Analysing the Network & Schedule Performance of Airlines and Developing a Passenger-Centric Commercial Methodology for Air Services

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ANALYSING THE NETWORK & SCHEDULE PERFORMANCE OF AIRLINES AND DEVELOPING A PASSENGER-CENTRIC COMMERCIAL METHODOLOGY FOR AIR SERVICES

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Abstract

In the aviation industry and academic literature, there are a number of methods to compute and benchmark the perceived quality of the airline schedule. However, these are open to criticism in the sense that they solely use the airline's schedules as the input for the quality computation rather than the consumer's perspective. Injecting dynamic consumer preference metrics on top of the existing network evaluation methods is the aim of this research.

Therefore, the research brings a new and innovative passenger-oriented perspective on airline network and schedule design, an outlook regarding the "quality" of supply rather than the sole "quantity" of the supply. The model also helps to compute schedule-service quality indexes by understanding consumers' priorities and preferences through a survey. Using the schedule data of main legacy and low cost carriers in the Middle East, Europe and Africa the model produces a "realistic market share" estimation for each airline serving particular routes.

The model's outputs provide guidelines to effectively shape the airline planners' investment decisions in the sense that, the airline executives will be enabled to numerically assess the estimated realistic market share change of a potential investment and to benchmark the performance of their products against competitors. Moreover, the research contributes to the academic literature by conceptualising the comparative and competitive advantages of airline schedules and network designs from a consumer-centric perspective.

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Author’s Declaration

I declare that all the material contained in this thesis is my own work.

Mehmet Şükrü Nenem

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To my dear son, Kerem Alp,

It has been a long time since I have not seen you. I miss you so much. You just turned 1 and you do not yet realise what is going around. But you will grow up and once you start to understand, you will learn a lot! Once you grow up, you will also realise that your father produced this study under very difficult circumstances. Kerem Alp, I dedicate this work to you. I love you so much. This research is for you my son.

Definitions & Gloassary

An extensive range of terminology, notation and definitions are used throughout this study. While Chapter 2 includes the general concepts and definitions covered in the Research, Chapter 8 focuses on capacity related concepts and Chapter 9 covers quality-related notations and terminology. The following table summarise the parameters introduced throughout the study.

Table A: The parameters introduced in the Chapters of the Research

Parameter	Explanation	Details
f	*Frequency* – refers to the number of flights operated by a carrier in a market	Ch. 2 / p.
s	*Available seat* – refers to total number of physical seats supplied in a market	Ch. 2 / p.
s_f	The installed physical seat capacity for each frequency	Ch. 2 / p.
s_{conn}	*Connecting seat factor* – maximum percentage of the physical capacity that could be allocated for a connecting destination.	Ch. 2 / p.
s_{code}	*Codeshare seat factor* – the maximum percentage available for sale to a given marketing carrier.	Ch. 2 / p.
t_{total}	The total travel time elapsed between the departure from the origin and arrival at the destination.	Ch. 2 / p.
t_{flight}	The total time spent on the flight.	Ch. 2 / p.
t_{conn}	*Connecting Time* – The total time spent at the hub airports for connecting itineraries	Ch. 2 / p.
MCT	*Minimum Connecting Time* – refers to the minimum time required to connect two flights at the hub airport.	Ch. 2 / p.
MaxCT	*Maximum Connecting Time* – refers to the maximum time permitted to connect two flights at the hub airport.	Ch. 2 / p.
q_{dep}	*Departure Time Quality* is the perceived attractiveness of the departure time from the origin of a given itinerary.	Ch. 2 / p.
q_{arr}	*Arrival Time Quality* is the perceived attractiveness of the arrival time to the destination of a given itinerary.	Ch. 2 / p.
$\%t_f$	*Flight Time Ratio* – refers to the flight time ratio of the entire journey.	Ch. 2 / p.
$\%t_c$	*Connect Time Ratio* – refers to the share of connecting time among t_{total}.	Ch. 2 / p.
MCT Surplus	A connecting passengers surplus time at the connecting airport	Ch. 2 / p.
t_{buffer}	*Buffer Time* – refers to the connecting passengers' additional time demand on top of the MCT.	Ch. 2 / p.
t_{stress}	*Stress Time* – refers to the connecting passengers' stress time at the hub airport.	Ch. 2 / p.

t_{waste}	*Waste Time* – refers to the connecting passengers' wasted time at the hub airport.	Ch. 2 / p.
$t_{inconvenient}$	*Total inconvenient time* – refers to either stress or waste time for connecting passengers.	Ch. 2 / p.
$\%_{inconvenient\_time}$	*Inconvenient time percentage* – refers to the share of inconvenient time within the total journey time.	Ch. 2 / p.
f_{split}	*Flight Time Split Ratio* – refers to the journey time splits of the legs of a connecting itinerary.	Ch. 2 / p.
u_{do}	The value of a direct and operating service	Ch. 4 / p.
u_{dc}	The value of a direct and codeshare service	Ch. 4 / p.
u_{co}	The value of a connecting and operating service	Ch. 4 / p.
u_{cc}	The value of a connecting and codeshare service	Ch. 4 / p.
$\%_{f\_i}$	*Physical Frequency Share* – refers to the percentage of physical frequencies of airline *i* in a given market	Ch. 8. / p.
$\%_{s\_i}$	*Physical Seat Share* – refers to the percentage of physical seats of airline *i* in a given market	Ch. 8. / p.
$\%_{a\_s}$	*Consumer Centric Supply Share* – refers to percentage of consumer centric capacity of an airline	Ch. 8 / p.
q_{split}	The additional score that an itinerary would gain if the journey is split with a connection either at the very early or very late stage of travel.	Ch. 9 / p.
$q_{convenience}$	*Time Convenience* – refers to the time quality of an itinerary calculated by summing q_{dep}, q_{arr} and q_{split}	Ch. 9 / p.
q_{index}	The quality index of an itinerary determined by 1) routing type (whether direct or connecting), 2) operation type (whether operating or codeshare) and 3) $q_{convenience}$	Ch. 9 / p.
$q_{index\_normalised}$	The normalised value of q_{index} with respect to $\%_{inconvenient\_time}$	Ch. 9 / p.
$q_{a\_index\_normalised}$	The final quality score of an itinerary which is calculated by adjusting $q_{index\_normalised}$ with respect to competing itineraries' t_{total} values	Ch. 9 / p.
ms	The estimated realistic market share	Ch. 9 / p.

Chapter 1: Introduction

1.1. Background

> "If there is one thing which has defined human nature throughout history it is our fidgety, irrepressible impulse to move, to discover and cross new frontiers, to adapt to new environments, to appease that same unquenchable curiosity which prompted our earliest ancestors to swing down from the treetops and start exploring the jungle floor six million years ago." (Jones W. , 2017, p. 1)

The history of transport is closely linked with the history of civilisation. While earlier ancestors travelled with the aim of survival, the later descendants' travel purposes had gone beyond physiological needs. Rising sophistication led civilisations to grow and expand, and so did the concept of travel as a means to trade and explore. Travelling contributed to economic welfare and created comparative advantages for humankind. Therefore, improvements in transportation contributed to the standards of human society which enhanced our ancestors from living in tribal classes into collectives referred to as cities or states. Facilitated by transport systems, the evolution of major cities and all permanent human settlements can be traced to the comparative advantage of places with respect to goods trade (Nolan, 2015). The interaction between collectives due to economic, political and cultural needs had been eased through transport which gradually formed the basis of today's modern societies.

Rodrigue et al. (2017) defines the ability to transport people and cargo faster, in high volumes over long distances and more conveniently as a very complicated process and relates it to the spatial evolution of economic ecosystems and corresponding technological developments. He summarises this evolution in four major stages: the pre-industrial era, the industrial revolution, Fordism and post-Fordism (globalisation). During the pre-industrial era, no forms of motorised vehicles were present; transport technology was limited to harnessing animal labour for land transport and wind for maritime transport. The increase in production during the industrial revolution made necessary the creation of a well-organised transport system. With the adoption of the steam engine in locomotives, transportation became more accessible, quicker and cheaper (Manolopoulou, 2017). The industrial revolution was followed by the Fordist era, which for Rodrigue et al. (2017) was epitomised by the adoption of the assembly line as the dominant form of industrial production, an innovation that benefited transportation substantially. The internal combustion engine made road vehicles operate faster and more comfortably. This era has also witnessed the emergence of leisure travel. The new middle class, composed of factory owners and managers, now had the time to travel thanks to industrialised production with efficient and faster machinery (Byttebier, 2017). Today, we are at the post-Fordism era that is marked and shaped by the drivers of globalisation. In recent decades, the rise of globalisation led individuals to go beyond their local ecosystem and to become interconnected with the outside world. This escalated the demand for faster and more efficient modes of transportation. Today, for many of us, travelling is an indispensable aspect of our lives. The mobility provided by transportation is part of our daily routine. To name a few, we travel for work, holiday, studies, visiting beloved ones and etc.

The growth of commercial aviation from the mid-20th century was inevitable. In 1956, airlines in the United States carried more passengers than railroad; in 1957 more passengers travelled across the North Atlantic by air than by boat. A decade later, passenger traffic by boat between Europe and North America ceased while air traffic exhibited 6 to 10 per cent growth per year (Hirschel, Prem, & Madelung, 2004). Air transport offered flexibility, and it was easier to build new airports rather than investing in massive infrastructure for railway tracks (Schmitt & Gollnick, 2016).

Over the decades, demand for air travel increased at a higher pace than global GDP growth. According to Boston Consulting Group's report (2006), historical growth rates for the airline industry indicate that demand for air travel indeed grew at a multiple of GDP rise where approximately 1.5 to 2 times per cent GDP growth was common. The demand for air travel has risen due to various internal and external factors. Parameters such as population, income, trade and consumers’ tastes composed the external influences for the surge in air travel demand. On the other hand, industry-specific developments such as the increase in the number of aircraft, deregulation and the rise of low-cost carriers have contributed to the induced growth of the industry which emerged as a response to carriers’ and governments’ actions.

Today, aviation is a giant industry that is expected to further grow in the coming decades. According to Morris (2017), as of 2017, aviation analysts estimate the total number of passenger and cargo aircraft in service to be 23,600 while there exist 2,500 more in storage. Aviation represents 2.7 trillion US dollars of global economic impact including direct, indirect, induced and tourism catalytic contributions supporting 62.7 million jobs (IATA, 2017). The airline industry is more than half the size of the global financial services industry, which accounts for 6.2% of GDP. In fact, if air transport were a country, its GDP would rank 21st in the world, similar to that of Switzerland or Sweden (Air Transport Action Group, 2016).

As per the International Civil Aviation Organization (ICAO), a United Nations (UN) body, thanks to the democratisation of international air travel, the real cost of flying has fallen by 60% over the past 40 years making it more accessible to more people. ICAO also estimates that, by 2030, the number of domestic and international passengers will reach 6 billion, travelling on approximately 50 million flights. These figures are almost double levels of the early 2010s (International Civil Aviation Organization, 2012). The growth in air travel is expected to create a significant demand for air vessels too. Boeing, one of the leading aircraft manufacturers, estimates a need for over 39,600 aircraft valued at more than 5.9 trillion USD over next 20 years (Boeing, 2015).

In the earlier years of aviation, flying was a luxury for travellers and accessible only to a small group of wealthy people. The growth and changes in the industry triggered air transport to commoditise and reach a broader segment of society.

> "Back when airplane travel became mainstream, it was considered a luxury. When I first began flying, the experience started when you got to the airport. You even 'dressed up' for the occasion. There was camaraderie among passengers because people felt lucky to be able to fly. Over time, the industry has eroded into a mode of mass transportation. Now, most travellers spend the majority of their time glued to electronic devices or counting down the hours and minutes until they reach their final destination." (Goldman, 2012, p. 1)

The flying experience in the mid-20th century was entirely different from today's standards. There were no personal TV screens, in-flight entertainment facilities or wifi. For Strutner (2014), seats had three to six inches more legroom than they do today – 1950s economy class looked more like how business class does today. First class was about as spacious as a modern hotel room. Flying was an over-the-top luxury experience. The fare for such a luxury service was extremely high inhibiting the broader segment of individuals from flying. In 1934, the privilege of flying a transcontinental flight from Newark, New Jersey to Glendale, California was priced at 160 USD. Adjusting this with inflation, a one-way fare on a flight making three stops along the way was equivalent to 2,700 USD today (Deia, 2013). An average person in the 1950s would pay up to 5% of his yearly salary for a chance to fly from Chicago to Phoenix. Thanks to the democratisation of airline industry, this figure has decreased to approximately 1% (Brownlee, 2013). Since deregulation, airfares drop steadily and have fallen by 50% in the past 30 years (Thomson, 2013).

Today, the air transport product is commoditised and accessible to a higher volume of people than in previous years. Between the late 1940s and the early 1970s, it could be said that flight was transformed from "a scientific phenomenon to a public utility at the disposal of the entire world." (IATA, 2017, p. 1) The total number of passengers utilising air transportation in a calendar year is roughly half of the world’s total population size today. Although it may be claimed through this statistic that one in two individuals experience the privilege of flying in a year, such an argument would be flawed as one person can fly more than once annually. Indeed, no world database keeps track of the number of unique individuals travelling by air. Therefore, whilst the exact absolute and percentile figures of individuals travelling by air in a year is uncertain, it is a fact that today, air transport is accessible to a higher range of individuals than in previous decades.

The surge in the demand and availability of air transport is among the principal motives contributing to the aviation industry’s commoditisation. The number of actively operating carriers has increased significantly. When IATA was founded in Havana, Cuba in 1945, it had only 57 member airlines from 31 nations, mostly in Europe and North America. Today it has some 275 members from 117 nations in every part of the globe (IATA, 2017). Deregulation is one of the principal motives that significantly contributed to the growth of air travel demand. For Berghöfer and Lucey (2014), the increased competition is a result of global deregulation of the industry that took place in the 1980s. Deregulation encouraged low-cost carriers to emerge as a new pattern in the industry. The expansion of low-cost carriers (LCC) subsequently facilitated competition in the market and took average ticket fares down deeming air travel to be more affordable for an extended segment of people. The US Department of Transportation's Bureau of Transportation Statistics compiled the average domestic airfare of US airports from 1995 to 2015 considering inflation, and it proved that with a few ups and downs, over the last 20 years the average cost of a flight has generally decreased with regards to purchasing power

(Roach & Hoeller, 2015). The expansion of the industry was not limited to the number of airlines but also covered average fleet size and the average seat capacity of each aircraft. While early aircraft were able to host fewer passengers, today jets can carry vast volumes of travellers. For instance, the Airbus A380-800 can accommodate 525 passengers in a three-class configuration; this can go up to 853 passengers depending on the seating layout of the jet.

Commoditisation of air transport and the inevitable rise in the supply and demand for air travel presented a broader spectrum of product choices for potential travellers. The fierce competition between carriers motivated them to differentiate their product to become a choice for their target customers. Airline executives spend time in defining key values offered to potential travellers to distinguish themselves from competitors. Airlines failing to compete effectively were deemed to disappear in the market. Since 1990, 189 airlines have filed for bankruptcy in America. Even the flag carriers of some nation states have collapsed (Hirby, 2016). According to former President of IATA, airlines have only been able to generate sufficient revenues and profit to pay their suppliers and service their debt. Maintaining a reasonable operating margin, a problem in the commoditisation of airline services and an incredibly fragmented industry structure, is key to poor airline profitability (Tyler, 2013). For Hanlon (2007, s. 5), "*the airline industry may often have achieved high rates of traffic growth, but this has not generally been accompanied by high rates of profitability, quite the opposite. Airline profit margins have been well below average compared with firms in other industries, and in some years there have been some heavy losses indeed*". Therefore airlines set different business principles and products to become competitive in the market. For instance, while in general terms, LCCs offer basic transportation from origin to destination, full-service carriers sell a journey "experience" through their pre-flight, in-flight and post-flight amenities. Although LCCs intend to achieve relatively lower operational costs in comparison to full-service carriers, their expected revenue per passenger is lower. Therefore, what determines the value of an air ticket is nothing more than what the market demands and how the airlines design their product in response to this demand in comparison to their rivals.

1.2. Rationale

As a response to intensifying competition, airlines invest in various areas to increase the likelihood of becoming a choice for travellers. In broad terms, they invest to categorical factors that are influential in consumers’ travel decisions. The first is the airline’s brand and the corresponding value proposition offered to their customers. In this context, most airlines continuously invest in their brand and image for being recognised as “the safest”, “the cheapest”, “the most punctual”, “best service” or any other slogans that their business proposition prescribe. An airline’s brand is an intangible asset that can have a substantial impact on profits and consequently market value (Sharma, 2017). The second category is the product or experience while taking consumers from origin to destination. Factors such as service level onboard, seat comfort, crew hospitality, on-time-performance, in-flight entertainment systems, loyalty programs, journey duration, flight connections etc. are all components of the product which together form the journey experience. The third category of consumer choice is the fare which is ultimately the output of the market dynamics and the first two categories of consumer choice, airlines’ brand and product. Especially for the price-sensitive segment, the comparative advantage in the fare can be the driver of choice. Although their weightings may not be equal, all three of these categories are blended in the thought process of travellers when making their purchasing decisions. It is possible, in one extreme, for a business traveller and a loyal passenger to neglect the fare parameter but rather focus on product convenience or their favourite airline’s itinerary; in the other extreme, a student with a limited budget may prioritise fare over other factors to meet budget constraints. Therefore, all of these parameters are evaluated together according to travellers' circumstances individually when making the purchasing decision for their itinerary.

The developments that are primarily triggered by the commoditisation of air travel have led to a shift in the business models of the airlines. Full-service carriers have unbundled many of their services to improve efficiency while the LCCs have expanded into larger airports, offered connections through their introduced hub-and-spoke network structure and hence shifted to more direct competition with legacy carriers (Henrickson & Wilson, 2016). In other words, the business models of the legacy and the LCCs have converged. The convergence of the business models happened in two forms; (1) two initially distinct models evolved into one hybrid, i.e. showing features of both initial forms, (2) one business model transformed into the other. Such a hybrid model implies that competing airlines target almost the same customer segments with more or less the same strategies, structures, and assets. As competition continues to intensify, the remaining players compete with equivalent or even almost similar tools and armoury portfolios – a typical "Red Ocean" setting. The hybridisation of business models implies that airlines now target a broader customer spectrum (Albers S. , 2015).

The commoditisation of air transport product and subsequent convergence in business models have encouraged airlines to focus more on their core product: simply transporting passengers from their origin to destination. For Mason (2008), the schedule is the core element of air travel. Although brand and product related parameters as well as fare, have always taken a central role in the decision-making process of the consumers and will continue to do so, the core product features of air travel have become further apparent in consumer choice. When a passenger purchases a flight ticket, which is almost entirely electronic today, what they obtain is merely a printout of the core product: the departure and arrival airport, date & time of the flight, the aircraft model and the reservation class information. For prospective consumers intending to buy a flight ticket, reservation systems and distribution channels display those core attributes along with their fares on screen. In other words, airlines put their schedules on the shelf, and they mainly sell this "core" attribute of their service.

As the competition between airlines deepened, the core product features of each flight alternative have become even more crucial in consumers' itinerary decisions. There exists plenty of parameters that together compose the “schedule attractiveness” of the carriers that collectively determine consumers' level of appreciation towards the itinerary's core features. When making their travel decisions, consumers skim the available flight options serving on the same route, and form an initial judgement concerning the schedule convenience of each product available in the market. As an example, consumers do not equally welcome a flight operated in the middle of the night when compared to another alternative service departing at a more convenient time of the day. Besides, most of the time a direct flight is the preferred option when compared to a connecting one in which consumers are required to change plane at an intermediary airport.

The complete set of scheduled products and timetable with the entire flight destinations make up the airlines network structure. The products available for sale “on the shelf” are displayed among the network arrangement of the carrier. Therefore, while consumers seek the attractiveness of an itinerary's schedule, airlines intend to maximise the level of their network's attractiveness to become a choice for their customers. On the other hand, the network efficiency of the airlines should not only watch for the customer satisfaction but also the commercial viability. The airlines would not be able to survive if they do not generate adequate revenues through their services.

From the consumers' standpoint, the perceived schedule quality of a particular itinerary designates the schedule efficiency of the air transport product. The relative superiority of one itinerary over another can be determined by comparing the numerical values of schedule quality whose methodology is introduced and elaborated upon in this research. From the airlines' standpoint, the set of all available products founded in their timetable embody the network structure of the carrier. The methodology offered in this research enables carriers to assess their overall "network efficiency". Network efficiency of a carrier is composed of the schedule efficiencies of all products that the airline offers. The terms of schedule efficiency and network efficiency are used interchangeably throughout the study.

1.3. Aim and Objectives

AIM: TO DEVELOP A PASSENGER CENTRIC METHODOLOGY FOR ANALYSING THE SCHEDULE AND NETWORK PERFORMANCE OF AIR SERVICES

This research intended to develop a model to examine the performance of the airline industry's core product, the schedule, from the consumers’ perspective. It aimed to introduce a methodology to assess the efficiency of basic schedule information displayed on air travel tickets and analyse its impact on consumers' itinerary decision-making process. Comprehending the dynamics of consumers’ judgments concerning schedule quality of the competing itineraries was the focal interest of the study. Factors that are influential in consumers' decision-making process other than schedule convenience were not included within the scope of the research. By eliminating the impact of other parameters, the sole effect of the air travel’s core element, the sechedule, was assessed.

OBJECTIVE 1: TO DETERMINE A CONSUMER CENTRIC CAPACITY SHARE ESTIMATION MODEL

The research intended to revisit the methodology to compute airline capacity supply in a market from a different, consumer-centric, perspective. When discussing capacity, usually the physical capacity is referred to. The physical supply of different carriers in the form of frequency and available seats serving on the same route is known by employing several data and market intelligence information. As different forms of itineraries emerged that further complicated air travel, the determination of physical capacity is no longer a straightforward process. Additionally, although there may exist some itineraries on the shelf waiting to be sold, they may not be considered as viable capacities for consumers due to some of their comparative disadvantages. For this reason, further enhancements were required to adjust the reported capacities to both re-calculate the physical capacity and to incorporate passengers' convenience. For instance, although a product offering a connecting time of 20 hours at an intermediary airport may theoretically be counted as a valid product, it may not be preferred by consumers should other itineraries prove to be a more convenient option. Therefore, a redefinition of capacity supply was made as part of this study to incorporate passenger preference.

OBJECTIVE 2: TO QUANTIFY AIRLINE SCHEDULE QUALITY

Consumers' preferences and priorities determine their perception towards the attractiveness of the schedules offered. In order to formulate the link between schedule convenience and customers' itinerary choice, the metrics and parameters that shape the quality perception need to be addressed. Each factor influencing schedule quality forms an insight regarding the “schedule attractiveness" of each product available on the market. Justifying the schedule quality of each itinerary with objective and concrete metrics was the second objective of this research. For this reason, the influential parameters that form the basis of customers' schedule quality judgments were established and tested with their quantitative impacts. Therefore, a universal and realistic schedule quality methodology was to be developed for each product serving on a route.

OBJECTIVE 3: TO DETERMINE A REALISTIC MARKET SHARE ESTIMATION TOOL (REMSET)

Through their business strategies including their network organisation, airlines compete to obtain a higher share of the market in which they are present. Market share is an absolute indication and output of a company's economic performance and its level of appreciation by the consumers. A company's market share performance is related to the various components of the firm's strategic profile (Pleshko & Helens, 2002). It is also a key indicator of market competitiveness, i.e. how well a firm is doing against its competitors (Farris, Bendle, Pfeifer,

& Reibstein, 2010). Vargo and Lusch (2004) urged scholars and practitioners to interpret market share as a measure of how well a company has been able to predict market dynamics and the needs of the targeted customers. Buzzell and Gale (1987) empirically tested the market share – profitability relationship. The study of 57 Fortune 500 companies revealed a definite link between ROI and market share. Therefore, this research is dedicated to analysing network efficiency and schedule convenience from a consumer-centric perspective by assessing market share estimations.

