinavian	X			X					X			
	Singapore		X	X									
	South African	X		X	X								
	Thai	X		X	X								
	Turkish	X			X					X			
	United								X				
		11	1	5	6	0	1	8	8	4	0	0	0
				23				17			4		
ST	Aeroflot	X								X	X		
	Aero Mexico									X			
	Air Europa										X		
	Air France-KLM	X		X					X				

China Eastern								X				X		
China Southern								X				X		
Delta								X						
Garuda Ind.												X		
Kenya														X
KLM			X					X						
Korean Air	X		X					X						
	3	0	3	0	0	0	0	6	2	2	3	1		
			6				6			8				

Table 41. Benchmarking Peers for Model 4: Standard Efficiency BCC Results

		Reference										
		OW	SA						ST			
Alliance	Ref. Unit	Srilankan	Air	Air New	Croatia	Ethiopian	Singapore	United	Aero Mexico	Air	Delta	KLM
OW	Air berlin		X						X	X		
	American						X	X				
	British		X				X	X				
	Cathay P.						X	X				X
	Finnair	X				X	X			X		
	Japan		X		X	X						
	Qantas		X				X	X				
	Royal J.	X			X		X					
	Srilankan	X										
	Tam		X				X			X		X
		3	5	0	2	2	7	4	1	3	0	2
		3				20				6		
SA	Agean			X	X					X		
	Air Canada		X									
	Air China		X				X	X				
	Air New Zealand			X								
	Ana		X			X	X					
	Aurian				X				X	X		
	Avianca				X			X	X			
	Copa		X		X				X	X		
	Croatia				X							
	Egyptair				X			X				
	Ethiopian					X						
	LH Pax		X				X	X				
	Scandinavian		X		X			X	X			
	Singapore						X					
	South African	X				X	X			X		
	Thai		X			X	X					
	Turkish		X				X	X				
	United							X				
		1	8	2	7	4	7	7	4	4	0	0

		1				35					8		
ST	Aeroflot		X			X	X						
	Aeromexico									X			
	Air Europa										X		
	Air France-Klm Group								X			X	X
	China Eaern				X				X	X			
	China Southern		X		X				X	X			
	Delta											X	
	Garuda Indonesia				X				X	X			
	Kenya		X		X				X				
	Klm												X
	Korean Air		X			X	X						
		0	4	0	4	2	2	5	4	1	2	2	
		0				17					9		

REFERENCES

Aegean Airlines. (n.d.). *Annual report 2014*. Retrieved from http://en.about.aegeanair.com/-/media/aboutaegean/ir/ir_annual_reports/annual-report-en14_final_for-web.pdf

Aigner, D., Lovell, K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*, 21-37. Retrieved from http://pages.stern.nyu.edu/~wgreene/FrontierModeling/Reference-Papers/Aigner-Lovell-Schmidt-JE1977-ALS.pdf

Air Canada. (n.d.). *Annual report 2014*. Retrieved from https://www.aircanada.com/en/about/investor/documents/2014_ar.pdf

Air France KLM. (2015). *Annual financial report 2014.* Retrieved from http://www.airfranceklm.com/sites/default/files/publications/annual_financial_report_2014_-_air_france-klm.pdf

Alzahrani, J. S. (2015). *Measuring efficiencies and economic impact of air transportation sector in the U.S. economy using data envelopment analysis and Leontief Analysis* (PhD thesis). Retrieved from www.proquest.com

All Nippon Airways. (n.d.). *Annual report 2015.* Retrieved from http://www.anahd.co.jp/en/ investors/data/pdf/annual/15/15_e_00.pdf

Asiana Airlines. (2015). Sustainability report. Retrieved from https://us.flyasiana.com/C/pdf/Sustainability_2015_eng.pdf

Assaf, A. (2011). A fresh look at the productivity and efficiency changes of UK airlines. *Applied Economics, 43*, 2165-2175. doi:10.1080/00036840903085071

Austrian Airlines. (n.d.). *Annual results for 2014*. Retrieved from http://www.austrianairlines.ag/Press/PressReleases/Press/2015/03/018.aspx?sc_lang=en