The network efficiency of a carrier could be assessed through its products' market share performance. An objective of this research is to introduce a realistic market share estimation tool (abbreviated as REMSET) as an output of schedule convenience and airlines network effectiveness. The proposed tool utilises consumer-centric supply/quantity (explained in Objective 1) and quality (as explained in Objective 2) to produce the forecasted market shares for each carriers' service in a particular market. Developing a market share estimation methodology through consumer-centric "supply" and "quality" is a distinctive contribution of this study to academic knowledge. The validity and credibility of the results of the REMSET model were cross-checked and tested using actual market share data of the operating airlines.

OBJECTIVE 4: TO DEVELOP A TOOL FOR INDUSTRY PRACTITIONERS TO ASSESS SCHEDULE, NETWORK AND HUB COMPETITIVENESS IN THEIR ROUTE AND CAPACITY PLANNING

Comprehending schedule efficiency and realistic market shares offers extensive benefits for airline managers. Executives can use this information to assess the competitiveness of their product. Therefore the methodological outputs of this research enable airline managers to scale their products better and position themselves among competitors. This process can also assist in developing efficient revenue management strategies while determining the right fare levels for air services. Using the research's models, airline executives can analyse the efficiency of their network investments. For example, they can measure the marginal market share impact of an additional frequency to a destination. Alternatively, they can judge the effect of deferring or bringing forward the departure time of a particular flight or signing a codeshare deal with another carrier. Besides, industry practitioners can assess the hub performance and connecitivity indexes of the airports as a hub from a consumer-centric perspective.

1.4. Contribution to Knowledge

This research has brought significant contributions to academic literature. It has replaced the obsolete and traditionally used network efficiency performance metrics with a contemporary approach incorporating passengers' perspectives. Quantifying the schedule quality of airlines was another significant contribution of this study into the literature. The research justifies the abstract phenomenon of good quality in airline schedules and translates them into numerical values (Objective 2). Furthermore, it brings a new and consumer-centric approach to the capacity determination (Objective 1).

Using quantitative (supply) and qualitative information, the research brings a fresh perspective towards airlines' network efficiency and realistic market share estimation models (Objective 3). Blending the consumer-centric supply data with the qualitative metrics has produced a consumer-centric market share estimation tool. Therefore, a unique passenger perspective has been inserted into the existing market share estimation models that is likely to better reflect the market dynamics. In this context, the contribution of the research is not only limited to academia but is also highly significant to industry. Since the study offers a distinctive tool, the REMSET, for airline executives to benchmark their product and assess their network investment analysis (Objective 4), the research outputs (including consumer-centric supply, quality and market share estimation for each carrier competing on a particular route) have practical implications in compliance with the industry practitioners' expectations.

1.5. Methodology

This study used a detailed methodology to determine quantitative schedule quality, capacity share and realistic market share estimation. The scope, coverage, and methodology introduced throughout the research is global and can be implemented by any airline in any region. In other words, the methodology for estimating all airlines realistic market shares, quality scores and supply shares is universal and readily applicable to any company. For instance, the computation of market share forecasts for all airlines competing on the New York – Vancouver route is no different than the procedure for calculating the market shares of carriers operating the Frankfurt – Cairo route. Furthermore, the process for assessing the same metrics on a route for Airline A is identical to the method applied to Airline B.

As an initial step, the gaps and weaknesses in the current network efficiency, capacity supply and quality determination models presented in the literature were extensively analysed to identify areas of improvement. Proposed enhancements to the currently available models were used to develop a consumer-oriented methodology. In this context, it was mandatory to understand the values and perceptions of consumers regarding the core attributes of the air transport product. Therefore, a passenger survey was utilised to understand the consumers and determine how to incorporate their perspectives into the proposed methodologies of this research. Before implementing the survey, papers were submitted and presented to the Air Transport Research Society (ATRS) 2013 conference held in Italy and ATRS 2014 held in France. Through these presentations, valuable feedback was received from the society's participants. These presentations and feedback assisted the fine-tuning of the survey design. The passenger survey was utilised in 9 different airports to more than a thousand respondents. The survey responses were carefully analysed and the research's proposed models were finalised using the invaluable information gathered from the survey results. The survey methodology and results were presented to the ATRS conferences held in Greece and Belgium in 2015 and 2017 respectively. The feedback received from the ATRS society confirmed that the study had addressed a substantial gap in the current literature.

Although the research’s proposed methodology is universal and can be applied to any carrier in the world, it focused on major airlines in Europe, the Middle East and Africa. This funnelling was performed for two reasons. First, limiting the study to major carriers in Europe, the Middle East and Africa offered an extensive volume of international origin and destination pairs with sufficient number of airlines competing in the route. The volume of international traffic is highest in the selected regions. Specifically, North America and Asia report the primary volume of domestic traffic. As per IATA figures, the United States domestic market holds 14.5% of the world's total capacity share (including international flights) while the same figure is 9.1% for China. The capacity share of the Indian domestic market is 1.4% while the value is again 1.4% and 1.1% for Russia and Japan respectively (IATA, 2018). Therefore, eliminating the Americas and Asia Pacific from the research's focus brought a higher level of international perspective to the study. Second, obtaining the current and past schedule information of all carriers operating in the world was challenging. After determining the major airlines to be included in the study within Europe, the Middle East and Africa, the schedule information of those carriers from 2005 to 2016 was retrieved. The model was applied over the schedule data to obtain quality scores, capacity shares and realistic market share estimations for each market from 2005 to 2016.

1.6. Excluded Scope

Network efficiency and consumer-centric supply and realistic market share estimation is a phenomenon of schedules derived directly from the timetable of carriers. Since charter flights are not sold publicly in distribution channels, but only available to a limited number of customers, non-scheduled and charter flights were not studied as part of this research. Passengers travelling on charter flights have relatively less authority on their itinerary selection because their travel agencies or tour operators are the ultimate decision makers for those flights. Moreover, charter flights are not listed in publicly available timetables published each season enabling individual consumers to know and prefer those flights. Therefore, charter flights could not be included to the realistic market share estimation process. On the other hand, even if the airline operates a part charter flight, implying that a portion of the available seats is available for sale to individual consumers, and the operation is published for sale in the global distribution systems, it was still kept outside the scope of the research since the definition of scheduled flights enforces the repetitiveness of the services on at least a weekly basis for the whole scheduling season. Hence, the criteria for the inclusion to the scope of this research required flights to be scheduled services operated and repeated at least weekly for the whole scheduling season.

Deviation from the published timetable, in terms of cancellation and flight delays wa not included within the scope of this study. On-time performance measures the extent to which carriers adhere to their schedules. When making their itinerary decision, passengers cannot foresee whether or not their chosen flight is to be delayed. The airlines may hold a reputation concerning their on-time-performance, but this would only impact the brand perception of the consumer towards the carrier, which also impacts consumer choice. However, the context of schedule efficiency and consumer-centric realistic market share applies to airlines' published plans, not to service delivery levels and therefore any deviation from the schedule was excluded from the scope of the study.

1.7. Research Outline & Structure

This research is divided into 13 distinct chapters. Following this Introduction Chapter, fundamental aviation concepts used throughout the study are covered in Chapter 2. Aviation is a complex discipline with significant number of terms, abbreviations and terminologies. The concepts Chapter assists in clarifying the research's language, especially for those who are less familiar with the industry, by elaborating on these terms through specific examples. Therefore, Chapter 2 serves as a definitive pre-requisite to comprehend the previous literature as well as the research's aim, objectives, proposed methodologies and key contributions to the knowledge.

Following the concepts Chapter, two detailed literature survey chapters are presented in order to develop a general understanding of the critical areas of the research. The first literature review Chapter (Chapter 3) offers a general outlook to the aviation industry and its growth with a focus on the commoditisation process. It discusses the deregulation of the industry and its impact on the emergence of new business models as well as introducing airline network models and their characteristics. The chapter also explains airline planning cycles in detail and addresses how airline networks and schedules are designed. The chapter also takes a closer look at airlines' market share estimation models, with a particular focus on Quality of Service Index (QSI). This information assists in developing an understanding concerning the network features and current market share assessment models. The chapter progresses comprehensively and elaborates on the weaknesses of the current market share estimation models present in the literature.

The second literature review chapter (Chapter 4) focuses entirely on consumer choice in air travel. The literature is scanned to develop an understanding concerning the underlying dynamics of travellers' itinerary selection process. Since the research focuses on airline networks and schedule attractiveness, consumers' perception towards airline schedules are the focus of this Chapter. The Chapter also addresses theoretical background related to consumer choice in air transport in a comprehensive manner to ensure that all relevant aspects of the travellers' itinerary decision-making algorithm is encompassed in the research methodologies.

Chapter 5 addresses the data sources that were used throughout the study. The data sources are introduced, analysed and discussed in detail within this Chapter. Since the research covers major airlines in Europe, the Middle East and Africa, the airlines whose schedule information were included in the dataset are clarified in the chapter. In order to elucidate the fields and attributes within the data, sample data were selected and introduced within the Chapter. In addition, the cross-check mechanisms that were utilised to validate the employed data are also covered. Furthermore, the sources of all other primary and secondary data are elaborated upon in detail. As the volume of the data that is being dealt with in the research is in the scale of millions, a web database environment to perform faster and reliable computations was developed which is also described in the chapter.

Chapter 6 discusses the survey design and implementation processes used throughout the study. The chapter covers the survey questions in detail along with the answer options and clarifies the implementation strategy. The survey results are thoroughly analysed in Chapter 7.

The following two Chapters (Chapter 8 and 9) outline the methodology that formulates the research outputs, which is among the significant contributions of this study to knowledge. The methodology is covered in two major chapters: supply and quality score determination. Chapter 8 covers the consumer-focused capacity share calculation model that was customised by taking consumer feedback received through the survey responses. This Chapter identifies supply determination for whole flight types and routings by also studying specific examples. Chapter 9 comprehensively covers the schedule quality determination model. Since the determination of quality scores is among the key contributions of this research, the Chapter iterates through each step of the process using representative and real examples from the airlines schedules. Moreover, the Chapter also details how the capacity shares and quality scores are blended to form the REMSET model. The Chapter is followed by a case study demonstrating step-by-step market share estimation process using real schedule data.

Chapter 10 discusses results employing the procedures introduced in Chapter 8 and 9 using real schedule information from 2005 to 2016. The chapter selected a sample of markets to further examine how the calculated realistic market share of the competing airlines serving in the designated routes was reported. All computations were performed electronically over the web environment since all schedule information and methodologies were uploaded onto the researchers' website, www.phdsukru.com. As part of the Chapter, the computed realistic market share estimations are compared with the actual market shares whose data was retrieved from alternative resources. The accuracy and credibility of the proposed model is evaluated by benchmarking the calculated figures with the actual performances. Moreover, being able to assess historical development in the outputs enabled the measurement of return on capacity investment in terms of realistic market share. Therefore, the REMSET model offers an indispensable tool for airline planners to assess the efficiency of their network investments.

Chapter 11 is a scenario analysis section intending to observe and quantify the impact of a marginal change in airline schedule on the calculated supply share, quality scores and the subsequent realistic market share forecast. The Chapter elaborates on how airline planners can use the introduced methodology for commercial practices while designing their network and schedule structure. This Chapter uses the identical markets referred in Chapter 10 and observes the deviation with the outputs under different scenarios. For this reason, the results covered in Chapter 10 are referred to as the base cases. In addition, the Chapter addresses the economic impact of codeshare agreements since the realistic market shares before and after such agreements can be assessed. Therefore the Chapter demonstrates how airline executives can utilise the proposed models and methodologies for the commercial benefits of their firms. Moreover, Chapter 12 covers a benchmark analysis of the selected hubs by studying the research outputs for specific regional markets. Chapter 12 assesses the connection quality and connectivity indexes of the selected hub airports by employing the research’s methodologies.

The final Chapter concludes this research. The Chapter suggests how the study has contributed to academic knowledge and addresses the limitations of the research. Moreover it discusses the fulfilment of the research aim and objectives in addition to identifying and recommending further research areas that would complement the study.

Chapter 2 – Concepts

2.1. Introduction

The airline industry is one of the most multinational sectors in the world. It is the motor force of the global economy, whose operations go beyond national boundaries. The industry receives significant attention from stakeholders and has a central role in ordinary individuals' daily routine as almost anyone has a story about their travel experience. According to the International Air Transportation Association (IATA) report (2018), more than 4 billion passengers all over the world were carried by airlines in 2017. Such extensive coverage and the global nature of the business have led to the production of its own glossary to ease communication across the actors of the industry. The sector is full of specific definitions, terms, phrases and abbreviations. Although certain terminologies are commonly used within our daily language, most of them are technical terms with some being misused and thus requiring clarification. In the course of this research, several additional concepts are also introduced. For these reasons, this chapter focuses on explaining the general terminology with detailed examples in order to familiarise with the concepts. Starting with the core industry-wide terms relating to airline schedules and networks in Section 2.2, supply and time-related concepts are explained in Section 2.3 and 2.4 respectively. Moreover, this Chapter also serves as an introduction to the literature review as the academic background of many key terminologies referred herein is further elaborated upon in the proceeding literature review Chapters.

2.2. Core Concepts

Each journey initiates with the formation of an itinerary. An *itinerary* is the travel plan including intended destinations and further various information concerning the journey. The itinerary is composed of the travel schedule including details of the booking such as date, time and route (Staudacher & Freese, 2012). The instructions and policies concerning the cancellation or change requests with the bookings may also be included in the itinerary. The itineraries are stored in the *Passenger Name Record* (PNR) which contains information provided by travellers during the booking process. PNR data includes the passenger name, contact details, itineraries, date of reservation, the form of payment used, the unique identifier of the ticketing agent as well as service-specific information (Busser, 2009). The PNR is eventually a database record in the *Computer Reservation Systems (CRS),* which may consist of single or multiple flight legs that start at the origin and terminate at the destination. The *origin* is the place where passengers start their journey, and the *destination* is the final arrival point.

Each itinerary is built through *legs* or *segments* referring to a single flight. A leg refers to a flight from the origin to the destination (O&D). Each leg is identified through a *flight number* that is composed of the carriers' two-letter *designation code* and a number (Pieraccini & Rabiner, 2012). Flight numbers uniquely identify scheduled services on an O&D, and therefore identical flight numbers are not utilised by airlines within a day to ensure the flights' distinctiveness. Flight segments on an itinerary indicate the routing of the passengers and can be in one of four different forms:

i) *Round-trip* refers to journeys travelling back to the origin after the passenger spend time at the destination. Round-trip flights encapsulate *outbound* and *inbound flights* denoting the outward movement from the origin and the inward towards the origin respectively (Ali, 2015). Although there might be a stopover or connecting city in between, round-trip journeys involve a single O&D where the passengers' ultimate goal is to reach final destination and arrive back to their origination point.

ii) *One-way trip* does not include a movement from the destination back to the origin and thus includes the outbound flight segment only.

iii) *Open jaw trip* involves three cities with no air travel information in the PNR between two of them (Monaghan, 2001). Passengers with an open jaw itinerary may have a separate one-way ticket on another PNR between the destination of the inbound flight and the origin of the outbound flight. They might also have travelled by other modes of transportation (such as bus, train, car or ferry) between the points whose routing information is absent on the PNR.

iv) *Circle flight trip* covers itineraries with two or more extended stopovers and returning to the originating city (Mancini, 2013). Unlike round-trip journeys, circle flights do not have a single destination. Passengers travel to multiple destinations in such itineraries.

The flights can either be *domestic service* or *international.* International flights are those which take off in one country and land at a destination in another country, whereas domestic flights are those whereby two destinations within the same country are connected (Smith & Stewart, 2014). In international flights, passengers need to go through passport, customs and other relevant formalities before boarding the aircraft.

The schedule conveniences are assessed at the O&D level since consumers perform schedule related evaluations independently for each segment. A passenger intending to take a round-trip journey may go through different evaluation and justification processes for the outbound and inbound segments separately. As each leg's schedule characteristics can differ significantly, consumers make purchase decisions separately and discretely for each segment on an itinerary. For instance, the outbound flight of an itinerary may have an appreciable departure and arrival time whereas the return journey could be offered at the least preferred timezone of the day. To overcome such imbalances in an itinerary, the airlines may offer attractive return fares to encourage passengers to make decisions for the entire itinerary, not for the individual legs. Through this strategy, the carriers blur the decision making on individual segments. Besides, many airlines require a round-trip (or at least an open-jaw trip) to access the cheaper fares which typically also has a minimum stay requirement to freeze out short duration business passengers. However, with the rise of Online Travel Agencies consumers have begun to find attractive one-way fares and make leg-based and directional itinerary decisions. By bundling different carriers' segments into one itinerary for competitive fares, online travel agencies like Expedia, Orbitz and etc can offer consumers good prospects for finding affordable one-way flights. (Smarter Travel, 2018) Therefore, the schedule efficiency evaluations are to be conducted disjointedly at the *directional* level for the outbound and inbound flights.

A flight from origin to destination is called *non-stop* if the aircraft does not make a break in an intermediary city and the passengers are not required to change aircraft at a midway airport. For Labrensis (2015), many people assume non-stop and direct flights are interchangeable terms, but there exist divergences between the two. A non-stop flight flies from one airport to the other without stopping. On the other hand, a direct flight can stop in a city in between the O&D due to commercial and technical reasons, with passengers remaining onboard without being required to change aircraft. Technical stops are usually for refuelling purpose. Landings for unforeseeable technical incidents, such as engine failure, are unplanned occurrences and as a result are not part of airline schedules. On the other hand, if a carrier intends to make a stop due to commercial reasons, so long as the flight numbers are unchanged and the passengers are not required to leave the aircraft, the itinerary is considered to be a direct service.

A *connecting flight* is a collection of two or more segments with different flight numbers from origin to destination. Passengers are typically required to change aircraft at an intermediary or *hub* airport where a vast system of *spoke flights* are accommodated. For this reason, a connecting flight also implies a *non-direct* service. When passengers with connecting itineraries board the aircraft at the origin, they fly to the hub airport first where they take the next flight routed to the destination. In *domestic hubs*, mostly domestic operations are handled whereas in *international hubs;* flights to other countries are performed. The majority of hubs handle both domestic and international traffic. The distance traversed through connecting flights is generally higher compared to its direct flight alternative. Most of the time, hub locations are not located somewhere along the O&D's direct route. The passenger is thus required to travel a greater distance with the connecting flights. In this context, the *detour factor* refers to the ratio between the distances travelled with a connecting flight to its direct substitute. Higher detour factor figures represent longer routings and thus greater journey times. If the connecting hub is along the direct O&D route, then the detour factor converges to 1. Passengers travelling with direct services are classified as *direct passengers* while those on connecting services are named either *transit* or *transfer*. A transfer passenger refers to travellers who are required to change planes and subsequently flight numbers at the hub airport. Alternatively, passengers who are continuing with the same aircraft and flight number from hub to the destination are named transit passengers.

Interline flights refer to an agreement between individual airlines to handle passengers travelling with itineraries that require multiple airlines (Wald, Fay, & Gleich, 2010). The phrase relates to the capability of one carrier to sell a journey, or part of a journey, on the services of another carrier, together with the procedures for the settlement of the revenue owed to the carrying airline (Szakal, 2013). If the flight is performed with the carrier that the ticket is booked from, this is called an *online* or *operating flight.* Conversely, a *non-operating* or *codeshare flight* refer to a form of interline partnership where a trip is “marketed” by one airline, but operated by another (Garrow, 2010). In codeshare flights, the *operating carrier* which physically performing the flight is different from the *marketing carrier,* the airline with which the booking is made. With this method, the marketing carriers are entitled to sell seats of the operating carriers' flight by placing its designator and flight number. For Gerlach et al. (2013) code sharing enables airlines to jointly market their capacity by assigning their designators to a flight, and provides an appropriate framework to build more efficient and profitable route networks.

The routing of a flight is either *direct* or *connecting* whereas the *type* of an itinerary is either *online/operating* or *codeshare/non-operating*. Table 2.1 presents examples from the concepts discussed above.

Table 2.1: Examples of Round-trip, One-way, Open-jaw and Circle Flights with Further Conceptual Clarifications.

Case	Remarks
Itinerary 1: Mr John Wood is scheduled to fly from Hamburg to Munich on 17 September 2016 and back from Munich to Hamburg the next day.	A round-trip, non-stop, direct domestic flight with two legs/segments.
Itinerary 2: Miss Elena Baker is scheduled to fly Rome to New York via Heathrow with no aircraft change on 12 January to enrol at her university with no return flight booked.	A one-way, direct international flight.
Itinerary 3: Ms Susan Hector books from Airline X but travels with Airline Y. The first leg is from Dubai to Brussels. The second leg is from Amsterdam to Dubai.	An open-jaw interline flight. Itinerary contains three cities with no travel info between Brussels and Amsterdam.
Itinerary 4: Mr Adam Baker flies from Tokyo to Osaka on 19 April and Osaka to Beijing on 21 April and back from Beijing to Tokyo on 23 April.	A circle flight itinerary with three segments.
PNR : Mr David Johnson, phone 212 7235599 XY 123 / C cabin from Bangkok to Hong Kong on 23 May 2014 departing at 15:05 pm XY 55 / C cabin from Honk Kong to Osaka on 23 May 2014 departing at 22:45 pm AB 78 / Y cabin from Osaka to Hong Kong on 28 May 2014 departing at 03:15 am AB 713 / Y cabin from Hong Kong to Bangkok on 28 May 2014 departing at 11:40 am Booked through Agency A on 18 May 2014, paid cash.	A round-trip connecting flight with following details. Passenger Name: Mr David Johnson Passenger Contact Number: 212 7235599 Origin: Bangkok Destination: Osaka Number of legs/segments: 4 Number of airlines in the PNR: 2 (XY and AB) Outbound journey: Bangkok to Osaka via Hong Kong Outbound cabin: C referring to business class Inbound journey: Osaka to Bangkok via Hong Kong Inbound cabin: Y referring to economy class Inbound departure: 23 May 2014 at 15:05 pm Outbound departure: 28 May 2014 03:15 am Booked on: 18 May 2014 Booked via: Travel Agency A Mode of payment: Cash

2.3. Supply Related Concepts

Matching the demand and the supply is a critical success criterion for the airline industry. Carriers seek to set the optimum capacity in order to meet demand effectively through capacity planning processes which involve the determination of frequency and available seats for each O&D pair. In this context, flight *frequency (f)* is one of the essential elements that affect airline demand (Du, 2008). It refers to the number of flights operated by a carrier on an O&D. Weekly frequency is the common phrase within the industry while stating the number of services offered by the carriers. An *airline seat* is a seat on an aircraft in which passengers are accommodated for the duration of their journey. *Available seat (s)* on the other hand refers to the total number of physical seats supplied on an O&D through these frequencies. Frequency and seat numbers together form the carriers' *capacity* or the *supply* from origin to destination.

The number of physical seats may differ depending on the aircraft type. In economic terms, the installed capacity for each frequency is referred to as the *available capacity per frequency* (s_f) (Petrick-Felber, 2014). The number of seats available on an aircraft is a factor influencing the total capacity supply in a market. As the size of an aircraft increase, the number of available seats for sale rises too. The number of weekly available seats for a certain O&D can be denoted as follows:

$$s_{o\&d} = f_{o\&d} . s_{f(o\&d)}$$

Where $f_{o\&d}$ and $s_{o\&d}$ denote the weekly frequency and seat per frequency respectively. The calculation of *f* and *s* for direct flights is straightforward and can be determined directly from the timetable, given the aircraft's seat capacity. However, the capacity determination for connecting flights is tricky as the full capacity of neither leg is completely allocated for a specific O&D.

Let's assume a connecting journey from Dubai to London via Amsterdam. In case, both segments of the itinerary (Dubai-Amsterdam and Amsterdam-London) are performed with 150-seat aircraft and the entire capacity of each leg is allocated to passengers travelling from Dubai to London, *s* for the Dubai-London market would be equal to 150. However, this would not be a realistic assumption, as the aircraft includes direct travelling passengers in addition to other passengers connecting to/from various destinations. The Dubai-Amsterdam flight may include travellers flying to Amsterdam whereas it may also include passengers connecting to other destinations such as Paris. Additionally, the Amsterdam-London flight may host passengers travelling directly to London or connecting elsewhere. Therefore, the frequency and seat supply calculation for connecting flights, which is covered in Chapter 8, is not a straight-forward process. However, in this Chapter a coefficient named *connecting seat factor,* symbolised with s_{conn}, is introduced. s_{conn} is a value between 0 and 1, denoting the maximum percentage of capacity that could be allocated for a connecting destination. In case s_{conn} is 0, it is implied that no seats are allocated for connecting passengers on a flight. On the other extreme if it is 1, the full capacity of the aircraft is allotted to connecting travellers.

s_{conn} can be defined globally for all O&Ds or determined individually for each market pair, and each airline *j* denoted as $s_{conn\text{-}odj}$. A global value of s_{conn} assumes that each flight can host the same maximum percentage capacity for connecting passengers all over the world. On the other hand, $s_{conn\text{-}odj}$ implies a customisation for the maximum connecting capacity percentage for each market and airline combination. As there exists no definitive capacity allocation for each market, the calculation of $s_{conn\text{-}odj}$ would be a weak estimate as each airline may have differing strategies for each route while determining the maximum share of connecting passengers on a flight. Moreover, an airline's capacity allocation strategy is not a publicly available information. Hence, any effort to compute $s_{conn\text{-}odj}$ would require enormous effort, as there exists vast number of O&D pairs and airlines operating in these routes. Although airlines can set different values on different segments according to their network optimisation algorithms and methods such as mixed-integral linear programming, stochastic simulations or neural networks could be deployed, a single s_{conn} value is used as part of this research's REMSET model as the study intends to develop a global methodology for capacity shares (Objective 1). Moreover, setting different s_{conn} values for different airlines and markets would bias the research outputs depending on the selected s_{conn_odj} value. For this reason, this research avoids $s_{conn\text{-}odj}$ and utilises a globally defined s_{conn} value. In the above-mentioned Dubai-London case, if s_{conn} is set to 10%, the capacity between Dubai to London via Amsterdam would be 15 seats for connecting passengers.

Codeshare agreements are another business strategy used by airline planners to extend their network and widen their product portfolio. Marketing airlines contract with operating carriers to secure seats on their flights and increase their products available for sale "on-the-shelf". The information concerning the existence of codeshare agreements between the airlines is known as they are readily observed in CRS systems. However, there exists no publicly available database disclosing the details of those bilateral codeshare agreements. Hence, the total number of available seats offered by the operating carrier to the marketing airlines' designation is unknown to third parties. However, there exists credible insight and market intelligence concerning the assigned percentage of the aircraft's seat capacity that is open for sale by other carriers. Therefore, the *codeshare seat factor* denoted by s_{code} is introduced to refer the maximum percentage available for sale to other carriers. If a codeshare agreement exists between two carriers, the value of s_{code} becomes greater than zero and smaller than 1. The higher value of s_{code} implies greater assigned capacity for the marketing airline. Therefore, total available seats for a codeshare carrier at an O&D become $s_{code}\ x\ s_{O\&D}$. Similar to s_{conn}, s_{code} can be defined at the individual level for each O&D pair for all airlines. However, this would be impractical as there are no publicly available details of codeshare contracts enabling access to information at the O&D scale. Furthermore, it would be extremely complex to employ such an approach considering the existence of hundreds of thousands of O&D pairs. Therefore, via s_{code}, a global metric is used throughout the research illustrating the average available capacity percentage on all operating flights. This percentage could be corroborated and justified by market insight and intelligence. Furthermore, an operating flight can be contracted with multiple marketing carriers. In such cases, each marketing partner is assumed to access $s_{code}\ x\ s_{O\&D}$ seats from the operating carriers' inventory.

Vast benefits of codeshare agreements have facilitated further growth of interline settlements among carriers. According to Uradnik (2011), codeshare flights now account for more than half of daily departures from the United States. The expansion of commercial cooperation through codeshare contracts has aided manifold forms of collaboration among carriers to arise. For instance, under a *hard-block space codeshare agreement,* a pre-specified space is purchased by the marketing airline whereby the carrier purchases and pays for a fixed amount of seats on the operating partners' aircraft irrespective of whether the capacity is sold or not. In a soft-*block space agreement* scheme, the marketing carrier only pays for the seat sold on the operating flight (Iatrou & Oretti, 2016). In case an (operating) airline engages into a hard-block space agreement for a specific flight, the physical number of seats available for sale for this flight reduces to $(1 - s_{code}).s_f$ assuming only one codeshare partner exist for the partnered flight. Conversely, in a soft block space arrangement scheme, since the operating carrier is unsure about the final sales figure of the marketing airline, they can disclose more than $(1 - s_{code}).s_f$ seat inventory on the CRS systems. Therefore, the sum of seats available for sale by the marketing and the operating carriers may exceed the actual physical capacity of the operated aircraft. Besides, the operating carrier may sign codeshare agreements with more than one partner and enable each marketing carrier to sell $s_{code}.s_f$ spaces which raise the total seats on the shelf more than the physical capacity of the flight. As there exists no public information concerning the seat allocation details of the codeshare arrangements, this research assumes the cooperation in soft-block space format where the presence of the codeshare contract does not limit the maximum number of seats available for sale for the operating carrier.

2.4. Time-Related Concepts

As per IATA statistics (2018), on average more than 8 million passengers travel each day on over 100 thousand flights. These figures are enormous so extensive organisation and planning is a prerequisite for achieving a coordinated and well-organised industry. Airlines operate their flights on pre-defined *timetables* and *schedules.* For Yu (2012), a flight schedule defines a feasible plan of what cities to fly to and at what times. Airline scheduling encapsulates a high volume of industry-specific time-related terminology which is elaborated in section 2.4.1. As Objective 2 of this research concerns quantifing the schedule convenience and itinerary quality that is to be utilised as an input to the REMSET, further time-related concepts which are specific to this research are introduced in Section 2.4.2.

2.4.1. General Schedule Related Concepts

Airlines base their business planning processes upon their schedules. Scheduling is the task of generating a timetable that achieves the most effective utilisation of airline resources. *Scheduled flights* are operated regularly and planned well in advance to address the existing demand on an O&D. On the other hand, *charter flights* are planned for specific demand that is out of scheduled flights' scope. Usually, timetables for scheduled flights are prepared twice a year in summer and winter term, with airlines adhering to these pre-fixed timetables with minimal alterations.

As explained in Chapter 1, since the *schedule convenience* refers to carriers' timetable attractiveness from the consumer perspective, charter flights are excluded from the research's scope as the concept only applies to journeys operating over a pre-planned timetable. The basic time-related attributes of an itinerary derived straight from the airline schedules are introduced below:

- *Total Journey Time (t_{total})* is the total travel time elapsed between the departure from the origin and arrival at the destination. This parameter includes any time spent at the intermediary points or hub airports, if any.

- *Total Flight Time (t_{flight})* is the total time spent on the flight. This parameter excludes the connecting time at the hub airport and includes the off-block, pushback and taxi time of the aircraft.

- *Connecting Time (t_{conn})* refers to the total time spent at the hub airports for connecting itineraries. t_{conn} is zero for direct flights. Thus, the equation for total journey time is $t_{total} = t_{flight} + t_{conn}$ for connecting services whereas it is $t_{total} = t_{flight}$ for direct and non-stop itineraries.

For Tu (2007), departure time on the timetable is the estimated push back time of the aircraft from the gate at the origin airport whereas the arrival time is the scheduled time to arrive at the gate at the destination airport. For direct flights, t_{total} is merely the elapsed time between passenger's departure time at the origin and arrival time at the destination. For connecting flights, t_{conn} is the elapsed time between the arrival time of the first flight to the hub airport and departure time of the second flight from the hub airport to the destination. It should be noted that changes in connection times are typically off-set by changes in fare to balance the demand. For instance, passengers opting to make a rather longer connection through a hub onto a less congested, later flight to the same destination with the same carrier will typically be offered a significantly lower total fare to do so.

Each airport authority enforces a minimum time, which is called the *minimum connection time (MCT)*, to enable flight connections. MCT is pre-determined by the airport management and compiled by airlines to ensure a feasible flight connection. For Wu (2016), the time required to process connecting passengers and baggage at an airport determines the MCT of an airline at the airport, which in turn influences the available connections between the inbound and the outbound flights at hub airports. Therefore, for a connection to occur, t_{conn} must be higher than the MCT. The MCTs set by the airport management have a direct impact on passenger convenience as a rushed MCT might put pressure on passengers to catch the connecting flight while a relaxed MCT could unnecessarily extend the t_{conn} and subsequently the t_{total}. Moreover, passengers looking forward to enjoying airport amenities might appreciate longer MCT durations. Despite these facts, for Graham (2003) most of the time airports still tend to offer one overall product, which has to appeal to a very heterogeneous collection of passengers. In this context, MCTs set by airport authorities are one-for-all parameters determining journey convenience of connecting passengers.

Having t_{total}, t_{flight} and t_{conn} at hand, an indicator named *flight time ratio* (*%t_f*) is introduced to reveal the flight time ratio of a journey. The %t_f equals to 1 for direct flights. For connecting services, the figure is less than one, and it descends as t_{conn} extends. On the contrary, *connect time ratio* (%t_c) is the share of connecting time among t_{total} which is 0 for direct flights. By definition, %t_f and %t_c together add up to 1. In the examples below (Table 2.2), time-related attributes of two competing itineraries from Dubai to Heathrow for British Airways (BA) and KLM Royal Dutch Airlines (KL) are contrasted. The schedule information is obtained directly from the 2016 summer schedule of the carriers.

Table 2.2: Example of t_{flight}, t_{conn}, t_{total}, %%t_f, and %tc for BA and KL Flights.

BA106 – direct flight, departing 01:35 UAE local time, arriving 06:15 UK local time.	t_{flight} = 7 hours 40 minutes t_{conn} = 0 minute t_{total} = 7 hours 40 minutes %t_f = 1 and %t_c = 0
KL428 from Dubai to Amsterdam, departing 00:50 local UAE time, arriving 06:00 Netherlands local time connected to KL1001 from Amsterdam to London, departing 07:20 Netherlands local time and arriving in London at 07:40 UK local time.	t_{flight} = 8 hours 30 minutes 1st leg is 7 hours and 10 minutes 2nd leg is 1 hour and 20 minutes t_{conn} = 1 hour and 20 minutes t_{total} = 9 hours 50 minutes %t_f = 0,864 and %t_c = 0,136

The BA flight offers a shorter t_{total} as the carrier performs a direct non-stop service. A passenger choosing the KL itinerary completes the journey in 9 hours and 50 minutes where 80 minutes of this duration is planned to be spent at the Amsterdam airport.

For a particular flight leg, the duration between the scheduled departure and arrival time is known as the *block time.* Any deviation from the scheduled time and *actual time* results with *delay*. For Cook (2007), an airline's planned departure time can be different from the schedule, namely having a different estimated off-block time. Thus he distinguishes between delay relative to the flight plan and delay relative to the schedule. Moreover, delay in departure time does not have to be identical with the delay in arrival time. Airlines can either close or extend the total delay time depending on performance through taxi times or during the flight. According to the Transportation Research Board (2014), airlines may add minutes to their block time schedules to accommodate for actual historical times, which include some delay resulting from flight restrictions, congestion and a variety of other factors. Therefore, different airlines can determine varying block times for the same O&D pair as shown in the example below (Table 2.3) for the same Dubai–Heathrow route obtained directly from the airline 2016 summer schedules.

Table 2.3: Example of t_{flight}, t_{conn}, t_{total}, $\%t_f$, and $\%t_c$ for BA and Emirates (EK) Flights.

BA106 – direct flight, departing 01:35 UAE local time, arriving 06:15 UK local time.	t_{flight} = 7 hours 40 minutes t_{conn} = 0 minute t_{total} = 7 hours 40 minutes $\%t_f = 1$ and $\%t_c = 0$
EK5 – direct flight, departing 15:45 UAE local time, arriving 20:15 UK local time.	t_{flight} = 7 hours 30 minutes t_{conn} = 0 minute t_{total} = 7 hours 30 minutes $\%t_f = 1$ and $\%t_c = 0$

Although, both BA106 and EK5 fly the same route directly and without making any stops at an intermediary point, due to the more extended block time set, British Airways' total journey time exceeds Emirates' by 10 minutes. Therefore, even if rival carriers fly the same routes, their total journey time proposition may differ depending on their scheduling.

Any delay could extend the t_{total} which could affect travellers' journey experience negatively. However, such a delay would most probably be unforeseeable in advance and therefore cannot be studied as part of the airline schedule convenience. Carriers' adherence to their timetables indicates how well they deliver the service promised. Although this is a crucial factor of airline choice, it is beyond the scope of the research. During their decision-making process, passengers evaluate alternative competing products "on-the-shelf", by judging the attractiveness of their planned schedules. At the moment of booking, travellers are less likely to predict if any delay with their flights will happen. Although passengers may have perceptions regarding the airline's reputation for on-time performance, this should be evaluated under the airline's brand attractiveness, which is again out of the scope for this research. If any historical divergence from the schedule and frequent delays are reflected to the block times in the schedule, this does fall within the scope of the research as it would be reflected in the airline timetable.

2.4.2. Research Specific Time-Related Concepts

The previous section addressed the traditional time-related concepts used in the industry which are generic and have a straightforward computation methodology. This section introduces additional time-related terminology affecting the schedule convenience. These concepts relate to network attractiveness and their role in the REMSET model are elaborated in the following Chapters.

t_{total}, t_{flight} and t_{conn} are objective quantitative measures determined strictly by the airline timetables. However, the perceived quality of a particular flight concerning the departure and arrival time is subjective and can change from one passenger to another. Travellers may depict varying degrees of preference for different time zones of the day. The study of Forister (2009) finds that there exists significant variation in the desirability of departure times across the day and that consumers have strong but statistically insignificant preferences departing closer to their desired departure time. Therefore the following attributes are introduced to illustrate the attractiveness of the departure and arrival time of an itinerary.

- *Departure Time Quality (q_{dep})*: The perceived attractiveness of the departure time from the origin of a given itinerary.

- *Arrival Time Quality (q_{arr})*: The perceived attractiveness of the arrival time to the destination of a given itinerary.

q_{dep} and q_{arr} are subjective factors and their influence on consumer choice are tested through the passenger survey. Another subjective time-related concept of a connecting itinerary is the *maximum connection time* (MaxCT). MaxCT specifies the maximum time a passenger is willing to wait for the connecting flight (Groesche, 2009). Not all connections meeting the

MCT criterion are attractive for travellers. Transfer passengers may not appreciate longer waiting times at the hub airports. While the MCT defines the lower limit of generating a successful connection at the airport hub, MaxCT sets the upper bound. Thus, in order to attain a successful connection, $MCT \leq t_{conn} \leq MaxCT$ must be satisfied. Unlike the MCTs, the MaxCT value of a hub airport is not a pre-defined value but depends on consumer's individuaş tolerance, deeming it to be a subjective factor. Therefore, while airport authorities determine the MCT, passengers define their acceptable MaxCT in their thought process. Although some airport authorities may be subject to regulations setting the upper limit for t_{conn}, they would not be in favour of such an approach, as it would limit their passenger flow and hence revenues. The passenger survey intended to assess the MaxCT tolerance of the consumers.

Although a connection is technically viable as long as the t_{conn} is greater than or equal to the MCT and smaller than or equal to the MaxCT, the passengers' appreciation for connections may vary depending on the length of t_{conn}. A connection may be stressful if the t_{conn} is very close to the MCT. Although such an itinerary would meet the airport's MCT criterion, it might not be found attractive by passengers as any delays with the incoming flight or any complication or inconvenience experienced at the connecting airport would increase the risk of missing the second flight. In this context, a surplus time can be formulated as follows:

$$MCT\ Surplus = t_{conn} - MCT$$

Since t_{conn} cannot be smaller than the MCT, the MCT surplus is always greater than or equal to zero. For Ziller (2008), journeys with limited connection times can leave passengers scrambling to secure a seat on a later flight, appreciating the existence of a non-zero MCT surplus. For this reason, it is assumed that passengers may prefer a *buffer time* (t_{buffer}) on top of the MCT to relax their journey at the intermediary airport. This assumption was tested with the passenger survey. If the t_{conn} is less than the MCT plus t_{buffer}, the journey is deemed to be stressful. For direct flights, the *stress time* (t_{stress}) is assumed to be zero, as the passengers do not experience any visit to an intermediary airport. For the connecting flight, the t_{stress} is calculated to be the difference of t_{conn} and (MCT + t_{buffer}), formulated as follows:

$$t_{stress} = \begin{cases} 0, if\ t_{conn} \geq (MCT + t_{buffer}) \\ [MCT + t_{buffer} - t_{conn}]\ OR\ [t_{buffer} - MCT\ Surplus], if\ t_{conn} < (MCT + t_{buffer}) \end{cases}$$

By definition, the minimum value of t_{stress} can be 0, implying that the passengers would experience a hassle-free trip, whereas the maximum value of the parameter can be equal to t_{buffer}, inferring a complete lack of buffer time in case no MCT surplus time exists.

On the other hand, overextending t_{buffer} might lead to *wasted time* (t_{waste}) to occur. The excess t_{conn} value may leave more than adequate time to catch the connecting flight and even enjoy the amenities of the hub airport. For direct flights, wasted time is zero, as passengers do not travel through any hub airport. For connecting itineraries, any t_{conn} that is more than the MCT plus buffer time is deemed to be "wasted" and can be formulated as follows:

$$t_{waste} = \begin{cases} 0, & if\ t_{conn} \leq (MCT + t_{buffer}) \\ [t_{conn} - (MCT + t_{buffer})]\ OR\ [MCT\ Surplus - t_{buffer}], & if\ t_{conn} > (MCT + t_{buffer}) \end{cases}$$

By definition, if t_{conn} is not equal to the sum of the MCT and buffer time demanded by passengers, then passengers would experience either a t_{stress} or t_{waste}. If the t_{stress} of a journey is a non-zero value, then the t_{waste} equals zero. Conversely, in case a journey includes a wasted time, then it lacks stress time. The minimum numerical value of t_{waste} is 0, referring to a tight journey, where its maximum value can be (MaxCT - t_{buffer}). Therefore, it is inferred that the t_{stress} and t_{waste} are mutually exclusive concepts. An itinerary's connection time is either stressful or wasted depending on t_{conn}, excluding the rare perfect case in which $t_{conn} = MCT + t_{buffer}$. In the perfect case, both t_{stress} and t_{waste} are minimised to 0 since the value MCT surplus equals to t_{buffer}. The relational table in this context is summarised as follows:

Table 2.4: Perfect, Stress and Waste Cases Along with Their t_{stress} and t_{waste} Values.

Case	t_{stress}	t_{waste}
$t_{conn} = MCT + t_{buffer}$ → Perfect case $MCT\ Surplus = t_{buffer}$	0	0
$t_{conn} < MCT + t_{buffer}$ → Stress case $MCT\ Surplus < t_{buffer}$	$(MCT + t_{buffer}) - t_{conn}$	0
$t_{conn} > MCT + t_{buffer}$ → Waste case $MCT\ Surplus > t_{buffer}$	0	$t_{conn} - (MCT + t_{buffer})$

Both stress time and wasted time are anticipated to be negative experiences for passengers. They together form the unappreciated duration of the journey defined as the *total inconvenient time* ($t_{inconvenient}$), which is equal either to t_{stress} or t_{waste}.

$$t_{inconvenient} = \begin{cases} t_{stress}, & if\ t_{stress} > 0 \\ t_{waste}, & if\ t_{waste} > 0 \\ 0, & if\ t_{stress} = 0\ and\ t_{waste} = 0 \end{cases}$$

It is noteworthy to restate that for direct services, $t_{inconvenient}$ equals to zero as both t_{stress} and t_{waste} parameters are not applicable for such flights. Moreover, $t_{inconvenient}$ also equals to zero for the perfect case for the connecting itineraries. The existence of $t_{inconvenient}$ in an itinerary has a negative impact on consumer convenience, implying that journeys with higher $t_{inconvenient}$ lead to consumer dissatisfaction. Thus, it is possible to introduce a parameter called inconvenient time percentage ($\%_{inconvenient\_time}$) assessing the share of inconvenient time within the total journey time, formulated as follows:

$$\%_{inconvenient\_time} = {t_{inconvenient}}/{t_{total}}$$

The concepts of t_{stress}, t_{waste} and subsequently $\%_{inconvenient\_time}$ can also be reformulated in terms of utility. In case the utility graph is plotted with respect to the MCT Surplus, the shape of the curve would be non-linear as for instance the negative utility of a tight connection (a positive t_{stress} equal to *x*) especially for onward long-haul connections is far less convenient than a positive t_{waste} which is equal to *x.* As per the Prospect Theory, individuals tend to be risk averse in a domain of gains and "*losing hurts more than a comparable gain pleases*" (McDermott, 2001), the losses or the penalty sourced due to a potential misconnection would infer a relative loss inversion, providing evidence for the asymmetry of such utility curve. Therefore depending on the specific circumstances of the passengers, the utility curve's shape can be changed. Although, the effect of t_{stress} and t_{waste} on consumer utility may change from one passenger to another and the demand for t_{buffer} may vary depending on the specific conditions of the traveller (like a passenger connecting to long haul onward flight may demand for a higher t_{buffer} in comparison to another traveller connecting to a short-haul flight) it is expected that, $t_{inconvenient}$ which is either sourced from a non-negative t_{stress} or t_{waste} has a negative effect on passengers' utility.

To maximise their utility and to experience a comfortable journey, consumers seek to minimise $\%_{inconvenient\_time}$. They may not compute this parameter while choosing their flights; however they do conduct a justification in broader terms while booking their itinerary. Inconvenient time percentage and flight time ratio is inversely correlated. As $\%t_f$ increases among competing itineraries, MCT surplus and thus $\%_{inconvenient\_time}$ are minimised. Also, as $\%t_c$ escalates $\%_{inconvenient\_time}$ increases too if t_{conn} is greater than the t_{buffer}. In case t_{conn} is between MCT and $MCT + t_{buffer}$, $\%_{inconvenient\_time}$ decreases despite the surge in $\%t_c$ as both t_{stress} and t_{waste} decrease in that band.

In the table below (Table 2.5), three connecting flight cases are introduced with an in-depth analysis of the above-mentioned time-related parameters.

Table 2.5: t_{stress}, t_{waste}, Tinconvenient, $\%_{bad\ time}$ for Different Flight Cases under Following Assumptions: t_{buffer} = 30 minutes, MaxCT = 300 Minutes (5 Hours). Under These Assumptions, t_{stress} can have Any Value Between 0 to 30 Minutes, while t_{waste} can be between 0 to 270 Minutes.

Case	Remarks
Direct Flights	t_{stress} = 0, t_{waste} = 0, $t_{inconvenient}$ = 0, $\%_{inconvenient\_time}$ = 0%
KL428 from Dubai to Amsterdam, departing 00:50 local UAE time, arriving 06:00 Netherlands local time connected to KL1001 from Amsterdam to London, departing 07:20 Netherlands local time and arriving to London at 07:40, UK local time.	t_{conn} = 80 minutes MCT for Amsterdam Schiphol Airport = 50 minutes MCT surplus = 30 minutes MCT surplus = t_{buffer} → Perfect connection case t_{stress} = 0, t_{waste} = 0, $t_{inconvenient}$ = 0 t_{total} = 9 hours 50 minutes and $\%_{inconvenient\_time}$ = 0%
LH631 from Dubai to Frankfurt, departing 01:00 local UAE time, arriving 06:00 Germany local time connected to LH924 from Frankfurt to London, departing 07:00 Germany local time and arriving to London at 07:40, UK local time.	t_{conn} = 60 minutes MCT for Frankfurt Airport = 45 minutes MCT surplus = 15 minutes MCT surplus < t_{buffer} → Stress case t_{stress} = 30 – 15 = 15 minutes, t_{waste} = 0, $t_{inconvenient}$ = 15 minutes t_{total} = 9 hours 40 minutes (580 minutes) $\%_{inconvenient\_time}$ = 15 / 580 = 2.58%
QR1003 from Dubai to Doha, departing 05:30 local UAE time, arriving 05:40 Qatar local time connected to QR3 from Doha to London, departing 07:55 Qatar local time and arriving to London at 13:15, UK local time.	t_{conn} = 2 hours and 15 minutes = 135 minutes MCT for Doha Airport = 45 minutes MCT surplus = 90 minutes MCT surplus > t_{buffer} → Waste case t_{stress} = 0, t_{waste} = 90 – 30 = 60 minutes, $t_{inconvenient}$ = 60 min t_{total} = 10 hours 45 minutes (645 minutes) $\%_{inconvenient\_time}$ = 60 / 645 = 9.3%

For connecting flights, the instance when the journey is interrupted with the connection for the next flight is a critical convenience factor. For instance, for two competing connecting itineraries with the same flight time of 10 hours, the passengers may have a preference for the option taking 9 hours in the first leg and 1 hour for the second over an alternative with 5 hours of flight time on both legs. If the flight is disrupted either at the very early or at the very late phases of the journey, this could be a more convenient choice over other alternatives enabling a relaxed time to sleep, watch a movie onboard or work. Therefore, a parameter named *flight time split ratio* (*f_{split}*) is introduced. f_{split} can be calculated by dividing the duration of the longer flight leg to the shorter one. In case, the flight is equally split between legs, f_{split} equals to 1.