Bai, C., Leung, N., Leung, P., & Wu, Y. (n.d.). *Global airlines* [PowerPoint Slides]. Retrieved February 21, 2016 from http://www.sfu.ca/~poitras/419_airlines_15-2.pptx

Barbot, C., Costa, A., & Sochirca, A. (2008). Airlines performance in the new market context: A comparative productivity and efficiency analysis. *Journal of Air Transport Management, 14*, 270-274. doi:10.1016/j.jairtraman.2008.05.003

Barros, C., & Peypoch, N. (2009). An evaluation of European airlines'operational performance. *International Journal of Production Economics, 122*, 525-533. doi:10.1016/j.ijpe.2009.04.016

Barros, C. P., & Wanke, P. (2015). An analysis of African airlines efficiency with two-stage TOPSIS and neural networks. *Journal of Airport Transport Management, 44-45*, 90-102. doi:10.1016/j.jairtraman.2015.03.002

Barros, C. P., Liang, Q. B., & Peyboch, N. (2013). The technical efficiency of US airlines. *Transportation Research Part A, 50*, 139-148. doi:10.1016/j.tra.2013.01.019

Belobaba, P. Odoni, A., & Barnhart, C. (2015). *The Global Airline Industry* (2nd ed.). Wiley.

Bhadra, A. (2009). Race to the bottom or swimming upstream: Performance analysis of US airlines. *Journal of Air Transport Management*, *15*, 227-235. doi:10.1016/j.jairtraman.2008.09.014

Boeing Commercial Airplanes. (2011). *MD-11 Airplane characteristics for airport planning.* Retrieved from http://www.boeing.com/ assets/pdf/ commercial/airports/acaps/md11.pdf

Boeing. (n.d.). *Current market outlook 2015 – 2034*. Retrieved from http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/assets/downloads/Boeing_Current_Market_Outlook_2015.pdf

British Airways Plc. (n.d.). *Annual report and accounts – Year ended 31 December 2014*. Retrieved from http://phx.corporate-ir.net/External.File?item= UGFyZW50SUQ9NTczNzgxfENoaWxkSUQ9Mjc2MjY2fFR5cGU9MQ== &t=1

Ceha, R., & Ohta, H. (2000). Productivity change model in the airline industry: A parametric approach. *European Journal of Operational Research*, *121*(3), 641-655. Retrieved from ScienceDirect.

Chang, Y., Park, H., Jeong, J., & Lee, J. (2014). Evaluating economic and environmental efficiency of global airlines: A SBM-DEA approach. *Transportation Research Part D: Transport and Environment, 27*, 46-50. doi:10.1016/j.trd.2013.12.013

Chao, C., & Li, R. (2015). Effects of cargo types and load efficiency on airline cargo revenues. *Journal of Air Transport Management*. doi:10.1016/j.jairtraman. 2015.11.006

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444. Retrieved from ScienceDirect.

Cui, Q., & Li, Y. (2015a). The change trend and influencing factors of civil aviation safety efficiency: The case of Chinese airline companies. *Safety Science, 75*, 56-63. http://dx.doi.org/10.1016/j.ssci.2015.01.015

Cui, Q., & Li, Y. (2015b). Evaluating energy efficiency for airlines: An application of VFB-DEA. *Journal of* Airport *Transport Management, 44-45*, 34-41. doi:10.1016/j.jairtraman.2015.02.008

Directorate General of Civil Aviation. (n.d.). Annual report 2013. Retrived from http://web.shgm.gov.tr/documents/sivilhavacilik/files/pdf/kurumsal/raporlar/2013_FAALIYET_RAPORU.pdf

Duygun, M., Prior, D., Shaban, M., & Tortosa-Ausina, E. (2016). Disentangling the European airlines efficiency puzzle: A network data envelopment analysis approach. *Omega, 60,* 2-14. http://dx.doi.org/10.1016/j.omega.2015.06.004

New York University Stern School of Business. (n.d.). *E62: Stochastic frontier models and efficiency analysis: Study guide.* New York, NY: Author. Retrieved from http://pages.stern.nyu.edu/~wgreene/FrontierModeling/SurveyPapers/LIMDEP-Chapter33.pdf