This chapter has addressed the fundamental concepts of airline schedules and research specific terminology concerning the supply and time-related concepts. Parameters such as t_{buffer}, t_{stress}, t_{waste}, $t_{inconvenient}$, $\%_{inconvenient\_time}$, f_{split} are unique time-related concepts introduced in this research. The impact of these parameters on consumer choice was assessed in the passenger survey, and was used for determining the schedule quality of competing airlines' itineraries in order to fulfil Objective 2. Additionally, s_{conn} and s_{code} are supply related factors unique to this study and function as prerequisites in determining the consumer-centric supply of the competing airlines to attain Objective 1. From this perspective, the concepts introduced in this Chapter are vital ingredients of the REMSET. This Chapter also served as an introduction to the literature review which is covered in the proceeding Chapters.

Chapter 3: Literature Review – Overview of the Airline Industry, Business Models, Network Types and Planning Processes

"Airlines spell glamour, high profits and big business. Television viewers watch airline programmes spellbound. The charismatic heads of certain airlines are known to everyone. But few know the real story" quotes Rigas Doganis in his book The Airline Business in the 21st Century (2001, s. foreword). Indeed the airline industry generates an enormous volume of revenue but only limited profitability. As per IATA figures (2018), in 2017 the global revenue of the industry was calculated to be 754 billion USD of which only 34.5 billion USD was estimated to be the sum of global net profit of airlines, contributing only to 4.6% net margin. Hitt et al. (2007) note if all of the profits and losses ever reported by all publicly traded passenger airline companies in the United States were summed up, the total would be negative. Since the industry generates smaller profit margins, every fine detail needs to be carefully planned and organised by the airline decision makers. For this reason, understanding the academic theory and applications relating to the airline industry can be a critical factor of success for carriers. The industry offers extensive areas of academic research enabling academics to develop the sector with their invaluable contribution.

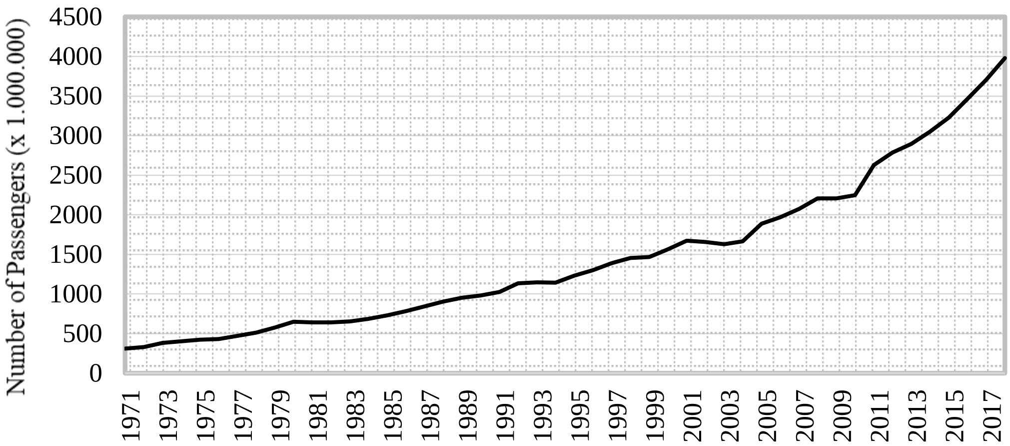
As this research aimed to develop a methodology analysing the schedule and network performance of air services from a consumer-centric perspective, reviewing previous academic knowledge was essential to develop an understanding concerning the dynamics of the airline industry. For this reason, this Chapter undertakes an in-depth literature review regarding the general framework of the research's focus areas involving airline schedules, networks and planning processes. At the same time, this Chapter also concentrates on the current market performance estimation models available in academia and identifies the gaps that are intended to be filled by this research.

The Chapter is structured into five sections. The first section analyses the airline industry in general by discussing the developments in recent history and develops an understanding of today's business environment. In the second section, different airline business models are discussed and benchmarked. The third section investigates airlines network types available in the academic literature and introduces several approaches to assess network performance of the carriers. The fourth section reviews the literature on airline planning processes in detail, with each of the sub-planning phases. In the final section, current literature regarding the airline market performance evaluation and quality service is covered.

3.1: Overview of the Airline Industry

Access to air transportation has boomed over the years. As a result of globalisation, macroeconomic developments, increases in the Gross Domestic Product (GDP), intensifying competition, deregulation and rising degrees of people and business mobility, the demand for air travel has soared substantially. As Figure 3.1 demonstrates, the number of air travellers has increased from 310 million in 1970 to almost 4 billion in 2017.

Figure 3.1: Number of Air Travellers since 1970. Source: Derived from World Bank Data.

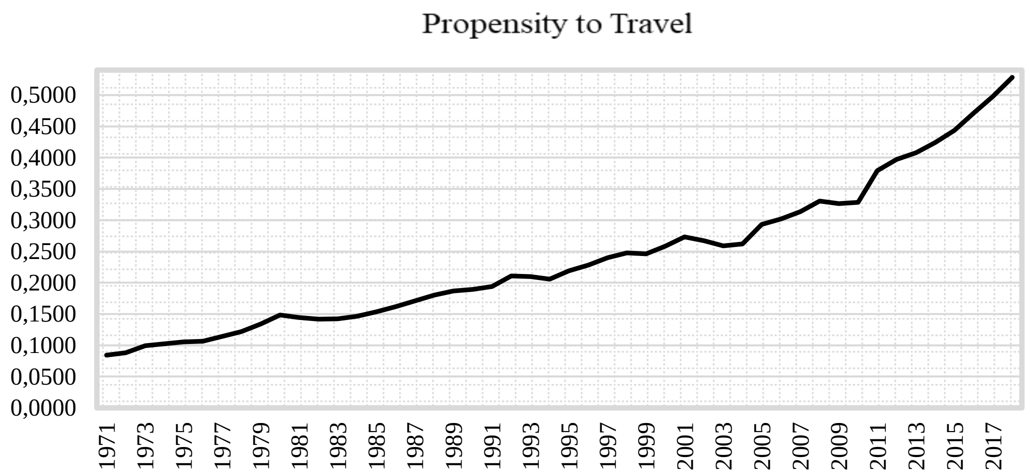


The industry has seen a compounded annual average growth rate (CAGR) of 4.8% from 1980 to 1999. At the beginning of 2000s, the aviation sector marked stagnation for growth due to the economic slowdown as well as the terrorist attacks on 11 September 2001. The SARS virus in 2003 exacerbated the situation, leading the industry to face the most difficult times in its history (Cento, 2009). Since 2004, the industry recovered and even accelerated with a 5.7% CAGR, with the only exception in 2009 due to the financial recession. Historically the growth of aviation has continued despite rising oil prices. Although jet fuel prices make up a significant share of airlines' costs, the industry has continued to see a growth trend. According to the US Energy Information Administration, the average crude oil price was 20 USD per barrel in 1990, 31 USD in 2003, 60 USD in 2006, even above 100 USD after 2008 with a sharp decline to 45 USD in 2016 which moved back to above 70 USD in mid-2018.

3.1.1. Commoditisation of Air Travel

Comparing the CAGR for air travel demand, which is above 5%, with the world's population surge of 1.5% CAGR since 1970, it is inferred that the propensity to travel by air has been increasing globally. Changes with the propensity to fly have a direct impact on global air travel demand. Using the World Bank data, the propensity metric was derived by dividing the total number of air travellers with the world's total population, as plotted in Figure 3.2 below. Whilst in the early 1970s less than one in every ten people had access to air transport product, from 2010 onwards, this figure increased and exceeded four, confirming the continuous rise for air travel demand and its subsequent commoditisation trend.

Figure 3.2: Propensity to Travel since 1970. Y-axis Demonstrates Flight Per Capita Per Year. Source: Derived From IMF and World Bank Data.



Early surveys of air passengers, such as Lansing and Blood's work (1984), demonstrated that as personal incomes rise, more is spent on all non-essentials including all modes of travel. Additionally, air transport, which is the costlier but more comfortable and convenient option, has become more competitive compared to surface travel leading to a shift in demand from surface modes to air. The boom in air travel demand has not been a result of spontaneous and unforeseen developments. The commoditisation process of air travel was ponderous but stable. According to Harrison (2013), since the early stages of commercial air travel, the growth in passenger traffic represents the culmination of changes in the industry. Positive macroeconomic developments, deregulation, increasing competition, the emergence and rise of low-cost carriers together with the proliferation of the internet allowing price transparency and product accessibility, have contributed air travel to penetrate into the mass market.

The report of IATA published in (2008) confirms the commoditisation trend of air travel from the perspective of demand elasticity. The study implies that lower travel prices greatly stimulate traffic and raise revenues. On the other hand, for an airline on a given O&D, increases in airfares are likely to result in a more than proportionate decrease in air travel. Apart from the fare impact on air travel demand, these findings confirm that air prices are elastic, responsive to market dynamics and thus imply that air travel is not a luxury good. However, it should be noted that in the literature there exists a wide range of (air travel) demand elasticity calculations. The results differ depending on the date of the research, market focus and methodology. Intervistas' report (2007) has a compelling compilation of previous studies on air travel demand elasticities. The report states the consensus among most aviation economists has been that demand for airline services is generally both price and income elastic. When consumers are choosing between airlines or destinations, there exists price elasticity; but as the report argued, "if all competitors on a route, or if a wide range of routes all experiences the same proportionate price increase, the demand for airline services becomes less elastic. As a price increase is extended to ever larger groups of competing airlines or competing destinations, and then the overall demand for air travel is revealed to be somewhat inelastic" (Intervistas, 2007, s. vi). This quote is a strong statement in the sense that affordability of the air product is indeed the top cause of the commoditisation of air travel. If the pricing structures move beyond travellers' level of affordability, the process is likely to be reversed, and the consumption decelerates.

Although increasing propensity to fly and commoditisation trends are globally valid facts, these processes are not actualised in an even manner. Albers et al. (2009) estimate that the 25 wealthiest countries by GDP per capita account for 51% of world's GDP, 15% of world's population, 69% of international passenger volume and 70% of total passenger volume. Demand growth scheme varies due to differing economic, political and regional trends. The table below (Table 3.1) which was derived from the World Bank data demonstrates that different regions of the world experienced different growth schemes from 1991 to 2013.

Table 3.1: Annual Number of Passengers and CAGR Figures for Different Regions of the Globe as of 1991 and 2017. Table Derived from the World Bank Data. (Available at https://data.worldbank.org/)

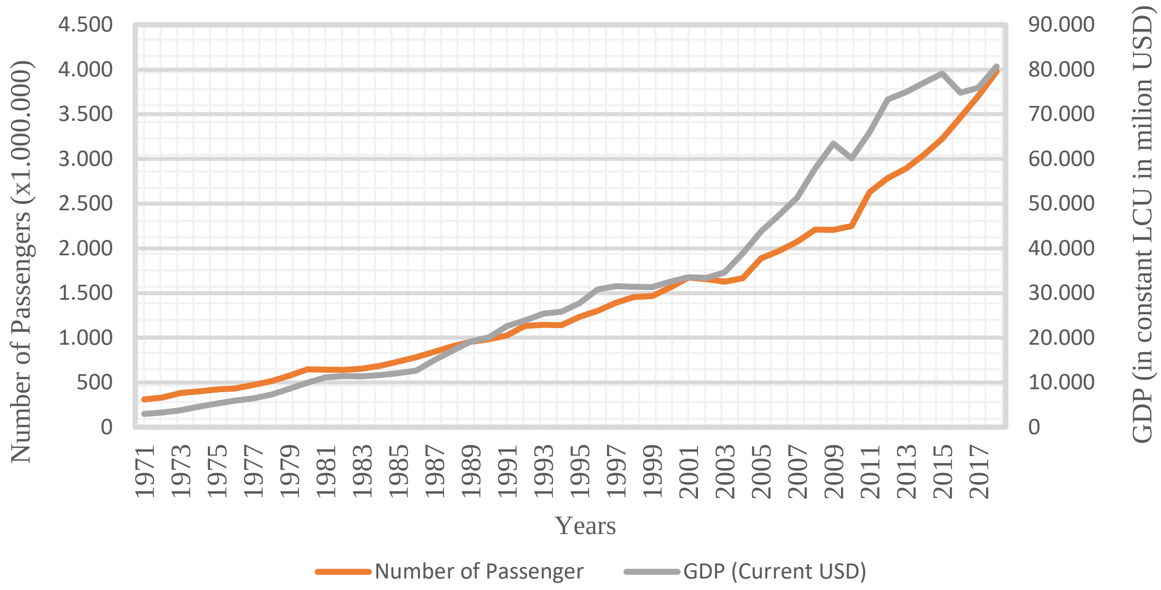
Regions	Annual Number of Passengers		
	1991	2017	CAGR Growth
United States	452,015,904	849,403,000	2.36%
EU	193,389,200	763,824,571	5.22%
OECD Countries	820,591,904	2,217,332,475	3.75%
BRIC Countries	178,151,100	876,826,306	6.08%
Latin America & Caribbean	54,218,500	223,748,010	5.39%
Middle East & North Africa	36,420,700	251,171,228	7.41%
Sub-Saharan Africa	13,966,200	50,643,817	4.89%
World	1,133,228,204	3,978,849,402	4.76%

As observed in Table 3.1, between 1991 and 2013, the pace of growth in air travel scored higher in emerging and relatively lower-income economies compared to wealthier and larger economies. This finding can be argued to support the commoditisation trend of air travel. Morphet (2011) argues that because of the varying speeds of factors affecting air travel demand from one country to another, the ranking within the top 20 countries by air trips will change over the decades. She points out that developing markets have enjoyed a more significant growth percentage in air travel demand, with the trend likely to continue over the coming years. Airbus' report on Global Market Forecast (2012) suggests that traffic growth between advanced and emerging air transport markets will grow at an average CAGR rate of 5.1%, above the world average growth rate of 4.7%, and not far off the 6.6% annual growth rate forecast between emerging markets.

3.1.2. Gross Domestic Product (GDP) Impact on Airline Industry

Increases in GDP is the driver of growth for air travel demand. According to Lyneis (2000), air travel demand can be affected by internal and external factors, with GDP nominated as a predominant external factor. Another study by Heinzl et al. (2007) also confirms that, being a representative variable of economic activity, GDP is a factor that shapes the demand for air travel. Figure 3.3 shows that the number of air travellers increased when global GDP has risen, with growth halting when GDP growth was stalled. Since 2000, GDP growth scored a CAGR of 3.5%, while the number of passengers has surged by 4.7% on average per annum.

Figure 3.3: Number of Passengers and World Cumulative GDP in Constant LCU in Million Usd. Data Derived from IMF. (Available at https://www.imf.org/en/Data)



Rising economic activities as well as per capita income push the demand for air travel forward as more company employees need to fly for their businesses and more individuals can book flights for their vacations. Swan (2009) argues that on average, 1% of GDP is spent on air travel in developed and developing countries. According to *The Global Airline Industry* (Belobaba, Odoni, & Barnhart, 2009), historically the annual growth in air travel realised around twice the annual growth of the GDP. In its Economic Outlook, Boeing (2014) estimates 3.2% for GDP growth and 5.0% for air travel demand growth per annum until 2033 while Airbus forecasts the same figures as 3.2% and 4.7% respectively (Airbus, 2014). These estimates imply $CAGR\ (demand\ growth)\ /\ CAGR\ (GDP\ growth)$ ratio to be between 1.5 to 1.6, meaning the demand is forecasted to grow between 1.5 and 1.6 times more than the predicted GDP development.

Gillen et al. (2007) find the elasticity of air travel demand, with respect to per capita GDP, to vary from 0.8 to 2.6 depending on the reference country of computation. In their study, the median value of air travel elasticity was calculated as 1.14 whereas the average was found to be 1.5. In other words, similar to what Boeing and Airbus estimates, if the GDP of a country surges by 1%, the air travel demand is expected to grow by 1.5% on average.

The contribution of GDP to the aviation industry is not one-sided; the benefits and effects are reciprocal. While air traffic demand has grown together with economies, air transportation is itself also a crucial facilitator of economic growth. According to IATA's report on Aviation Economic Benefits (2011), the connectivity of air services has a statistically significant relationship with labour productivity levels, where a 10% rise in connectivity boosts labour productivity by 0.07%. According to ATAG's report (2013), aviation supports 8.7 million jobs and more than 600 billion USD of GDP worldwide directly. As per the report, including the industry's indirect, induced and tourism catalytic impacts, it supports 58.1 million jobs and 2.4 trillion USD economic value.

3.1.3. Deregulation of the Airline Industry

Air travel became a preferred and available mode of transportation in the 20th century. Jets were integrated into the market in the late 1950s, and the industry achieved an accelerating growth pace thereafter. However, the growth in air travel triggered several issues to be dealt with from the regulatory perspective. Due to the complex nature of the airline industry, the surge in the demand began placing strains on government authorities. While rising labour and fuel costs created severe obstacles for the growth of the industry, an increasing degree of internationalisation with booming cross-border demand and supply was achieved. Such an extensive internationalisation led to the introduction of certain regulations. In the mid-20th century, initial frameworks were set by the institutions and governments in order to regulate the aviation industry. At the Chicago Convention in 1944, fifty-two member states agreed the regulation of (1) capacity and frequency, (2) airfares, (3) freight levels and (4) the application of traffic rights or "air traffic freedoms" at the Chicago Convention in 1944. The convention had also established the International Aviation Organization (ICAO) to coordinate worldwide technical and operational standards (Cento, 2009). The regulatory elements obstructed new entries, competition and pricing freedom. Nation states had extensive control over its civil aviation policies. In an attempt to provide a counterweight to the dominance of governments and ICAO, an institutional body, representing the collective interest of airlines named the International Air Transport Association (IATA) was established in 1945. IATA had the authority to set the ticket prices that seemed to encourage a price-controlling or fixing culture (Greg, Jody, Thomas, & Nordenflycht, 2009). Governments and multinational institutions were protecting the industry to the benefit of nation states and legacy carriers.

For some scholars, it would not be fair to argue that governments imposed regulations solely to support the hidden agenda of their national interests. Most scholars agree that the purpose of government regulation is to create a stable industry (Kaps, 1997). According to the public-interest theory of regulation, regulation is established primarily for the benefit of society at the expense of regulated firms. In this view, “the government is the mechanism by which individuals in the economy express their demands to cure market failures such as public goods, monopolies, and spill-over problems” (Chmura, 1984, s. 1). To avoid the deleterious impact of destructive competition and to avoid economic chaos, governments established a regulatory framework for the public interest (Dempsey & Goetz, 1992).

The other view towards regulation holds that regulation enhances the wealth of some parties at the expense of society’s interests. Stigler (1971) suggests that regulation is acquired, designed and operated by the industry for its benefit. It is claimed in this argument that firms including airline companies and aircraft manufacturers benefited from regulation. For Levine (1976), regulation was an obstacle for achieving further growth in the airline industry, harming passengers in the sense that through protection, airlines were enjoying a competition-free business environment. Friedman (1995) argues that the growth in regulation is responsible for the slowdown in economic growth. Christainsen (1981) and Haverman studied the effect of regulation on labour productivity and found that 10% of the slowdown in labour productivity was due to the expansion of federal regulation in the mid-1970s.

The acceleration and growth of the aviation industry initiated the deregulation process which began in the USA after 1978. For Borrenstein (1992), deregulation meant a rejection of the inefficient regulation of the past 50 years. Without deregulation, the global airline industry would hardly observe commoditisation limiting the propensity to fly. Deregulation in the United States has been part of a larger global airline liberalisation trend, especially in Asia, Latin America and the European Union (Smith & Cox, 2006). Before 1978, due to the increasingly complex nature of air travel, governments introduced a set of regulations to ensure the stability of the industry. The regulations were usually protecting national carriers, discouraging new entries and even enabling governments to directly or indirectly control airfares. High-cost national and full-service airlines benefited from regulatory measures implemented by governments. "*Since the profitability of the sector was marginal the case was made that the economic rents from the protectionism afforded by governments to their national airlines were overwhelmingly enjoyed by the staff in a combination of high ratios of wages to*

GDP per head and low productivity by comparison with" (Barrett, 2004, s. 138). Almost all states had regulatory mechanisms requiring the governmental approval of rates for international air transportation. In order to foster public interest values, which balance the competing interests of airlines, consumers and other national policies, the governments had the authority to suspend, modify and establish tariffs (Dempsey, 1987). However, these regulations led to the onset of high inflation, low economic growth, falling productivity, rising labour costs and higher fuel costs that devastated the airlines and only deepened the problems (Thierer, 1998). Regulations hindered competition and protected national carriers. Those protectionist policies averted the legacy carriers to focus on efficiency and cost control.

Protectionism in the aviation industry was not only an internal policy of governments. It was also part of international politics in the sense of traffic rights, airline designations, capacity and fare controls. The governments were protecting their national carriers through bilateral agreements with other governments. In his book, Doganis (2001) mentions the gradual transition of bilateral agreements towards liberalisation instigated by deregulation. During the 1980s through the pioneering of the US, the trend was spread to different regions of the world, especially to Europe, but the process was gradual and bilateral. During the 1990s international liberalisation and open markets, bilaterals were not adequate to create the desired boom in the industry. Bilateralism was still the restricting factor. At the ICAO Air Transport Colloquium in 1992, it was discussed that “the bartering process of bilateralism tends to reduce opportunities available to the level considered acceptable by the most restrictive party” (Samuel, 1992, s. 30). The 1990s witnessed the extension of initially limited versions of open skies agreements in which the nation states progressively removed limitations on flight rights. At later stages, further extensions of the facilitation of liberalisation were achieved. Although protectionist tendencies are still valid, especially in the eastern regions of the world, deregulation has widely opened up the industry.

Through deregulation and liberalisation, the industry has achieved significant progress in market access, capacity, designation and tariffs. The deregulation of the US air travel industry aimed to ensure the maximisation of consumer benefits through the extension of fair competition among airlines. Airlines were able to access new markets, offer capacities on different O&D pairs by considering demand schemes rather than following government’s restrictions. From the consumer perspective, one of the most significant achievements of deregulation is lower airfares. According to Robson (1998) airfares have consistently fallen under deregulation, with some economists finding that fares are 22 per cent lower today than they would have been if the industry stayed under government control. Winston and Morrison, in their study (1995), calculated the annual savings to air travellers attained with deregulation at 12.4 billion USD. They also found that passengers saved an additional 10.3 billion USD each year in reduced travel time because of the availability of more convenient flights and more efficient route systems offered by airlines. Crandall and Ellig (1997) estimated that when figures are adjusted for changes in quality and amenities, passengers save 19.4 billion USD per year directly from airline deregulation.

3.2: Airline Business Models

The liberalisation process created a competitive pressure on airlines, with their efficiency beginning to be the ultimate differentiating factor. In the aftermath of deregulation, a large number of new entries and mass exits were observed throughout the industry. The survivor airlines had no choice but to focus on increasing their efficiencies. Khan (1988) states that new entrant and the ability of efficient airlines to quote much lower fares than the incumbents were a clear reflection of the extent to which the latter's costs had become inflated behind the protective wall of regulation. Even if a limited number of airlines served particular routes, more accessible market entry options were inhibited by increasing tariffs to obtain excessive profits, for fear of new entrants (Doganis, 2009). As consumers were now more price-sensitive, the airlines had no choice other than regaining profitability through cost control and efficiency.