Egyptair Airlines. (n.d.). Annual report 2013-2014. Retrieved from http://www.egyptair.com/NewPages/Reports/2013-2014/airlines/index.html

Ethiopian Airlines. (n.d.a). *Annual report 2012/13*. Retrieved from http://www.ethiopianairlines.com/Cms_Data/Contents/EthiopianAirlines/Media/Corporate/Company/Reports/ET_Annual_Report_12_13.pdf

Ethiopian Airlines. (n.d.b). *Annual report 2013/14*. Retrieved from https://www.ethiopianairlines.com/Cms_Data/Contents/EthiopianAirlines/Media/Corporate/Company/Reports/EAL-REPORT_2013_14-oct-21.pdf

Fethi, M. D., Jackson, P. M., & Weyman-Jones., T. G. (2000). *Measuring the efficiency of European airlines: an application of DEA and Tobit Analysis*. Leicester, England: University of Leicester Efficiency and Productivity Research Unit. Retrieved from ResearchGate.

Finnair. (n.d.). *Annual report 2014*. Retrieved from http://www.finnairgroup.com/linked/en/konserni/Finnair_Annual_Report_A4_final.pdf

Francis, G., Humphreys, I., & Fry, J. (2005). The nature and prevalence of the use of performance measurement techniques by airlines. *Journal of Air Transport Management, 11*(4), 207-217. doi:10.1016/j.jairtraman.2004.10.003

Gerede, E. (2010). The evolution of Turkish air transport industry: Significant developments and impacts of 1983 Liberalization. *Yönetim ve Ekonomi, 17*(2). Retrieved from http://www2.bayar.edu.tr/yonetimekonomi/dergi/pdf/C17S22010/63_91.pdf

Garuda Indonesia. (n.d.). *Annual report 2014*. Retrieved from https://www.garuda-indonesia.com/files/pdf/investor-relations/report/2014.pdf

Ghosh, P., & Bandyopadhyay, G. (2014). Efficiency and ranking of operating no-frill airlines in Eastern India: An application of data envelopment analysis (DEA). *2nd International Conference on Business and Information Management (ICBIM)*. Durgapur, India: The Institute of Electrical and Electronics Engineer. doi:10.1109/ICBIM.2014.6970975

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega, 17*(3), 237-250. doi:10.1016/0305-0483(89)90029-7

Gong, Z., & Kim, T. S. (2015). Comparative analysis of operational efficiency of major airlines in Asia-Pacific region. *Journal of International Logistics and Trade, 13*(1), 3-21, 25-30. Retrieved from www.proquest.com

Grupo Aeromexico. (n.d.). *Reporte annual*. Retrieved from http://aeromexico.com/export/sites/default/es/descargas/inversionistas/Reporte_Anual_2014.pdf

Hollanders, H., & Esser, F. (2007). *Measuring Innovation Efficiency. INNO-Metrics Thematic Paper.* Retrieved from http://digitalarchive.maastrichtuniversity.nl /fedora/get/guid:46a68016-6c74-4576-b337-e00c41715756/ASSET1

Hossain, K., Kamil, A., Baten, A., & Mustafa, A. (2012). *Stochastic Frontier Approach and Data Envelopment Analysis to Total Factor Productivity and Efficiency Measurement of Bangladeshi Rice.* http://dx.doi.org/10.1371/journal.pone.0046081

Hussein, A., & Jones, M. (2010). *An introduction to Frontier Analyst 4.* Banxia Software Limited. Retrieved from http://www.banxia.com/pdf/fa/ FAWorkbook1.pdf

Inglada, V., Rey, B., Rodriguez-Alvarez, A., & Coto-Millan, P. (2006). Liberalization and efficiency in international air transport. *Transportation Research Part A: Policy and Practice, 40*(2), 95-105. doi:10.1016/j.tra.2005.04.006

International Civil Aviation Organization. (2015). *Tables Relating to the World of Air Transport in 2014*. Retrieved from http://www.icao.int/ annual-report-2014/Documents/Appendix_1_en.pdf

International Civil Aviation Organization. (n.d.). *Air Transport in Figures*. Retrieved from http://www.icao.int/ sustainability/documents/AirTransport-figures.pdf

Istanbul Technical University. (n.d.). *Types of aircraft lease: Study guide*. Istanbul, Turkey: Author. Retrieved from http://aviation.itu.edu.tr/img/aviation/datafiles/Lecture%20Notes/ AirLawRegulationsComplianceManagement20142015Spring/Readings/Module%2028_TYPES%20OF%20AIRCRAFT%20LEASE.pdf

Jain, R. K., & Natarajan, R. (2015). A DEA study of airlines in India. *Asia Pacific Management Review, 20*(4), 285-292. doi:10.1016/j.apmrv.2015.03.004

Jang, S., Choi, K., & Lee, K. (2011). External shocks and efficiency changes in the US airline industry. *Service Industries Journal*, *31*(14), 2411-2435. doi:10.1080/02642069.2010.504819

Joo, S., & Fowler, K. L. (2014). Exploring comparative efficiency and determinants of efficiency for major world airlines. *Benchmarking: An International Journal, 21*(4), 675-687. http://dx.doi.org/10.1108/BIJ-09-2012-0054

Junior, S., Rubem, A., Soares de Mello, J., & Meza, L. (2015). Evaluation of Brazilian airlines nonradial efficiencies and targets using an alternative DEA approach. *International Transactions in Operational Research, 23*(4), 669-689. doi:10.1111/itor.12162

KLM. (n.d.). *2014 annual report*. Retrieved from https://www.klm.com/corporate/nl/images/KLM_annual_report_2014_tcm730-579492.pdf

Korul, V., & Küçükönal, H. (2003). Türk Sivil Havacılık Sisteminin Yapısal Analizi. *Ege Academic Review, 3*(1), 24-38. Retrieved from www.acarindex.com/dosyalar/makale/acarindex-1423877167.pdf

Lee, B., & Worthington, A. C. (2014). Technical efficiency of mainstream airlines and low-cost carriers: New evidence using bootstrap data envelopment analysis truncated regression. *Journal of Air Transport Management, 38,* 15-20. doi:10.1016/j.jairtraman.2013.12.013

Li, Y., Wang, Y., & Cui, Q. (2015). Evaluating airline efficiency: An application of Virtual Frontier Network SBM. *Transportation Research, Part E: Logistics and Transportation Review, 81,* 1-17. doi:10.1016/j.tre.2015.06.006

Lita, I., & Stamule, T. (2011). Stochastic frontier analysis of production function and cost function estimation methods. Study of efficiency at industrial level. *Management and Marketing Challenges for the Knowledge Society, 6*(1), 163-179. Retrieved from http://www.managementmarketing.ro/pdf/articole/218.pdf

Lozano, S., & Gutierrez, E. (2011). A multiobjective approach to fleet, fuel and operating cost efficiency of European airlines. *Computers & Industrial Engineering, 61*(3), 473-481. doi:10.1016/j.cie.2011.04.001

Lozano, S., & Gutierrez, E. (2014). A slacks-based network DEA efficiency analysis of European Airlines. *Transportation Planning and Technology, 37*(7), 623-637. doi:10.1080/03081060.2014.935569

Lu, W., Wang, W., Hung, S., & Lu, E. (2012). The effects of corporate governance on airline performance: Production and marketing efficiency perspectives. *Transportation Research Part E: Logistics and Transportation Review, 48*(2), 529-544. doi:10.1016/j.tre.2011.09.003

Lufthansa Group. (n.d.). *Annual report 2014*. Retrieved from https://investor-relations.lufthansagroup.com/fileadmin/downloads/en/financial-reports/annual-reports/LH-AR-2014-e.pdf

Marti, L., Puertas, R., & Calafat, C. (2015). Efficiency of airlines: Hub and Spoke versus Point-to-Point. *Journal of Economic Studies, 42*(1), 157-166. http://dx.doi.org/10.1108/JES-07-2013-0095