Cento (2006) identifies three pronounced types of airline business models that are the most dominant in the post-deregulation era: the Full-service carriers (FSC), the LCCs and the charter carrier models. Through market deregulation, the FSC model transformed from the former state-owned flag carrier model, into a new and efficient model utilising the hub and spoke networks. LCCs appeared in the industry after deregulation, offering value for a new segment of air travellers by having superior cost advantages. While FSCs and LCCs both operate scheduled services, charter carriers address ad-hoc demands not captured by the scheduled services, by a hiring arrangement with a particular customer (Doganis, 2001). Therefore charter carriers do not adopt a long-standing business strategy in line with regular air travel demand.

The following sections discuss the FSC and LCC business model with a comparative perspective. Charter carriers are not emphasised within these sections as their non-scheduled business principle is beyond the scope of this research. A recent airline business type called “hybrid carriers” is also covered in section 3.3.5. However, the hybrid type is not categorised as a separate business model as its business principle is argued to be a combination of the existing FSC and LCC models.

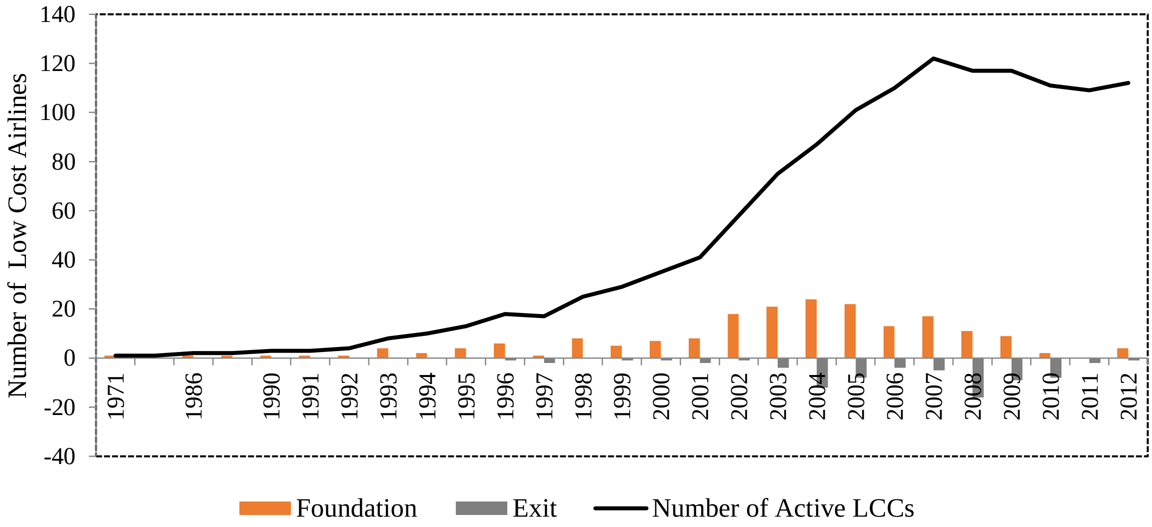
3.2.1. Full-Service Carriers (FSCs)

FSCs, also termed as "legacy carriers", provide a wide range of all included services covering pre-flight, onboard and post-flight phases. FSCs operate the traditional airline business model, in which the services are bundled, an all-inclusive fare is quoted, and the major proportion of revenue is generated through the mainstream flow of flight revenues with limited a share of ancillary share. FSCs incur additional costs on global distribution, in-flight catering, ground facilities and the frequent flyer programme. These additional costs are more than recovered through higher revenues and yields (Aggarwal, 2011). According to Cento (2009), a FSC is defined as a carrier developed from the former state-owned flag carrier, through the market deregulation process, into an airline company with its core business focused on passengers and cargo. FSCs can employ a hub and spoke or point-to-point network model, and usually participate in a global alliance. They engage in customer relationship management and yield management to maximise revenues. They also utilise a multi-channel sales strategy to diversify the areas that would enable the carrier to generate additional sales flow, usually by participating in the global distribution systems. Full-service carriers with extensive flight networks can be named as full-service network carriers (FSNC).

3.2.2. Low-Cost Carriers (LCCs)

The emergence and rise of the LCC business model stemmed from the necessity for airline executives to create affordable, efficient and competitive carriers. The low-cost business model proved successful, and their capacity shares have continuously been increasing. Figure 3.4 depicts the total worldwide number of active, founded and exited low-cost carriers from 1971 to 2013. The data indicates that the real jump in the number of low-cost airlines was from 2001 to 2006. Forsyth et al. argue in their book that (2013) while liberalisation was a necessary condition for the growth of the LCCs, the patterns of entry and exit are not closely correlated with key events in the liberalisation process. They also suggest that the LCCs are not one variety; rather there exists two definable stylized successful business models – the "truly low cost model" and "the full service airline competitor model", where the latter is the FSCs response to a LCC threat implying that the rise of the LCC business model posed a concern for FSCs, who had to restructure their business to adopt the changing industry environment.

Figure 3.4: Number of Founded, Exited and Active Low-cost Airlines Adopted From the Low-cost Carrier Worldwide (2013)



According to Airline Profiler data (Israel, 2014), by 2013 the worldwide market share of the LCCs increased to 22% of the whole available seat capacity. The article reports that no-frills carriers' performance on certain metrics are higher than FSCs, justifying the FSCs concern over the LCC threat. According to Najda (2013), low-cost carriers can successfully neutralise the dominance of its competitors by competing on price. Some of the major carriers started their own subsidiaries under the low-cost banner to compete on price, with the objective of regaining their lost market share (Francis, 2006). The scope of market share loss is substantial for FSCs. OAG data cited in The Telegraph (2014) demonstrate that low-cost carriers make up 36% of the whole European aviation market, directly taking away from the share of traditional legacy carriers.

Gross et al. state that literature tends to agree that a general definition of LCC is ambiguous because there is no globally distinct and unique business model of an LCC, but instead a range of product and business differences when comparing them (Gross, Landvogt,

& Lück, 2013). For Mason and Morrison (2008), the difficulty of defining the low-cost airline business model is a sign of the coexistence of several business models that are categorised under the LCC label. In principle, as a common characteristic, LCCs develop one or more bases to maximise their destination coverage and defend their market that encourage them to focus on cities and point-to-point services rather than operating traditional hubs (Bamber, Gittel, Kochan, & Andrew, 2009). By offering point-to-point services, LCCs are able to schedule services at the right time of the day to compete with FSCs without being subject to the imperatives of a flight connection system. Low-cost carriers promote á la carte pricing; in addition to the basic cost of the flight, passengers pay separately for almost every additional component such as catering, seat selection, checked bag and etc (Tuttle, 2013).

The central aspect for all LCCs is their low-cost approach in each step of their process chain. On the markets they serve, LCCs focus on cost reduction and minimisation to implement a price leadership strategy. The differences in the operating costs between FSCs and LCCs are quite relevant (IATA, 2006). Their cost structure can be quantified by aggregating the cost savings of their unbundled services, point-to-point network arrangement and wage savings – as they usually pay less than traditional airlines. Meehan as cited in Cook & Goodwin (2008) finds the labour cost per available seat mile was 2.8 dollar cents for the LCCs while the figure was 3.5 cents for the legacy carriers by 2005 - with savings made by excluding numerous add-on services from the product. They reduce their unit cost structures by eliminating services, increasing the number of seats at the expense of passenger comfort and standardising their cabin amenities. Major business principles of LCCs are compared with FSCs in Table 3.2.

The emergence of the LCCs in the market and their consequent consolidation contributed to the commoditisation process of air travel. According to DLR’s report (2008, s. 10) *"on the sales and demand side, the pricing policy of the low-cost carriers is usually very dynamic, with heavy discounts for tickets booked long in advance, which leads to the generation of new demand from low-yield passengers and heavy bargainers who would not have flown otherwise"*. LCCs’ affordable fare structures, offering much lower prices than legacy carriers, enabled more price sensitive passengers to access air travel. The LCCs’ success coincides with attracting travellers who are interested in affordable airfares to destinations previously not offered, some of whom are first-time air travellers and would not have flown otherwise (Franke, 2004). For the LCC segment, low fares have become paramount and have overtaken comfort; service and punctuality as the primary decision driver for at least short-haul travel (Thanasupsin, Chaichana, & Pliankarom, 2010). In his article, Whitelegg (2005) states that through cost advantage, LCC's profit accumulation is a result of 15-18 per cent gap between break-even and actual load factors; as long as this gap is maintained it can continue to charge low fares. Cheaper fares appeal to more passengers encouraging them to travel more, which reduce unit costs per passenger even further. This cyclic process enables the LCCs to charge even lower fares.

Table 3.2: Comparison of Legacy / Full-service Carriers and Low-cost Carriers – Compiled by the Author

Attribute	Legacy / Full-Service Carriers	Low-Cost Carriers
Network Type	Usually Hub and spoke networks are employed to achieve efficiency (see next section for details)	Point to point network (see next section for details)
Connectivity	Most passengers connect at the hub(s) for a continuing flight(s) to destination	Direct flights are offered with limited frequencies
Pricing	In return for full service, travellers are ready to pay higher fares. Business travellers pay a premium for services such as late booking. Seat inventory reserved for late booking (Lott, 2006).	Cheaper especially when the tickets are purchased well in advance – towards the date of departure as seats are filled, the fares converge to legacy carriers.
Fleet type	Variety of aircraft types are utilised to serve different markets	Limited – fewer number of aircraft types are used to ensure standardisation and cost advantage
Source of revenues	Primarily passengers revenue – ancillary revenue forms a limited portion of the whole revenue gain	In addition to passenger revenue, ancillary revenue composes an integral revenue source
Loyalty programs	Employed as a method to ensure customer retention	Resist using a loyalty program as it is known to increase cost
Service	Full service is offered although the degree and quality of free amenities vary	Reduced "frills" and seating space on board: elimination of food and beverages reduces passenger service costs, while reduced seating space increases the capacity produced by each flight, in turn lowering its unit costs (Belobaba, Odoni, & Barnhart, 2009).

Coenders et al. (2011) in their study assert that LCCs attract not only price-sensitive passengers but also the business travellers. According to their study, LCCs generally offer a product for more price-conscious business travellers that better meet their requirements. Hence, the lower fare is not the sole factor for some of the consumer’s preference for the LCCs. As Kim and Lee (2011) state in their article, customer satisfaction is crucial for newly emerging LCCs in order to be competitive and establish successfully. According to their study, for LCCs, it is not only the fare but also tangible items and responsiveness of perceived service quality which are significant antecedents of customer satisfaction. Likewise, economic recessions encourage more business travellers to prefer LCCs too. Neal and Kassens-Noor (2011) studied the impact of economic recession on air travel for business purposes. They find that during national recessions, legacy and low-cost carriers’ market niches converge. This observation confirms that the target market of the LCCs is not limited to the price-sensitive segment but also shifts to a wider spectrum, since the LCC product can meet the expectations of various passenger profiles under certain circumstances. Therefore, LCCs take various revenue-maximising measures for different customer profiles depending on the market conditions and competition. For this reason, although fares charged by the LCCs are lower on average, just before the flight date or seasonal periods such as around sporting events, the fare for a seat on LCCs can be higher than the comparable fare charged by a legacy carrier (Gilbert & Perl, 2012).

3.3: Airline Network Types

As competition between airlines has intensified, and more customer segments have begun to access air travel, the existence of the itinerary as a core product feature has become more evident. The schedule, or the airline's published timetable, has always played a central role in creating preferences for one itinerary over the other. The schedule does not merely cover flight departure and arrival times but also a wide range of other details, including the flight routing (direct or connecting), type (operating or codeshare), aircraft category, stopovers and departure and arrival airports as well as the terminals. To varying degrees, all these parameters are critical in consumers' decision making. From the airline's perspective, the network structure consists of the complete set of its scheduled services and timetable for the entire flight-destination portfolio. A carrier's network determines its capacity, particularly flight frequency and seat supply, in the market route at the origin and destination pair (O&D). Moreover, O&D

pairs' routing (direct or connecting) and type (online or codeshare) are determined through the network strategy. The network structure of an airline, therefore, encompasses not only its physical flights but also its partnerships with the other carriers.

As discussed earlier, airline executives must effectively design their network structure to remain competitive in the market. A carrier's network is an influential factor in the planning cycles of the firm and is therefore a vital element of the airline's cost structure. It is the airline's network that determines the flight routes and frequency as well as the aircraft utilised for each service. Indeed, all of the network's capacity-related factors influence the company's cost base, including the necessary staff, crew, sales offices, handling agreements, catering contracts and etc. As its network structure substantially determines the airline's cost base, efficient design of the network is a crucial parameter of commercial success.

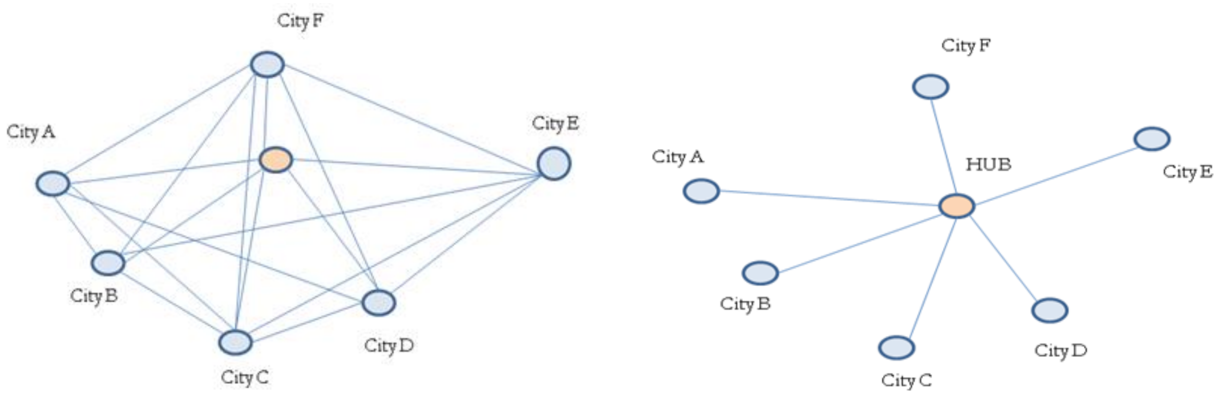
As stated in *Straight and Level – Practical Airline Economics* (Holloway, 2008, s. 366), an "airlines' network is an overt manifestation of strategic behaviour". The way in which airlines construct their network and develop journey paths for their passengers is an outcome of how they are structurally organised. Networks compose the brand identity of an airline and define the product and core services, as well as being an integral driver of corporate revenue and cost scheme. Through their network strategies, airlines inject a competitive perspective into their products. Lederer (1993) models and defines airline competition as a non-cooperative challenge, where in order to connect one node into another, carriers select network designs and prices for transportation.

The impact of deregulation on the legacy carriers has led to a business paradigm shift. After deregulation, airlines were free to determine their optimal network type. In most cases, this was predominantly a hub and spoke network, allowing the exploitation of density economies (Pels, 2008). The process of liberalisation has altered the way networks were effectively structured. Before deregulation, direct and fully connected networks were principally utilised. In order to provide convenient service to the public, regulators encouraged non-stop, point-to-point services. Point to point airlines chose to fly direct as long as the demand was met. However, after deregulation, airlines became free to choose their networks and fares as part of their efficiency priorities. This process has led to Hub and Spoke (HS) systems in place of point-to-point (PP) transport systems to rise and concentrated the traffic on spoke routes, increasing the flight frequencies (Morrison & Winston, 1995). HS networks are competitive and effective route networks. In addition to the transportation industry, HS networks are employed in other sectors such as telecommunications. In HS network configuration, the operator companies (in the case of aviation, the airlines) can use larger vehicles (aircraft) and thus reduce costs per unit through accumulating flows on a hub. It results in lower total network cost and therefore the firm gains a competitive edge.

3.3.1. Hub and Spoke (HS) vs Point-to-Point (PP) Networks

HS networks entail the concentration of traffic on intermediate hub airports where passengers can change planes on their way to final destination whereas in PP systems, passengers travel directly from origin to destination without transferring at a central hub (See Figure 3.5). On the other hand, within the context of HS distribution paradigm, the traffic moves along the spokes which are connected to the hub that is located at the centre (Babcock, 2002). Travellers who are moving between airports and not served with point-to-point modes of transportation options need to change planes on the way to their destination. Thus by connecting at the hub, passengers can travel between any two cities in the routing system or "from anywhere to everywhere" (Hansson, Ringbeck, & Franke, 2002). HS networks can resemble a delivery system: the decision maker (the airline), positions the facilities (destinations and flights) and determines the principles of allocation to these facilities (the passenger flow) (O'Kelly & Bryan, 1998).

Figure 3.5: An Illustration of PP Transportations Systems (on the Left) and HS Network (on the Right) – Compiled by the Author.



For a network of n cities, in PP systems, to connect every node into each other, a total of $n\ x\ (n-1)/2$ connections are required to cover all nodes. On the other hand, for an HS network, to connect each node into the other, a single connection to a hub is sufficient, hence requiring only a total of $(n-1)$ connections throughout the network. For an airline, these figures refer to the minimum number of flights needed to undertake a journey from any origin to any destination within the network. Since the required number of flights is smaller in HS systems as long as $n > 2$, an efficiency is gained for the airline utilising HS systems. To operate effectively, any flight flown by the airline must either start or terminate at a hub. Thus, in a HS principle, the hub is characterised with numerous flights while the spokes have only fewer flights that are directed to the hub (Abdelghany & Abdelghany, 2009).

In HS systems, the actual source of the efficiency gain is sourced from the phenomenon known as economies of scope and density. Economies of scope are observed when passengers travelling in many different O&D markets are combined, for at least part of their journeys, on a single aircraft by channelling the traffic over the hubs. On the other hand, economies of density refers to the reduction of unit cost in response to density. The unit cost per passenger declines on a route as the traffic volume on the route rises. Through the additional effect of larger aircraft assignment, cost per available seat falls, and the fixed costs of the airline operations at the endpoints of the route can be spread over more passengers as traffic density rises (Lee, 2007). Flores-Fillol (2009) argues that HS network structures prevail in the presence of lower operating costs. Bailey et al. (1985) also show that by using HS networks, airlines can decrease costs compared to direct routings by exploiting economies of scale through the use of larger aircraft. They mention in their book that when deregulation occurred, airlines had excess wide-body jets available, which they found cheaper to fill through marginal pricing implying the reflection of the cost advantage to passengers. Brueckner and Spiller (1991) in their study model economies of scale and analyse the public welfare effects of competition between airlines due to cost externalities.

Airline network investment cost is smaller in HS systems. For any given level of frequency and number of destinations, the HS system requires the fewest number of aircraft and investment (Button, 2002). It is inefficient for airlines to offer direct flights from each city to the other within its network given the limited resources, scarce fleet and insufficient market conditions. Besides, insertion of a new route into an airline's network is less costly in a HS system as the new destination is required to be connected to the hub airport only. However, in the PP model, the new route needs to be connected to multiple nodes wherever the demand exists. For a PP carrier, the injection of a new route into the airline’s portfolio would only be possible in case the local demand exceeds the critical mass to establish a direct link between cities.

Literature agrees that HS network can be a useful tool to protect an airline's local markets leading to hubs. For Pels (2008), HS airlines do not entail a motivation to enter each other's local markets with a direct flight, limiting the degree of competition. Entry with an indirect flight is possible via their hub, but it would be a connecting flight rather than a direct link, which is an imperfect substitute. He argues, "*competition, mainly takes place in 'thick' markets between hubs, or between large airports. Deregulation, therefore, did not lead to increased competition in many markets. Instead, many markets were characterised by concentration* (Pels, 2008, s. 74)*."* Pels refers to Zhang's work (1996) where he argues invading a competitor's market can lead to lower profits for the HS airlines. These findings confirm that, through the employment of HS networks, airlines create a tool to secure their local market. Hendricks et al. (1997) claim that HS networks are likely to be utilised when carriers do not compete aggressively. Oum et al. (1993) analyse the strategic use of HS networks to discourage entry. Aguirregabiria and Ho's study (2010) re-confirms all studies mentioned above and finds that HS networks can be an effective strategy to deter the entry of competitors. However, it is noteworthy to state that by transferring via a connection at a hub, an airline can always offer a connecting product on another airline's home market. As long as the capacity exists in both routes (from origin to hub and from hub to destination), the connecting airline can offer a more competitive value proposition than the direct service provider to gain a competitive advantage. It should be noted that the demand may also exist in thin markets where there are no or limited direct flights. In this case, the transfer flights would be the main available product in the market.

Given the level of competition observed in the industry today, many airlines, especially in Europe and the Middle East, are intensely competing via their HS networks. Airlines are effectively designing their networks as a strategic tool in response to their competitors' actions. Table 3.3 presents a comparison of the HS and PP network models on several attributes.

Table 3.3: Comparison of HS and PP Network Systems Cited from (Cook & Goodwin, 2008)

Attribute	Hub and spoke (HS)	Point to point (PP)
Scope	Optimized by connecting service to wide geographical area and many destinations	Each route serves a single city pair. Individual routes may be dispersed.
Connectivity	Most passengers connect at the hub(s) for a continuing flight(s) to destination	No connections provided (although incidental or "rolling hub" connections are standard).
Dependence	Each route highly dependent on other routes for connecting passengers	Routes operate independently, traffic is not affected by demand from other routes
Demand	Varying demand in any given city-pair may be offset by demand from other markets	Only varying frequency and pricing available to counter demand variance
Market Size	Efficiently serves cities of hugely varying size	Requires high-density markets with at least one end-point being a high demand origin/destination
Frequency	Supports high daily frequency to all destinations	Generally lower frequency depending on the market type and density
Pricing	Frequency and coverage appeal to business travellers providing a margin for higher business fares	Both business and leisure passengers are generally price-seeking
Cost of flight from City A to City B	Hub connection increases the cost per available seat	Lowest cost per available seat per city pair
Network cost of connecting n number of destinations	Cheaper as (n-1) flights will connect each city into each other via the hub	More expensive as n.(n-1)/2 flights need to be performed to connect each city into another

The employment of the HS or PP network model has a direct impact on consumer convenience in terms of t_{total}. Kawasaki (2008) examines an airline's adoption of an HS or PP network when considering network effects from the demand side and the heterogeneity of the passengers' time value. He finds that if the time value for leisure passengers is sufficiently small and the operating cost is medium, or the time value for leisure passengers is high and operating cost is small, the monopoly airline adopts an HS network; otherwise, a PP network is adopted. It is deduced from this finding that, apart from fare constraints, time-convenience of the itineraries is among the primary motivations for consumers to choose direct flights. For Berechman & Shy (1996), a fully connected network provides an extra benefit for travellers because of the reduction in total travel time. However, HS networks could allow the airlines to increase their schedule frequency. The increased frequency thus reduces the t_{conn}. According to Brueckner and Zhang (2001), some passengers who could make a connecting trip under the HS network may find the existing flights not sufficiently convenient given their long duration. For Schipper (1999), the ratio between the direct and indirect flight in terms of time or kilometre, and the cost of t_{conn} at the hub airport may cause in an inevitable loss of passenger demand for indirect transfers through the hub.

Burghouwt (2007) argues that airline networks are path dependent, which refers to the dependence of economic behaviour of a firm on its specific history. Path dependency implies that if a strategy is successful, the companies tend to sustain their actions and behaviours. Mintzberg (1994) claims that, this process is likely to be incremental rather than radical. Otherwise, in case of failure, companies may adopt a different strategy according to the resources and knowledgebase they have. The nature of the HS systems is argued to be path dependent as HS networks encourage the insertion of frequencies and destinations to the existing hubs. Each inserted flight add up to the economies of scale and network economics of the airline. Thus, cumulative causation of hub connectivity favours large nodes over smaller nodes in the development of HS networks (Barabasi & Albert, 1999). In contrast, for an LCC’s network, since the motivation is based on lowering the unit costs rather than the network economics, different path dependency may be implied covering short-term dynamics.

As a consequence of the cost advantage, the attraction of transfer passengers is facilitated for airlines employing strong HS networks. According to O’Connor (2001), by developing traffic along the feeder spokes, an HS airline increases its transfer passenger traffic along its longer hauls. Moreover, it facilitates the flow of spoke traffic onto its long-haul flights by controlling the arrival times of the feeder flights at the hub airport. On the other hand, HS networks enable airlines to access a broader spectrum of markets. Whilst an airline employing PP network can only offer a product between the O&D pairs it flies direct; an HS airline can offer all relevant O&D pairs within its network as long as they are connected to each other through the hub. To quantify the magnitude of broader market access for the HS carriers, Table 3.4 compares the total number of directional products for airlines employing PP and HS network systems assuming that they fly to *n* destinations. The same procedure is also repeated for *(n+1)* destinations in order to demonstrate the marginal effect on the number of O&D pairs

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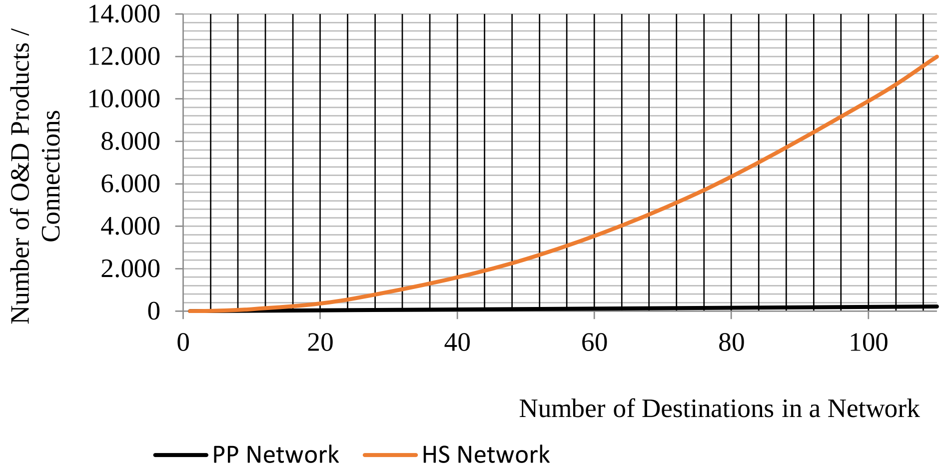
Table 3.4: Number of Directional (to and From) O&D Pairs (Products) Served in PP and HS Systems. The Number of O&D Pairs Would Be Halved if Directionality is ignored.

Destinations	Number of Products for PP Carrier	Number of Products for HS Carrier
n	2 (n-1)	n (n-1)
n + 1	2 (n+1-1) = 2n	(n+1)(n+1-1) = (n+1) n
Difference = 1	2n – (2(n-1)) = 2	(n+1)n – (n(n-1)) = 2n

For an airline flying to *n* destinations, while *2(n-1)* directional O&D pairs can be generated through PP networks, this figure scores as *n(n-1)* at the HS systems. As long as *n>2, n(n-1)* is always greater than *2(n-1)*. Therefore, given the same number of destinations in the network, HS airlines offer more product options to travellers in comparison to the PP carriers. When a new route is added into a flight portfolio, as Table 3.4 suggests, only two new O&D pairs are introduced in the PP systems, which are from origin to the new destination and back. In HS systems, the additional number of O&D pairs are *2n* as the flight would be connected to each *n* destinations in the network and all the existing *n* destinations would be connected to the new route on the way back, summing up to *2n*. Since HS airlines offer a connection between each spoke and therefore accesses to a broader market, they attract more transfer passengers. The graph below (Figure 3.6) depicts the total number of O&D connections for different number of destinations served by the HS and PP network systems assuming that all destinations are properly connected to the other destinations in the HS network.

Figure 3.6: Directional Number of O&D Pair Connections vs The Number of Destinations in A Network for PP and HS Carriers. The Function of PP Network is $2 \, x \, (n-1)$, and The Function of HS Network is $n \, x \, (n-1)$



It is observed in Figure 3.6 that, as the number of destinations in a network increases, the number of products (O&D pairs) offered through the HS networks outperforms PP networks in an exponential manner.

<u>*3.3.2. Network Assessment Methods*</u>

Modelling complex networks is a challenge for airlines in the sense that the topology of the network governs the connectivity dynamics and the connectivity determines the functional and economic feasibility of their network structure. For this reason, it is crucial to analyse network geometry and concentration. The number of airports and number of weekly flight frequencies that an airline serves usually expresses and measures the physical size of the airline network (Janic, 2000). The following sections elaborate the existing literature concerning the networks' size and index assessment.

3.3.2.1. Network Topology Indices

The topology index of a network refers to its connectivity based on its geometry. In order to assess the networks' performance and to benchmark them, the global properties of such systems need to be captured and modelled as graphs whose nodes represent dynamical units. This process translates the interaction between dynamical units that usually depends on time, space, and many other details into a binary number (Boccalettia, Latorab, Morenod,, Chavez, & Hwang, 2006). In Table 3.5 below, some of the widely used topological measurements are introduced.

Table 3.5: Network Topology Indexes Derived from the Network Experience – New Value from Smart Business Networks (Vervest, van Liere, & Zheng, 2009)

Measurement	Description	Formulation	Variables	Source
Degree	The degree of a given node is given by the number of its links	$k(v)$	k(v) is the number of links of node v	(Barabasi & Oltvai, 2004)
Closeness	It indicates a node's proximity to the other nodes	$C(v) = \frac{1}{\sum_{t \in V} d_{vt}}$	d_{vt} is the shortest path (geodesic distance) between nodes v and t. n is the number of nodes in the network	(Newman, 2010)
Betweenness (Circuitry)	It indicates a node's ability to stand between the others, to control the flows among them	$B(v) = \sum_{s \neq t \neq v \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$	$\sigma_{st}(v)$ and σ_{st} are respectively, the number of geodesic distances between *s* and *t* that passes through node *v*, and the overall number of geodesic distances between *s* and *t*	(Freeman, 1977)
Diameter	It measures the maximum value of the geodesic distances between all nodes	$D = max_{s,t \in V, s \neq t} d_{st}$	d_{st} is the geodesic distance between nodes *s* and *t*	Boccalettia et al. (2006)
Clustering Coefficient	It measures the cliquishness of a node	$Cl(v) = \frac{l_v}{\max l_v}$	l_v and max l_v respectively, the number of existing and maximum possible links between the nodes directly connected to node *v*.	(Watts & Strogatz, 1998)

3.3.2.2. Network Concentration Indexes

The degree of concentration is a measure to assess airlines' network connectivity. Different from topology indexes, concentration indexes measure the centrality figures of the networks. In the literature, several procedures to calculate the degree of concentration were introduced. Toh and Higgins (1985) compute a hub index by dividing the number of outlying cities served by the hub to the number of spokes radiating from it. This index's value is always greater than 1, and a central network with an active hub reports an index value closer to 1. Although this index provides an insightful intuition regarding the airline's network centrality, the methodology needs to know beforehand not only the airports in the network but also which of these airports is a hub (Paul, 2010). According to Reynolds-Feighan (2001), HS airlines' network has a high concentration level of air traffic in both space and time. In contrast, the traffic flows of PP airlines are spatially and temporally dispersed.

3.3.2.2.1. Gini Concentration Index

Reynolds-Feighan (2001) recommends the Gini index as the most appropriate concentration measure for airline networks. The Gini index is a statistical indicator evaluating the inequality among values of a frequency distribution. Alderighi et al. (2007) formulate the Gini concentration index for airlines as:

$$G = \frac{1}{2n^2}\,\bar{y}\sum_i\sum_j\left|y_i - y_j\right|$$

where the y_i and y_j is the air traffic at airport *i* or *j* defined in terms of frequency ranked in increasing order; $\bar{y} = \sum_i y_i$ is the mean of the weekly frequency, and *n* is the number of destinations in the network. According to Burghouwt et al. (2003), the Gini index increases with the number of airports in an airline network, and in a fully connected single hub HS network, the maximum Gini index inferring extreme concentration can be equal to:

$$\hat{G} = 1 - \frac{2}{n}$$

To calculate the degree of network concentration (*NC*) for a specific airline *a* in percentage terms where 100% refers to full concentration and 0% represents full dispersion, *G* needs to be divided to the maximum Gini, $\hat{G}$. Hence the *NC* figure of an airline may range between 0 and

1, where higher *NC* represents an uneven spread of frequency over the network population. If an equal number of frequencies exist in each *n* destinations of the airline's network, *NC* converges to 0. An *NC* result that is equal to 1 implies a network where the flow is concentrated in a hub on a single radial scheme. The degree of concentration does not necessarily need to be measured by the frequency only. Bughouwt et al (2003) employ the Gini index based on total seats supplied and defines *y* as the air traffic at *i* and *j* as the total number of seats supplied per week.

3.3.2.2.2. Entropy Index

Different entropy-based measures were introduced in the literature, but the entropy index usually refers to the Theil's index as mentioned in Economics and Information Theory (1967). The index formulated below is a robust measure of inequality and its inverse is a measure of equality or centrality.

$$T = \sum_{i=1}^{n} s_i \log \frac{1}{s_i}$$

In the above formulation *n* refers to the number of destinations in the network and s_i denotes the ratio of capacity at airport *i* to the airline's total capacity. Conceicao and Ferreira (2000) highlight that Theil's entropy measure is superior to the Gini index in the sense that it provides a much better understanding of the concentration that exists within a clustered group.

3.3.2.2.3. Hirschman Herfindahl Index

The Hirschman-Herfindahl (HH) index is defined by Tirole (1988) as $HH = \sum_{i=1}^{n} s_i^2$ where *n* is the number of destinations in the network and s_i is the ratio of capacity at airport *i* to the airline's total capacity. Studies such as Papatheodorou and Arvanitis (2009) and Borenstein (1992) use the HH index to measure the concentration in the airline industry by comparing capacity shares at the airports. However, Wojahn (2001) shows that the interpretation of the HH index is scale dependent and thus has limited use for network concentration.

The other possibility of employing HH indices is to compare city-pair specific routes as Borenstein (Borenstein, 1992) performs. This measure allows benchmarking of concentration and competition on these routes. From this perspective, by making use of the city pair HH indices, hubbing concentration indexes (HC) can be generated as suggested by Martin and Voltes-Dorta (2009). They argue that with the HC index, the difference between a hub and a critical origin or destination is taken into account. HC relates concentration to two significant verdicts: the importance of hubbing in the network and the concentration of the hubbed traffic on each O&D market. To compute the HC, initially, the hubbing behaviour of the connecting passengers on the market between *i* and *j* needs to be computed as follows:

$$H_{ij} = C_{ij} \sum_{k=1}^{n} s_{k,ij}^2$$

Where C_{ij} is the share of connecting passengers between *i* and *j*, and $s_{k,ij}^2$ is the square of traffic share of airport *k* on the market *i, j*. From this perspective, H_{ij} is a variant of HH index and represents the routing concentration on market *i* and *j*. The HC index is computed by weighting the hubbing behaviour according to this route's relevance, within airline's network denoted by q_{ij} in relation to the overall traffic *Q* shown in the formula below

$$HC = \sum_{i} \sum_{j} \frac{q_{ij}}{Q} H_{ij}$$

The value of HC can range between 0 and 1 where a single HS network would yield to HC index of 1 where in the other extreme, no connections to any flights would result with HC value of 0 (Paul, 2010).

3.3.2.2.4. Freeman Network Centrality Index

Freeman index measures the network's inequality shape with respect to a perfect star network. A perfect star network symbolises a pure hub and spoke network. Freeman index attempts to measure the centrality of nodes where a central node is structurally important. Cento (2009) uses the term betweenness centrality to elucidate centrality concept since for transit connections, being in a "between" position from origin to destination ascends the attraction of the node's hub attribute. Alderighi et al. (2007) state that betweenness centrality represents the economic behaviour of passengers as it provides an understanding whether the hub lies on geodesics through the airline's network and thus preferential for consumers for their journeys. According to their study, a centrality index for point x_i denoted by $C_B(x_i)$ requires an analysis of the geodesic linking pairs of other points. Geodesic distance is defined as the shortest path between two points. “If g_{gk} is the number of geodesics linking points x_j and x_k in a network, and $g_{jk}(x_i)$ is the number of such paths that contain point x_i, then the betweenness

$$b_{jk}(x_i) = \frac{g_{jk}(x_i)}{g_{jk}}$$

is the proportion of geodesics linking x_j and x_k that contain x_i. To determine the centrality of point x_i, sum all these values for all unordered pairs of points where $j < k$ and $i \neq j \neq k$

$$C_B(x_i) = \sum_{i<k}^{n} \sum_{i<k}^{n} b_{jk}(x_i)$$

The maximum $C_B(x_i)$ can only be achieved in a star network where each node is connected to a single hub, which can be equal to $\frac{(n-1)(n-2)}{2}$. Therefore, the relative centrality of any point in the network whose value can range between 0 and 1 can be expressed as follows:

$$C'_B(x_i) = \frac{2C_B(x_i)}{(n-1)(n-2)}$$

that provides a measure of the general centrality of x_i” (Alderighi, Cento, Nijkamp, & Rietveld, 2007, s. 535). The Freeman centrality index for the whole network can be computed as follows

$$C_B = \frac{\sum_{i=1}^{n}[C'_B(\mathrm{x}*) - C'_B(x_i)]}{n-1}$$

Where x^* represents the node with the highest centrality.

Alderighi et al. (2007) introduce the Freeman centrality index as being superior to Gini concentration index as the geodesic paths minimise network costs and hence maximise social utility. It is worth stating that the Gini index ranges between 0 and 1 and in the case of a pure hub and spoke system, it results in 0.5 and scores 0 in the case of a pure PP network. The Gini index is incapable of detecting the difference between HS and PP networks. According to Cento (2009), in several forms of multi-HS, the Gini index assumes the value of 0.5. While frequency and Gini value are correlated; there is no relation between the spatial morphology and the index figure.

3.3.3. Location of Hubs

In HS networks, demand and passenger traffic is increasingly constructed around ‘spaces of flows’ rather than the reciprocal demands between cities. For Sassen (2001), the relative importance of the relationships between global cities and their surrounding hinterlands seems to have dramatically decreased with respect to the importance of the relationships that interlink global cities in highly specialised, transnational networks. For HS networks, the criteria for a city to be relevant for a network cannot solely be evaluated with its demand to a particular destination but rather through its contribution to the overall network. Thus cities derive their functional centrality from a privileged position in transnational networks (Derudder, Devriendt, & Witlox, 2006). The study of Jalliet et al. (1996) proposes that hub candidates depend more on their geographical position than their demand levels. Therefore, the central role of big hub airports exhibits a magnifying force for their host cities to expand and grow. Kasarda and Lindsay (2011) argue that airports are becoming the drivers of a new type of city defined as “aerotropolis”. In the aerotropolis city plan, the airport is a focal point in the economy, layout and infrastructure. They argue that emerging corridors, clusters, passenger and freight flows as well as the rise of airport induced businesses to encourage cities to develop around airports. This development includes not just hotels and restaurants, but also, more importantly, transport-focused or transport-dependent businesses. There is sufficient volume of examples in the world confirming the “aerotropolis” perspective in the sense that less inhabited cities can outperform highly populated cities’ performance due to the airport’s strong hub nature due to its location, centrality, connectivity and size.

3.3.4. Disadvantages of HS Networks

Although HS networks provide a huge cost advantage and increased market access opportunities for airlines, there are several disadvantages associated with the employment of such networks at strategic and financial levels which needs to be taken into account by the airline decision makers. Because of the hub airport’s vitality in HS business model, a dependency relationship between the airline and airport emerges. For Graham (2001), the relationship between the airline and airport operator is fundamental for reciprocal success, and the on-going problem is that demand is outstripping capacity at a growing number of airports. Since hub airports compose a high share of airlines' businesses, any capacity limitation in terms of slot availability, terminal infrastructure, runway limitations and etc. may have a significant impact on the airlines' flexibility. As stated in the The Global Airline Industry (Belobaba, Odoni, & Barnhart, 2009), airport capacity is widely believed to be one of the most important long-term constraints on the growth of air traffic. Since connectivity is the key motor of HS business model, any restriction due to hub airport's capacity, even at a small time interval of the day, would limit the airlines' playground. In other words, even small changes at the hub airport could have unexpected consequences throughout the network. From this perspective, the hub may constitute a bottleneck or single point of failure in the network (Sorgenfrei, 2013). Additionally, Graham and Dennis (2006) find in their study that LCCs have been largely responsible for strong passenger growth at some European airports. It may be the case that airports aiming for higher passenger turnover may target LCCs compared to network carriers, designing their business priorities and investments based on the LCC principles, which may not necessarily comply with the requirements of HS airlines.

Excess reliance on transfer passengers poses a vulnerability for the HS business model. Passenger demand and consumer preference may shift to direct travel options in case of a rise in competition and direct flight capacity. Congestion at the hub airports and a potential delay may result in severe inconveniences and thus pose a risk for consumers. A delay in the departure from a hub to link can cause chain effect delay across the network resulting in several O&D pairs missing their guaranteed arrival times (Hult, 2011). Offering direct services lets carriers schedule their products at the desired time of the day allowing them to effectively compete with other airlines without being subject to the imperatives of a flight connection system. Thus, as Doganis (2013) argues hubbing can have severe negative ramifications concerning network economics.

Another drawback of the reliance on transfer passengers for HS business model relates to airlines' yields. According to Dennis (2012, s. 6), "*network airlines have benefited from the wide range of origins and destinations they can offer a service between and this is reflected in the pricing of connecting flights, whereby they typically offer a through journey (with a direct transfer but no stopover) for less than the sum of the individual fares*". This statement suggests accepting one transfer passenger instead of two direct passengers results in less revenue generation for the airline in total, although the direct travelling passengers do not create a higher cost. Therefore, accepting transfer passengers in place of direct, local travelling passengers where direct flight demand exists represent an opportunity cost for the airline. Lower yield on transfer products is valid for airlines cooperating with an interline agreement. The traditional interline fare would be less than the sum of available fares on the individual sectors (IATA, 2012), implying lower profitability which is also shared by the cooperating airlines. As a result, while the transfer market enables wider market access opportunities, higher degrees of dependence on transfer passengers creates concern on yields and the overall profitability of the carrier.

3.3.5. Hybrid Carriers and Their Business Model

There are numerous advantages and disadvantages of the HS and PP networks in comparison to each other. Additionally, the differences between the strategies of the LCCs and the FSCs are wide. To maximize their competitive advantage and benefit from the gains of both business strategies, a shift to a hybrid model has been observed across the industry. With carriers veering from the traditional and fundamental business strategies, models combining the cost-saving methodologies of a true LCC with the service, flexibility and route structure of a FSC have been introduced, where they were named as hybrid carriers (Sabre, 2012). The hybrid model aims to attain growth by attracting a broad spectrum of passengers through a customised business strategy. The DLR report (2008, s. 13) argues that “not least because the aviation market is a very dynamic one, a growing number of airlines, especially the smaller ones, are looking for market niches and thus adopting business models that do not exactly fit the typical business models”. This implies that depending on the individual circumstances of the business environment, carriers may choose to customize their business and network strategy, and may adopt a hybrid model rather than sticking to a clear-cut traditional full service or low-cost model. In order words, airlines implementing a hybrid business structure aim to reduce costs and ensure efficiency compared to a FSC but not more than what LCCs achieve, while on the service side, they offer more than LCCs but less than FSCs. On the network side, hybrid carriers are not bound by a full PP model but at the same time do not engage in a full-connected HS system. For PP operators, utilising hybrid business model can help to reduce the route density problem (De Wit & Zuidberg, 2012) as such a model allows for capturing the increasing number of passengers already practising self-hubbing (O’Connell & Williams, 2005). Table 3.6 below summarises the fundamental characteristics and distinctions of the hybrid business model compared to the traditional ones.

Table 3.6: Comparison of Traditional Full Service, Traditional Low Cost and Hybrid Airlines Elaborated From (Mason & Morrison, 2008) and (Doganis, 2013)

Attribute	Hybrid Airlines	Traditional Low Cost	Traditional Full Service
Network Type	Combination of PP and HS – an extensive hub system is not established.	Mostly PP	Mostly HS
Connectivity	Both connecting and direct flights are offered. Direct flights' sector range can be longer than traditional low-cost carriers.	Direct flights are offered with usually short sector lengths.	Connection through hub(s) to the final destination
Pricing	Different fare bundles offering varying levels of service	No fare bundling	Mostly all-inclusive bundled fares, ancillary revenues do not represent a high share
Fleet type	Narrow body and wide body	Narrow body	Combination of narrow-body and wide-body
Distribution channels	Mostly online but global distribution systems (GDS) are also used to reach travel agencies	Mostly online	GDS and online
Loyalty programs	Can offer Frequent Flyer Programmes	No	Extensively used to ensure customer retention
Service	- Single Class Service - Frills depending on fare bundle - Can be a member of a global alliance	- Single class service - No frills - Not a member of a global alliance	- Multiple class service - Frills - Global alliance member

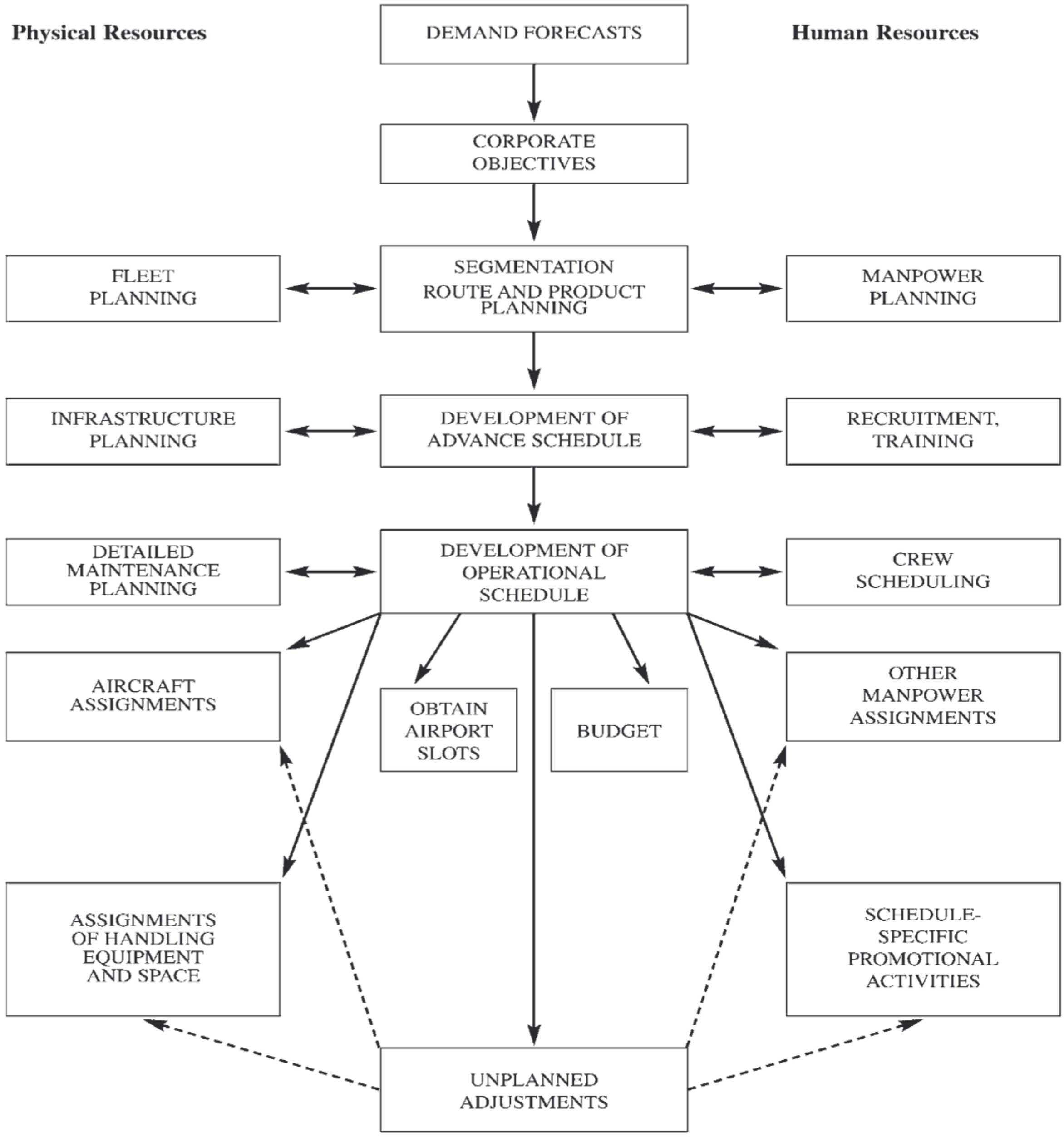
3.4: Airline Planning Process and Scheduling

While the business and network strategy of an airline are fundamental parameters of their competitive advantages, realising an effective scheduling mechanism complementing the network strategy is an indispensable element of the airline's success. Given the O&D pairs, frequency and fleet, the scheduling process covers the assignment of flights to the relevant day, time and aircraft type. Although this assignment seems like a technical procedure derived by several constraints, it becomes a factor of itinerary choice for consumers. While Bazargan (2004) views the scheduling process as a more technical process in which basic optimization methods are employed for utility maximization, Holloway (2008, s. 425) argues that the scheduling is a response to demand and claims that the "routing and scheduling decisions are attributes of the service an airline offers into each of its markets, and as such will themselves have an impact on demand" clearly emphasizing the prominence of schedule within the airline's product mix. From this standpoint, scheduling forms a crucial feature of an airline's service and is a vital step in their planning cycle.