Merkert, R., & Williams G. (2013). Determinants of European PSO airlines efficiency – Evidence from a semi-parametric approach. *Journal of Air Transport Management*, *29*, 11-16. http://dx.doi.org/10.1016/j.jairtraman.2012.12.002

Merkert, R., & Hensher, D. A. (2011). The impact of strategic management and fleet planning on airline efficiency- A random effects Tobit model based on DEA efficiency scores. *Transportation Research Part A: Policy and Practice*, *45*(7), 686-695. doi:10.1016/j.tra.2011.04.015

Michaelides, P. G., Belegri-Roboli, A., Karlaftis, M., & Marinos, T. (2009). International air transportation carriers: Evidence from SFA and DEA Technical Efficiency Results (1991-2000). *European Journal of Transport and Infrastructure Research, 9*(4), 347-362. Retrieved from www.ejtir.tbm.tudelft.nl/issues/2009_04/pdf/2009_04_02.pdf

Oum, T. H., & Zhang, A. (2001). Key aspects of global strategic alliances and the impacts on the future of Canadian airline industry. *Journal of Air Transport Management Part 7*(5), 287-301. doi: 10.1016/S0969-6997(01)00023-0

Oum. T. H., Fu X., & Yu C. (2005). New evidences on airline efficiency and yields: A comparative analysis of major North American air carriers and its implications. *Transport Policy, 12*(2), 153-164. doi:10.1016/j.tranpol.2005.01.002

Pires, H. M., & Fernandes, E. (2012). Malmquist financial efficiency analysis for airlines. *Transportation Research Part E: Logistics and Transportation Review, 48*(5), 1049-1055. http://dx.doi.org/10.1016/j.tre.2012.03.007

Rai, A. (2013). Measurement of efficiency in the airline industry using data envelopment analysis. *Investment Management and Financial Innovations*, *10*(1), 38-45. Retrieved from http://businessperspectives.org/journals_free/imfi/2013/imfi_en_2013_01_Rai.pdf

Ramsay, M., Stamp, J., Regueiro, J., Richards, D., & McGilvery, S. (2013). *2013 Airline Disclosure Handbook*. Retrieved from https://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/2013-airline-disclosures-handbook.pdf

Rigas, D. (2006). *The Airline Business* (2nd ed.). New York, NY: Routledge.

Royal Jordanian Airlines. (n.d.). *Annual report 2014*. Retrieved from http://www.rj.com/en/reports

Scandinavian Airlines. (n.d.). *Annual report with sustainability review.* Retrieved from http://www.sasgroup.net/en/wp-content/uploads/sites/2/2016/02/SAS-Annual-Report-2013-2014-B.pdf

Scherage, C. A. (2004). Operational efficiency versus financial mobility in the global airline industry: A data envelopment and Tobit analysis. *Transportation Research Part A: Policy and Practice*, *38*(5), 383-404. doi:10.1016/j.tra.2003.12.003

Seiford, L. M., & Zhu, J. (1999). An investigation of returns to scale in data envelopment analysis. *Omega International Journal of Management Science*, *27*(1), 1-11. Retrieved from http://www.deafrontier.net/papers/OMEGARTS.pdf

Semenick, I. M. (1994). *Issues in technical efficiency measurement with an application to the domestic airline industry* (PhD Thesis). Retrieved from https://scholarship.rice.edu/handle/1911/16880

Singh, A. (2014). *Virgin Atlantic – New Delhi to New York – 4 lessons in mobile Tech*. Retrieved from https://www.linkedin.com/pulse/ 20140727091708-4206613-virgin-atlantic-london-to-new-york-4-lessons-in-mobile-tech

Siregar, D., & Norsworthy, J. (2001). Pre- and post-deregulation financial performance and efficiency in U.S. airlines. *Change Management and the New Industrial Revolution*, 421-429, Albany, NY: The Institute of Electrical and Electronics Engineer. doi: 10.1109/IEMC.2001.960578

Sjögren, S., & Söderberg, M. (2010). Productivity of airline carriers and its relation to deregulation, privatization and membership in strategic alliances. *Transportation Research Part E: Logistics and Transportation Review, 47*(2), 228-237. doi:10.1016/j.tre.2010.09.001