Network design and scheduling are two distinct but complementing processes for an airline's planning phase. Based on the network strategy, taking the resources, limitations and passenger perspectives into consideration, airline planners compose the most feasible schedule for their network. According to Doganis (2009), aircraft selection, route development, network planning, scheduling and thus product planning are just some of the many decision areas which ultimately are dependent on an analysis of demand for passenger and freight transport. Demand drives the initialisation of the airline's entire planning cycle. While network planning is the input triggering the scheduling process, the timetable is the final output presented to the passengers for their itinerary choices. Scheduling is a milestone for the carriers' other planning processes as the timetable information is a prerequisite input for their next planning processes, including crew, marketing and operations planning. According to Yu and Thengwall (2002), the flight schedule is the starting point of all other airline planning and operations. These arguments confirm that scheduling is a strategic area of the airline business management as it composes the airline's product, shapes the proceeding planning steps and even drives the demand.

As highlighted previously, the timetable development is an outcome of the airlines' resources, constraints, limitations as well as the passenger demand. In other words, scheduling is established on top of a series of other planning processes that are completed before the schedule development. In the pre-scheduling phase, the airline executives take core strategyic and tactical decisions for their company. The major blocks of decisions during the pre-scheduling phase can be outlined as 1) strategic business planning cycle where corporate objectives are defined, 2) network and route planning 3) fleet planning. The following sections briefly address each of these pre-scheduling decision blocks that are the prerequisites of timetable formation process. Figure 3.7 illustrates the processes affecting schedule development in addition to the processes affected by the timetable development.

Figure 3.7: A Schematic Representation of the Schedule Development Process by Holloway (1992) as Cited in Straight and Level (2008)



3.4.1. Strategic Business Planning Cycle

In the strategic business planning phase, airlines define corporate objectives and strategic goals. According to Clark (2012), planning an airline business is concerned with defining overall objectives and goals, evaluating the target demand and business environment, generating supply and monitoring the achievements. In Doganis' book (2009), it is stated that the airline executives have to bear in mind some objectives in deciding what products to offer in the different markets.

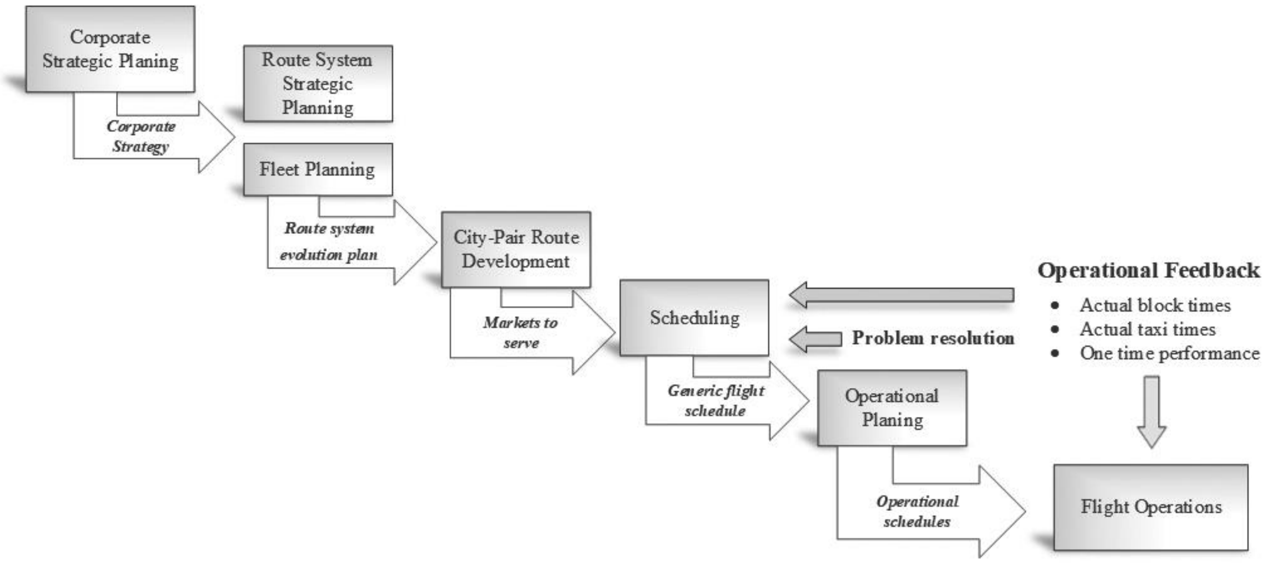
The objective of an airline should be built upon the vision and mission statement of the airline. The mission outlines the company's business strategy and the vision is a reflection of future achievement intentions that are both customer-focused (Robinson, 2009). Whilst the vision of an airline should not often change over time, the mission can be modified in order to back the vision of the company in response to changing market dynamics. The mission need to be decomposed into objectives which set the principles of the airlines' business planning. When setting the business principles of the airline, executives need to comprehend the market environment and key stakeholders' expectations including the investors, customers, competitors, regulators, suppliers and etc.

The mission and vision of a firm determine its corporate governance strategy. For Lu et al. (2012), being simultaneously the set of processes, customs, policies, law and institutions affecting the way a company is directed, corporate governance includes the relationships among the stakeholders of the company and may have a direct impact on the performance of the airlines. Ching and Lin (2007) and Carline et al. (2008) demonstrate that corporate governance is often correlated with organisational performance.

Demand analysis and understanding customers are the prerequisites for the development of a successful business plan. The plan "must set out to attract and satisfy potential customers in the different market segments that it has identified. This means using its understanding of the needs and requirements of these different market segments. Such understanding will have been acquired through a range of market research activities" (Doganis, 2009, s. 227). According to John Wensween, (2011), the primary functions of the airline's management are planning, organising, staffing, directing and controlling. He states, however, historically airlines have not done a good job when it comes to efficient networks planning.

After the identification of the business model, an airline may proceed to its long-term network arrangement determination and route planning, which is followed by the fleet plan. Alternatively, executives may choose to initially determine the fleet structure and subsequently make the network planning decisions. Most of the time, these processes are bundled with airline planners simultaneously conducting fleet planning and network planning processes of their company. The diagram below summarises the flow of airline corporate planning - obtained from the book Air Transportation Systems Engineering (Donohue, 2001).

Figure 3.8: Airline Planning Process Flow



3.4.2. Fleet (Capacity) Planning Cycle

The fleet or aircraft inventory of an airline is the primary asset. Fleet acquisition decisions are both costly and have a long-lasting impact on the life cycle of the carriers. According to the US General Accounting Office report (2004), executives perform long-range planning, with such planning designed to ensure the program has the most cost-effective mix of aircraft to meet long-term mission requirements. The fleet decision-making process is complicated as it involves many dimensions such as corporate strategy, ownership and operation cost, maintenance, aircraft finance, financial creditability and aircraft operational efficiency. Not only internal, but company-specific factors and dynamics also affect fleet decisions. Shaw's book (2007) notes that supplier related issues can impact the fleet planning process too. The aircraft market, availability of aircraft and the airline's balance within aircraft supplier mix are some key detriments to be assessed from the supplier perspective.

When deciding their fleet composition, airline executives may take a top-down approach, in which the corporate strategy and objectives drive the capacity planning. Alternatively, they can adopt a bottom-up strategy in which after all routing and network planning decisions are made; capacity decisions are built upon. Whether the fleet decision is taken after a bottom-up or top-down method, or through their simultaneous combination, cost efficiency of the proposed capacity is among the crucial factors of choice. For Hirst (2008), "the complexity of the task of finding the best-suited aircraft type is more difficult than just simply getting ‘ticks in boxes'." For him, due to the intense competitive environment, the unit cost of operation is the most influential selection parameter followed by payload-range; the remaining parameters are less, but they are still critical. The fleet decision affects not only the cost structure of the company but also revenues in the sense that aircraft seat configurations, payload and cargo capacity have a direct impact on the revenue sources of the airline.

The final output of the capacity planning process is the fleet plan and total available seat miles (or kilometre) figure. The most frequently used measure of airline capacity is available seat miles (ASM), which is the product of the total number of supplied seats and miles (Duetsch, 2002). If the stage length of a flight is 1,200 miles and the airline flies a 100-seat aircraft, ASM is 120,000 seat-miles. The unit cost and revenue of operation should then be calculated per ASM (Bazargan, 2004). Cost per available seat miles (CASM) and revenue per available seat miles for flight *i* can be expressed as follows:

$$CASM_i = \frac{Total\ Cost\ of\ Flight\ i}{ASM_i} \quad , \quad RASM_i = \frac{Total\ Revenue\ of\ Flight\ i}{ASM_i}$$

where $ASM_i = m_i\ x\ s_i$, where m_i is the mileage, s_i is the total number of seats at flight *i*. Total cost refers to all fixed and variable costs that are associated to perform the flight *i* from origin to destination. Total revenue covers all flight revenues including flight, ancillary and cargo revenues that are generated through the flight *i*. These figures imply that the total cost and revenue of an airline is

$$Total\ Cost = \sum_{i=1}^{n} CASM_i\ x\ m_i\ x\ s_i$$

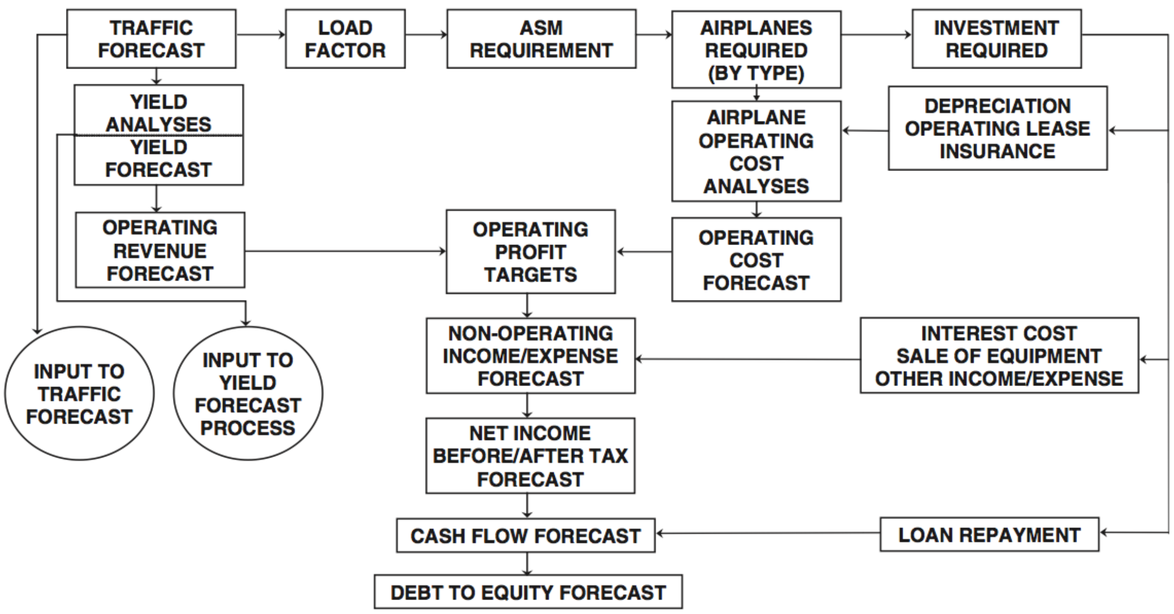
$$Total\ Revenue = \sum_{i=1}^{n} RASM_i\ x\ m_i\ x\ s_i$$

where *n* is the total number of airline’s flights. With this information, the total profit function that the airline aims to maximise is:

$$\sum_{i=1}^{n} RASM_i \; x \; m_i \; x \; s_i - \sum_{i=1}^{n} CASM_i \; x \; m_i \; x \; s_i$$

The following figure demonstrates a capacity planning cycle in which cost efficiency, revenue expectations and profitability are assessed.

Figure 3.9: Fleet Planning Economic Evaluation Process Adapted from (McDonnell Douglas Aircraft Company, 1981) as cited in (Belobaba, Odoni, & Barnhart, 2009).



The work of Merkert and Hensher (2011) highlight the importance of the efficiency perspective in aircraft selection in response to the industry's liberalisation, LCC growth, oil price volatility and fluctuations in the global economy. They argue that on top of aircraft technical efficiency, airline size and critical fleet mix characteristics such as aircraft size and number of different aircraft families in the fleet is more relevant to an airline's successful cost management. Through their fleet planning processes, airlines need to create economies of scale to obtain a competitive advantage. Undoubtedly, cost efficiency is a more significant concern for LCCs as their business philosophy is centred on this concept. Barbot et al. (2008) studies economies of scale, showing that LCCs are usually more technically efficient than FSCs. For Morrell (2011), aircraft operating costs are a significant input to the fleet planning process, whether for passenger aircraft or freighters. Since cargo is a noteworthy revenue source for airlines in addition to passenger revenues, there are studies in literature stating the crucial role of cargo capacity in the fleet mix. For example, the study of Hong and Zhang (2010) finds that passenger carriers with higher cargo capacity share are more efficient than those with lower cargo share.

In order to rationalise their fleet plan, airline decision-makers shape the capacity determination based on the routes and O&D pairs. "Airlines' capacity planning also involves multi-level assessments of individual city pair routes, while potentially considering route interactions and network connectivity both online (within their own network) and inter-line (with their partners' networks), and in relation to competitors' networks" (Boeing, 2013) implying that that strategic network planning affect the fleet decision. Janic (2000) illustrate a procedure for the determination of optimal fleet size based on the number of routes operated by an airline. Although his demonstration is purely based on routes and does not cover competitive dynamics, the methodology is useful in terms of creating a reference standpoint. He observes the subset of *K* routes contained in the original network of *L* routes. Assuming that only one aircraft type is engaged to realize the flights on these routes in time T, $f_{kj}\ (T)$ denotes the number of scheduled flights realized by the aircraft type *j* on the route *k* in time *T*. Aircraft capacity represented by N_j, route length by d_k , average block time by $t_j(d_k)$, utilization of aircraft *j* on the route *k* in the time *T* by $U_{jk}(T)$, average anticipated delay per flight *j* on route *k* by $w_j(d_k)$, the number of aircraft to undertake the planned flights $f_{kj}\ (T)$ denoted by $A_{jk}(T)$ can be forecasted as follows:

$$\sum_{k=1}^{K} f_{kj}\ (T)\left[t_j(d_k) + w_j(d_k)\right] \leq A_{jk}\ (T)U_{jk}(T) \qquad \text{(a)}$$

And

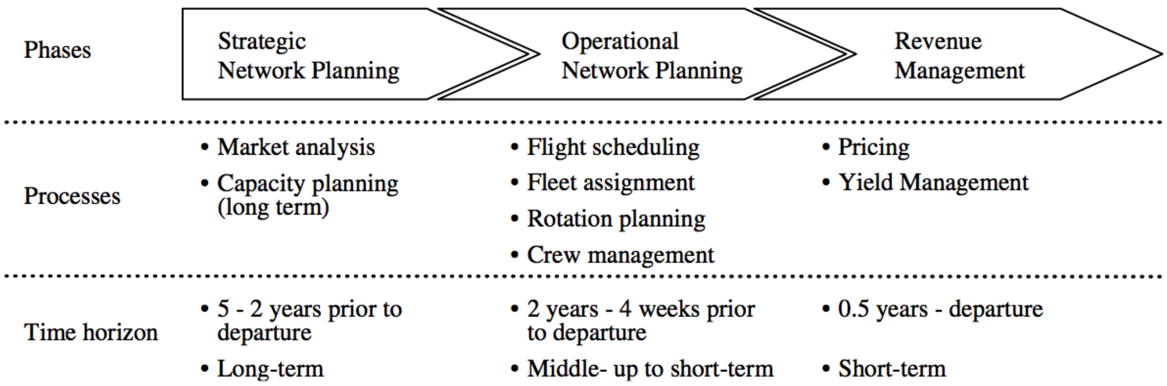
$$A_{jk}(T) \geq 1/U_{jk}(T) \sum_{k=1}^{K} f_{kj}\ (T)\left[t_j(d_k) + w_j(d_k)\right] \qquad \text{(b)}$$

where $t_j(d_k)$ = $d_k/v_j(d_k)$ and $v_j(d_k)$ is the average block speed of aircraft *j* on route d_k. The total size of the fleet can be computed by identifying all possible subsets of routes where aircraft of the same or similar types are engaged. Expression (b) implies that the number of routes in an airline network, anticipated delays and T are positively related with $A_{jk}(T)$, implying that as they increase, so does the required number of aircraft. The number of aircraft can be expected to reduce with the rise in average utilisation (Pollack, 1979). Therefore, an airline's operational parameters like aircraft utilisation and delay figures may impact their capacity planning cycle.

3.4.3. Network and Route Planning Cycle

Network and route planning cycle cover the identification of flight routes as well as the identification of weekly capacity between the O&D pairs. While route planning covers the determination of a single O&D pair, network-planning processes encapsulate the planning of all O&D pairs as a whole, including non-operating flights. For Barnhart and Smith (2012), conceptually, the network planning models refer to a collection of models that are used to determine how many passengers want to fly, which itineraries they choose, and the revenue as well as cost implications of transporting passengers on their chosen flights.

Figure 3.10: Phases and Processes of Network Management Adapted from Sterzenbach & Conrady (2003)



Network planning covers all planning processes related to flight operations. This planning process includes a strategic outlook in addition to operational and revenue management aspect mapping to different time horizons as shown in Figure 3.10. Furthermore, network and route planning can be based on tactical principles if the decision maker is under tactical circumstances. Competitive dynamics, emerging opportunities and market intelligence can encourage an airline decision maker to take tactical initiatives.

At the strategic network-planning phase, market analysis along with the capacity planning is conducted and the initial potential routes are identified. At this stage, the details of the network plan are flawed as there exists little information regarding the operational feasibility and profitability of the routes. In the operational network-planning phase, in order to get the plan into a more concrete status, the strategic plan is fine-tuned by taking resources and limitations into consideration. The criteria that are often referred to during an airline’s network design process ensures that the O&D demand is satisfied and the total operational costs are minimised (Teodorovic, Kalic, & Pavkovic, 1994). In the short term planning, profitability figures are estimated to realise the flights. To accurately forecast profitability, demand, yield and cost of the operation need to be assessed. Demand and cost estimates are quite likely to be inaccurate in the face of changing the market environment in the long and mid-term plans deeming the profitability expectations to be computed towards nearer time horizons.

3.4.3.1. Airline Profitability

For airlines, profitability expectations and economic drivers affect route evaluations. In order for an airline to launch a new route into its network or increase the capacity of an existing one, it needs to generate profit. To launch a flight i on an O&D (unless the airline does not have a different strategic goal), the flight should be profitable by holding the following equation true:

$$(RASM_i - CASM_i) > 0.$$

As this equation dictates, the profitability evaluation of each flight i requires powerful tools to comprehend the yield and costs of every single route. For Gleich and Wald, (2010), evaluating the profitability of a route is a challenging task, first because the accounting practice should allocate the revenue of different flights for connecting passengers. Passengers pay a single fare for a flight but travel on more than one leg. Secondly, good accounting practice should allocate costs to the flight legs that are incurred. Since some costs associated with a given route include fixed costs that have a value to several routes, the costs need to be apportioned to individual flight legs.

With the rise and evolution of HS networks, not only the local passengers' contribution to revenue and costs but also the connecting passengers' impact has to be addressed when analysing route profitability. As stated previously, airlines can accomplish a cost advantage through the utilisation of HS networks, while the revenue of a single connecting passenger occupying two seats in two different flights is less than the total revenue which could potentially be obtained by capturing two different local passengers on the same seat. Routing both flights and passengers through a connecting hub is more profitable for an airline if the *cost savings* from operating fewer flights with larger aircraft and more passengers per flight are greater than the *revenue loss* from passengers who reject a connecting service and choose a non-stop flight instead, if one exists (Morrison & Winston, 1986). For Nenem and Ozkan-Gunay (2012), an airline can attract connecting passengers if it can offer a cost advantage through its network. The geographical position of the hub is a key element in this context, which can offer smaller detour factors and the capability of flying aircraft with lower unit cost.

In case the airline reflects this cost advantage to passengers, the connecting traffic can be attracted to carriers. “The hub airline’s ability to consolidate traffic from many different O&D markets on each flight leg into and out of the hub allows it to provide connecting service even to low-demand O&D markets that cannot otherwise support non-stop flights. Consolidation of O&D market demands further allows the hub airline to provide increased frequency of connecting departures, as it likely operates several connecting banks per day in each direction at its hub airport.” (Belobaba, Odoni, & Barnhart, 2009, s. 164)

3.4.3.2. Route Profitability Analysis (RPA) and Network Profitability Analysis (NPA)

Computing a single route’s profitability, by correctly and concretely mapping revenues and costs at the leg level, refers to *Route Profitability Analysis* (RPA). RPA assumes a PP network; the route result is thus determined independently from any connected flights where the revenues and costs of connecting passengers are prorated to individual flight legs. Therefore RPA assumes that only revenues and costs which are generated on the analysed flight will be at risk if a flight is eliminated (Lufthansa Consulting, 2008). However, in line with the development of HS network patterns, executive decision-making is more focused on evaluating the network as a whole rather than a single flight route basis (Frainley, 2002). To assess the performance of single flights and their overall contribution to the network, airlines apply methodologies such as *Network Profitability Analysis* (NPA). The assumption behind the implementation of the NPA is that the economic impact of a flight is not limited to its O&D pair, but it affects the whole network because of the existence of connecting passengers. For instance, by cancelling the analysed flight, the contribution of the connecting passengers is not incurred on either the cancelled flight or the connecting flights (Lufthansa Consulting, 2008). This implies that while RPA solely concentrates on the profitability of the onboard segment of a single flight, NPA determines the financial impact of a single flight on the overall economics and profitability of the airline’s whole network. In other words, if a route is making a loss in an airline's network based on the principles of RPA or traditional accounting practices, it can contribute positively on the overall profitability of the airline’s network with NPA evaluation.

In both the RPA and the NPA methods, all cost and revenues are allocated to single flight legs. O&D revenues are prorated to segments by applying full fare ratios or by the mileage-based approach (Talluri & van Ryzin, 2004). As an example of mileage-based allocation, if the flight cost from A to C via hub B is x dollars, the distance from A to B is $d1$ miles and B to C is $d2$ miles, the revenue to be prorated to flight from A to B and B to C are,

$$\left(x * {}^{d1}/_{(d1+d2)}\right) \text{ , } \left(x * {}^{d2}/_{(d1+d2)}\right)$$

respectively. The allocation of the cost side is a more a complex procedure; all costs, which are not directly associated with one flight are split using the allocation keys and cost drivers. For instance, in the case of accepting available seat mile *(ASM)* as the allocation key for the crew cost, an individual flight *x*'s crew cost is calculated by;

$$c_{crew}(x) = \frac{ASM(x)}{\sum_i^n ASM(i)} \ x \ c_{crew}$$

where c_{crew} denotes the whole crew cost of the company, while *n* represents the total number of flights legs. In case the airlines decide to split the crew cost based on the block hour, the computation then changes as follows:

$$c_{crew}(x) = \frac{bh(x)}{\sum_i^n bh(i)} \ x \ c_{crew}$$

where *bh(x)* represents the block hour duration of flight *x* and *n* represents the total number of flights performed. Although best practices exist, there are no globally accepted revenue and cost allocation keys and drivers. Therefore, the basic input for any RPA and NPA are the airline's operating statistics (Baldanza, 2002).