Star Alliance. (2015). *Star Alliance – The way the Earth connects*. Retrieved from http://www.staralliance.com/documents/20184/22080/General+Star+Backgrounder/0e31a9c3-2a75-4091-b1ae-8324db1997d7

Thai Airways International. (n.d.). *Annual report 2014*. Retrieved from http://thai.listedcompany.com/misc/ar/20150326-thai-ar2014-en.pdf

Toloo, M., & Nalchigar, S. (2009). A new integrated DEA model for finding most BCC-efficient DMU. *Applied Mathematical Modelling*, *33*(1), 597–604. doi:10.1016/j.apm.2008.02.001

Tugores-Garcia, A. (2012). *Analysis of global airlines alliances as a strategy for international network development* (MS Thesis). Massachusetts Institute of Technology, Cambridge: MA. Retrieved from https://dspace.mit.edu/bitstream/handle/1721.1/75853/821869736-MIT.pdf?sequence=2

Turkish Airlines. (n.d.a). 2013 FY results. Retrieved from http://investor.turkishairlines.com/documents/ThyInvestorRelations/download/sunumlar/2013_4q_presentation.pdf

Turkish Airlines. (n.d.b). *Fact sheet 2016*. Retrieved from http://investor.turkishairlines.com/documents/ThyInvestorRelations/download/icerikler/FACT_SHEET_2016v04.pdf

Turkish Airlines. (n.d.c). *Annual report 2014*. Retrieved from http://investor.turkishairlines.com/documents/ThyInvestorRelations/download/yillik_raporlar/2014_Annual_Report_EN.pdf

Tyler, T. (2015). *Annual review 2015*, MI, USA: International Air Transport Association. Retrieved from https://www.iata.org/about/ Documents/iata-annual-review-2015.pdf

United States Securities and Exchange Commission. (n.d.a). *American Airlines Group, Inc.* Retrieved from http://phx.corporate-ir.net/phoenix.zhtml?c=117098&p=irol-reportsannual

United States Securities and Exchange Commission. (n.d.b). *Delta Air Lines, Inc.* Retrieved from http://www.sec.gov/Archives/edgar/data/27904/000002790415000003/dal1231201410k.htm

United States Securities and Exchange Commission. (2015a). *Avianca Holdings S.A.* Retrieved from http://www.aviancaholdings.com/en/images/informes_anuales/20F_2014_as_Filed.pdf

United States Securities and Exchange Commission. (2015b). *Copa Holdings, S.A.* Retrieved from http://files.shareholder.com/downloads/CPA/2165694700x0x825161/38A49871-7ECF-4E35-9A46-7CA639AD5499/913667A.PDF

Vaidya, A. (2016). Efficiency ranking method using DEA and TOPSIS (ERM-DT): case of an Indian bank. *Benchmarking: An international Journal*, *23*(1), 165-182. http://dx.doi.org/10.1108/BIJ-09-2013-0093

Vaisgn, B., & Fleming, K. (2005). A total factor productivity based for tactical cluster assessment: Empirical investigation in the airline industry. *Journal of Air Transportation*, *10*(1), 3. Retrieved from Proquest.

Vassiloglou, M., & Giokas, D. (1990). A study of relative efficiency of bank branches: An application of data envelopment analysis. *Journal of the Operational Research Society*, *41*(7), 591-597. doi:10.1038/sj/jors/0410705

Wanke, P., Barros, C. P., & Chen, Z. (2015). An analysis of Asian airlines efficiency with two-stage TOPSIS and MCMC generalized linear mixed models. *International Journal of Production Economics. 169*, 110-126. doi:10.1016/j.ijpe.2015.07.028

World Bank. (n.d.). *Air transport, passengers carried*. Retrieved from WorldBank.

Wu, W., & Liao, Y. (2014). A balanced scorecard envelopment approach to assess airlines' performance. *Industrial Management & Data Systems*, *114*(1), 123-143. http://dx.doi.org/10.1108/IMDS-03-2013-0135