When allocating revenues and costs within RPA and NPA, the profit contribution (PC) approach is applied to distinguish multiple contribution levels. This design provides a management tool to analyse sources and areas of profitability in addition to the mere profitability of a flight (Niehaus, Ruehle, & Knigge, 2009). The number and types of applied PC levels can vary depending on the needs and reporting structure of the airline. The depiction below illustrates a design of the RPA with 4 PC levels. In this example, prorated flight revenues and onboard revenues are summed as the total flight revenue at the top. At the first PC level, the allocated passenger and flight related variable costs are written down and deducted from the revenues and PC1 is obtained. PC1 calculates whether the analysed flight revenue is higher than the variable costs of operating that flight.

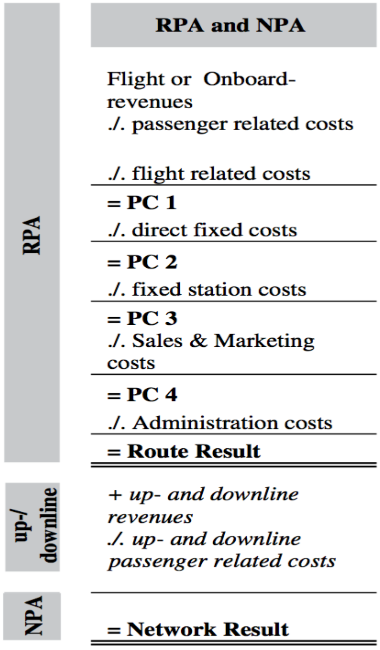
Figure 3.11: RPA Analysis with 4 PC Levels Adapted From (Sterzenbach & Conrady, 2003)

Flight or On board-Revenues	
./. passenger related costs	direct variable costs
./. flight related costs	
= PC 1	
./. direct fixed costs	direct fixed costs
= PC 2	
./. Fixed station costs	indirect fixed costs
= PC 3	
./. Sales & Marketing costs	
= PC 4	
./. Administration costs	
= Onboard- or Route Result	

If PC 1 < 0, the flight is incapable of covering its variable operating costs, and hence not economically feasible. It should be noted that the costs addressed within the scope of PC1 only cover the flight and passenger related variable costs that are directly impacted by the number of passengers onboard, such as catering, passenger handling and fuel cost. Fixed costs involving staff, aircraft ownership or station cost are not included at the PC1 level. Direct fixed costs are included at PC2. Operated aircraft mainly drives the fixed costs included at PC2, making PC2 as the basis of decisions related to capacity and flight schedule. To assess the profitability of the handling and station operations, PC3 is used as an indicator, while by further including sales and marketing costs, PC4 is calculated. Finally, the route result is obtained by subtracting all administration costs from PC4. It is noteworthy to state that due to the reporting needs and organisational performance evaluation structure of the airline, PC levels at the RPA measures can be adjusted. Such an adjustment would not change a route's profitability, as all costs concerning the flight leg is included for the final route result calculation.

The design of the NPA has a similar methodology and the PC approach to the RPA model. NPA evaluates a flight's contribution impact to the entire network by applying incremental cost and revenue analysis. This suggests that in addition to the on-board revenues, the proration of connecting passengers' O&D revenues (which are allocated to the single flight legs in the RPA) are integrated into the calculation (Niehaus, Ruehle, & Knigge, 2009). In other words, in the NPA model, the revenue that is prorated to the other leg of the connecting journey is recorded as an incremental revenue. The logic behind this approach is that, in case of a certain route's removal from the network, the total revenue loss would not be limited to the prorated revenue of that route but it also includes connecting passengers' allocated revenue to other legs. On the cost side, only the incremental cost of connecting passengers is classified as incremental costs and included for NPA computation. The incremental costs and revenues are commonly referred to as up and downline costs and revenues (Frainey, 2002). Figure 3.12 demonstrates the design of NPA model built on top of the RPA with 4 PC levels.

Figure 3.12: Design of An NPA Adapted from Maurer (2003)



Including incremental up and downline revenues and costs results in double counting throughout the NPA. Up and downline revenues and costs of a flight are at the same time local revenues and costs for another connected flight. From this perspective, NPA is far from being a traditional accounting practice but rather strategic management reporting. This double counting is widely accepted in order to recognise the dynamics of a network with co-dependent flights. Since NPA is a strategic reporting tool that does not necessarily have to comply with traditional accounting reports, airlines can further enhance the model mentioned above by inserting "opportunity costs" into the analysis. Assuming the existence of demand, if the airline accepts connecting rather than local passengers, an opportunity cost arises for the airline. Therefore, NPA can be further elaborated by including spill costs as up and downline costs.

3.4.4. Schedule Development Cycle

With the fleet, route and network plans ready, creating the timetable, encompassing the information of which cities to fly to on which days and at what times, is the next step to plan. The airline-scheduling problem is extremely complex as it involves various limitations, rules and regulations that are linked with airports, aircraft, airlines and governments. From this perspective, the scheduling needs to be broken into manageable pieces. For Etschamaier and

Mathaisel (1985), the schedule formation phase is about developing a rough first schedule, which requires extensive modification to be both feasible and economically viable. The level of detail in constructing the timetable varies among airlines, but it will be a complete schedule for a full cycle, which is normally one week (Grandeau, Clarke, & Mathaisel, 1998). For Weide et al. (2010), an airline seeks to construct a schedule of flights where each flight is specified by an "origin, destination, departure date, time and duration" where market demand determines the O&D pairs and frequency of flights. The frequency of a flight from City *A* to City *B* per cycle can be calculated as;

$$\frac{d_{AB}}{LF\ x\ c_{AB}}$$

where d_{AB} represents the projected unidirectional demand between *A* and *B,* LF stands for the load factor and c_{AB} is the average aircraft seat capacity to be offered between A and B.

3.4.4.1. Relationship between Scheduling and Operating Costs

As highlighted in the earlier sections, the profit margin for the airline industry is very limited and indeed plenty of carriers are suffering from severe losses. The current airline industry is extremely competitive and operates under a diminutive profit margin; thus airlines are striving to introduce profitable flight schedules that maximize their revenues and exploit their resources. *(Abdelghany, Abdelghany, & Azadian, 2017)* Airlines need to present sustainable competitive pricing to effectively tap into growing markets and a crucial factor to sustain low prices is the maximisation of operational efficiency. *(Lawton & Solomoko, 2005)*

*For Sakthidran and Sivaraman (2018) LCCs are operating at better efficiency than FSCs. This suggests that some policies of the LCC model can be emulated by FSCs for better operational efficiency. This is in line with the observa*tions of Gillen and G*ados (2008) who argue that the LCC model is more suitable for higher staff productivity. Greer (2006) examined the productivity change using Malmquist Productivity Index (MPI) and Data Envelopment Analysis (DEA) on a representative sample data from ten major American airlines from 2000 to 2004. The study demonstrated that most carriers made strides in pro*ductivity improvement more from operational efficiency improvement than from technology changes during this period. *The presence of LCC competition* can also impact the yields of a service airline in the hubbing strategies of the carriers. For instance, Tan and Samuel *(2016) find in their study that, yields tend to decrease* at the de-hubbed airport in *the* case *when* LCCs are present at the airport and tend to increase in *the* case *when* LCC competition is lack*ing*. As *de-hubbing can also increase the operating costs for the airlines*, in*deed airlines may prefer to increase costs by de-hubbing* to focus on service (or schedule) quality at the expense of higher operating costs.

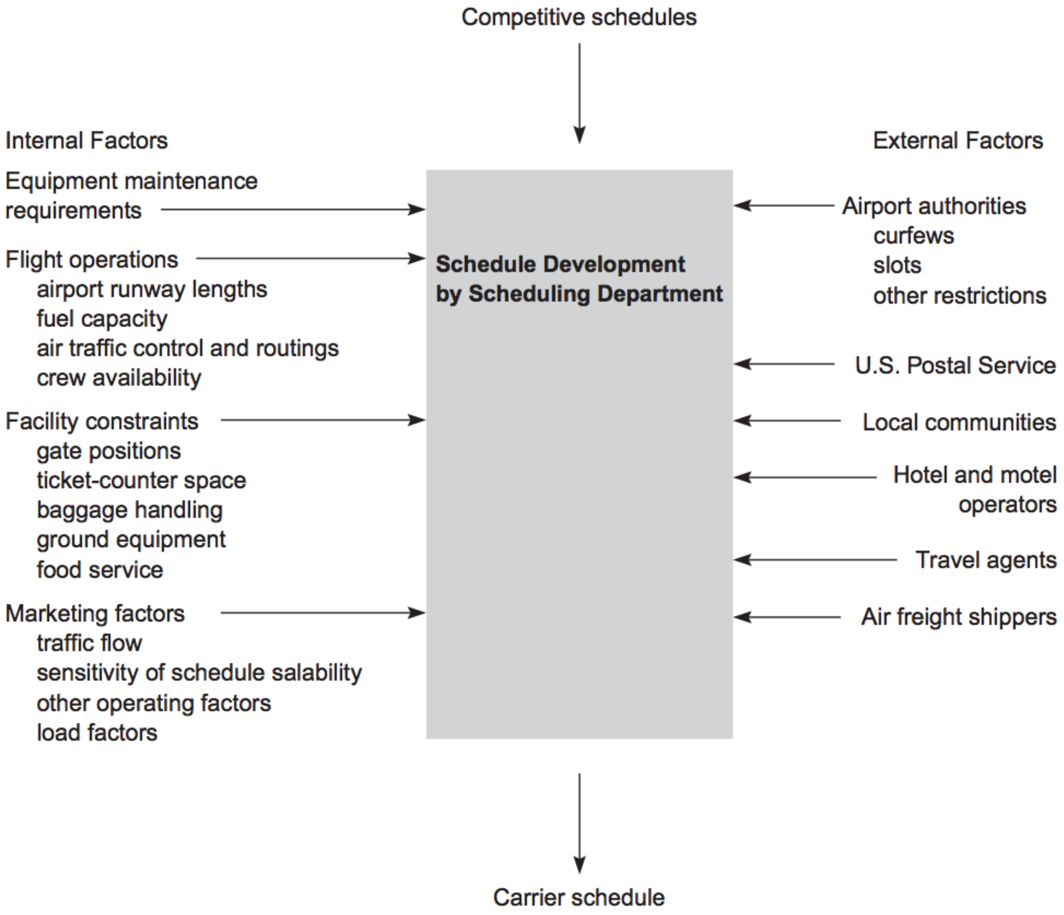
There exists a strong link between airlines' operating costs and their strategic actions in terms of establishing joint ventures. The main motivation behind joint venture establishment is strategic behaviour to prevent rivalry and operational efficiency. Alliances enable partners to increase efficiency, reducing expenses by cutting back on fixed costs and wedding out redundant operations. By coordinating aircraft and schedules, members can reduce their fleet requirements or take more advantage of the capacity available, as operating a larger aircraft is more suitable for matching the aircraft size with the demand of a particular route. (Ustaomer, Durmaz, & Lei, 2005)

Alliances between airlines on international markets have become a dominant feature of the airline industry. Many customers demand a 'from anywhere to anywhere' service, which is impossible for one airline to supply efficiently, and there are significant economies of density that can be achieved by merging networks.Airline cooperations and Joint ventures provide efficiencies in terms of density of passenger flows. Although economies of scale in operations seem to be relatively limited, there are very clear economies to be obtained from generating denser flows of passengers, which boosts seat utilization and enables the use of larger and lower unit cost aircraft. (Pearce & Doernhoefer, 2014)

3.4.4.2. Internal and External Factors of Schedule Design

When developing the timetable, internal and external factors exert limitations to the scheduling process. Figure 3.12 presents the general framework of schedule development phase. While internal factors are under an airline's control determined by company-specific strategies and policies, external parameters are beyond the airline's governance and hence pose a direct limitation to the scheduling cycle. Some of the major internal and external factors are presented in the following sections.

Figure 3.13: Conceptual Framework for the Schedule Development Process Referred to in (Wensween, 2011)



Aircraft Utilisation: Aircraft utilisation is the number of hours that an aircraft is used per day. As mentioned earlier, aircraft utilisation is an efficiency measure for airlines as more sellable capacity is generated with the available fleet by keeping them in the air longer. According to Vasigh et al. (2012, s. 105-106), "*the airlines have a better chance of making a profit with higher aircraft utilisation since the fixed costs are spread out over a greater number of revenue hours. Efficient fleet utilisation is one of the key factors in an airlines' efficiency, productivity and profitability.*" When developing the schedule, the planners need to maximise aircraft utilisation as much as possible. Any inefficiency that leads to low aircraft utilisation may result in an increased unit cost.

Turnaround Time: The time from the arrival of the aircraft until its next departure is called turnaround time. For Van Den Briel et al. (2005), turnaround time is a major metric for airlines' operations and schedule development since aircraft generate an economic value as long as it flies, rather than being kept on the ground. From this perspective, higher turnaround time reduces aircraft utilisation. Airline operations should minimise turnaround time by taking relevant measures at the airport in order for planners to ensure higher aircraft utilisation.

Airport Constraints: The growth of air transport poses a significant challenge to some airports with limited capacity concerning demand (Czerny, Forsyth, Gillen, & Niemeier, 2008). In order to deal with limited airport capacity and excess demand, authorities employ systems such as slot allocation that is required to use the airport at a specific time. Such airport constraints constitute a great limitation for airline planners as their flexibility to offer frequencies that best meet demand and to maximise aircraft utilisation is restricted. Therefore, airport limitations can force planners to diverge from ideal schedules. For this reason, airport slots for the congested airports are now great assets for airlines that can even be traded. On the other hand, airport night curfews limit capacity (Forsyth, Gillen, Müller, & Niemeier, 2010). A night operation restricted airport, the curfew, is always an additional factor in finalising timetables. Likewise, some airports are subject to noise quota again restraining the available capacity to be offered by the airlines.

Traffic Rights: Traffic rights are exercised by the country's designated airlines under the term of Air Services Agreement. Airlines are not free to fly to any destination. They need to be designated by their civil aviation authorities and approved by the relevant authorities at the intended destinations. Through the Air Services Agreement, governments can regulate the frequency, seat capacity, designated airlines and permitted flight destinations. "The entry of a new airline into a route is impossible unless its national government is willing and able to negotiate the necessary traffic rights." (Doganis, 2009) Although countries with liberal policies on civil aviation eliminate the limitations for air services, protectionism and constraints related with the destination country's permissions and home country's designations are still a concern for airlines, embodying a large restriction on effective schedule design.

3.4.4.3. Flight Connections

Carriers aiming to receive a reasonable share from the transfer market need to design their schedules enabling passengers to make the highest degrees of flight connections. In order to realise the maximum benefits of the transfer passenger market, a group of flights needs to be scheduled to arrive at a hub and other groups of flights should depart from the airport within a given window of time. For this reason, airlines construct a wave structure scheduling mechanism. Dennis (1994) refers to an incoming bank and outgoing bank of flights being linked together as a wave. According to Bootsma (1997, s. 32), "*a wave-system structure consists of a number of connection waves, which are a complex of incoming and outgoing* *flights, structured such that all incoming flights connect to all outgoing flights*". For Burghouwt and de Wit (2003), three elements determine the structure of a wave:

1) The minimum connection time,
2) The maximum connection time,
3) The maximum number of flights that can be scheduled per time period.

3.4.4.3.1. Minimum connection time (MCT)

As addressed in Chapter 2, a connection must exceed the MCT that is determined by the airport management. This is the minimum time required for a passenger to leave the plane of the incoming flight at the hub, complete formalities and catch the next flight. The MCT window is required for the transfer of passengers and baggage between two flights as well as for the aircraft itself to be turned around (Burghouwt, 2007). Additionally, airports' published MCT figures may include some allowance for delays and baggage processing. As per IATA (2017), in determining MCT intervals, "physical and operating characteristics of the particular airport, e.g. air traffic delays, ramp and baggage sorting area congestion, history of on-time performance, terminals, specific flight origin and/or destination region (such as Schengen countries), customs/immigration 'pre-clearance' situations, etc." shall be taken into account. Any connection that fails to meet the MCT requirement cannot be counted as a viable connection. Transferring bags from one flight to another is a complicated process at the hub airport and has a direct impact on determining the MCT. It is even sometimes a more constraining process than the transfer of passengers. From this perspective, the airport capacity, capability and infrastructure have a direct effect on MCT. The MCT might depend on multiple parameters such as the configuration of the passenger terminal, the airline/airport parking strategy and the time needed for the passenger's security check (Janic, 2008). Smaller airports tend to have a smaller MCT while larger airports publish higher MCTs due to their restrictions, formalities and terminal infrastructure.

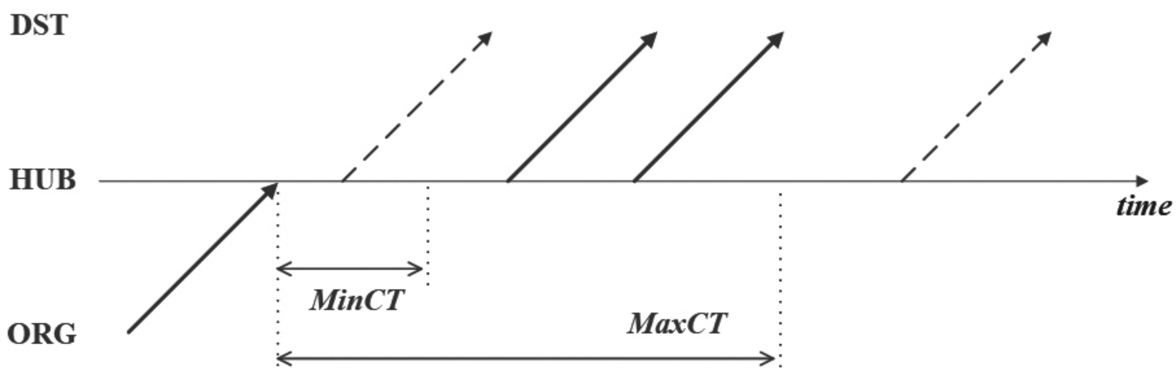
From the passengers' perspective, tight flight connections that are barely above the MCT can lead to t_{stress}. By considering the worst-case scenarios, such as the delay of the incoming flight, extended security checks, walking distance within the terminals, to serve as a buffer, passengers may want to add some minutes (conceptualised as t_{buffer} as addressed in Chapter 2) more to the MCT.

3.4.4.3.2. Maximum connection time (MaxCT)

Not all connections which meet the MCT criterion are attractive for passengers. For Dennis (2001), longer waiting times at the hub airports may not be acceptable for transfer passengers. As covered in Chapter 2, in order to eliminate unattractive connections, the maximum acceptable connection time (MaxCT) is employed whose value may vary by fare, length of haul, journey purpose and etc. Therefore, a connection is attained, or 'hit', if the second flight departs after the completion of the MCT and before the completion of MaxCT. Figure 3.13 presents an illustration of attaining a hit that is achieved in case the below conditions are met:

$$arrival\ time\ of\ inbound\ flight + MCT \leq departure\ time\ of\ second\ flight \text{ and}$$
$$arrival\ time\ of\ inbound\ flight + MaxCT \geq departure\ time\ of\ second\ flight$$

Figure 3.14: Minimum and Maximum Connection Time Requirements. (Only the Second and Third Outbound Flights (Showed by Dotted Lines) are Hits and Feasible Connections. Adapted From (Seredynski, Rothlauf, & Groesche, 2004))



Goedeking (2010) discuss that due to the diverse region and working nature of airports and passenger profiles across the world, it would be disadvantageous to define globally accepted fixed MaxCTs. He proposes that a dynamic, auto-adaptive hit is the only way to ensure direct comparability of the connectivity of hubs located in diverse markets. However, given its simplicity in implementation, a fixed MaxCT is preferable when evaluating schedule scenarios. The examples of fixed MaxCTs are summarised in the table below. It is noteworthy to state that, MaxCT's shown in Table 3.7 got longer nowadays due to the increasing security requirements, raising the volume of transfer passengers and of course decreasing on-time performance.

Table 3.7: MaxCT Propositions in the Literature for the Different Type of Connections

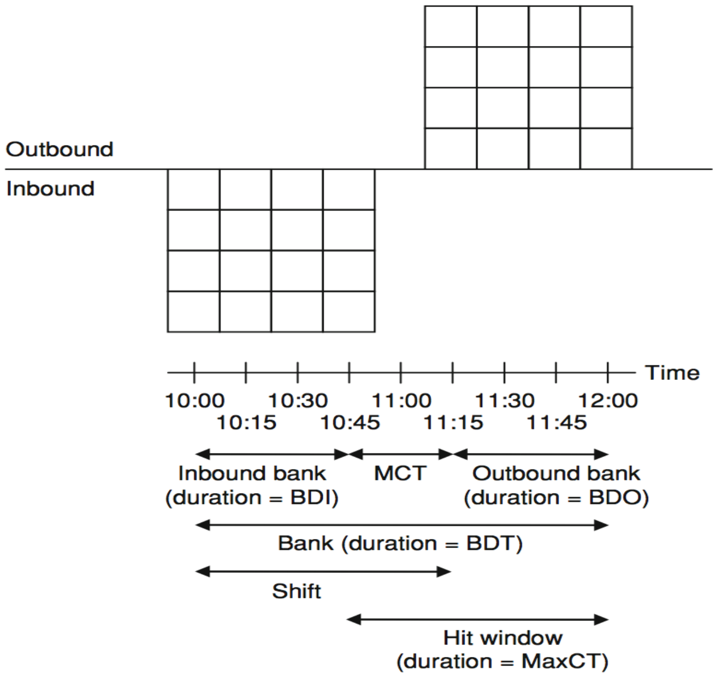
MaxCT	Type of Connection	Reference
90 minutes	All type of connections	(Doganis & Dennis, 1989)
180 minutes	Continental flights	(Bootsma, 1997) and (Burghouwt & DeWit, The Temporal Configuration of European Airline Networks, 2003)
300 minutes	Continental to intercontinental flights	(Burghouwt & DeWit, The Temporal Configuration of European Airline Networks, 2003)
720 minutes	Intercontinental connections	(Burghouwt & DeWit, The Temporal Configuration of European Airline Networks, 2003)
120 minutes	Continental connections	(Danesi, 2006)
180 minutes	Connections involving intercontinental flights	(Danesi, 2006)

3.4.4.3.3. The maximum number of flights that can be scheduled per time period

For Dennis (2001) since no airport has unlimited capacity, an airline intending to add flights to a hub has two principal options. It can either schedule the flight to the edge of a wave or it can develop new waves. Adding flights to existing waves is advantageous because of the higher number of hits generated. However, due to limited airport capacity, additional connections created by an extra flight, which must be located at the earlier edges of a wave, would likely involve long t_{conn}. If the additional flight is placed towards the tail of the wave, some connection hits are likely to be missed due to the MCT requirements and passenger preferences. Additionally, a wave could be at its maximum limits preventing airports from accepting further flights. In this case, the airline should develop new waves if there are other available waves, facilitating relevant hits. From this perspective, airport and airline schedules are restricted by the maximum flight accommodation level at a wave in addition to the potential number of waves that can be generated within a day. According to Graham (2001), the capacity of the airport cannot be assessed by a single measure. The capacity of the runways, terminals, gates and so on all have to be considered. These can be measured on an hourly, daily, monthly and annual basis. This reality further restricts airline network planners and airport management.

The term wave is a pattern of movements in a system where an outbound bank follows an inbound bank then again by a sequence of inbound and outbound banks. The proper up and down sequencing of inbound and outbound banks compose the wave structure. An example of inbound and outbound banks is demonstrated in Figure 3.15 below where each square represents an individual flight.

Figure 3.15: Definition of Inbound and Outbound Banks from Networks in Aviation (Goedeking, 2010)



As Figure 3.15 demonstrates, the inbound bank duration *(BDI)* refers to the time interval between the first and last flight of the inbound bank, whereas the outgoing bank duration *(BDO)* is the time interval for the outbound bank. The duration of the bank is;

$$BDT = BDI + MCT + BDO$$

Under optimum circumstances, in order to avoid any missed hit, the last flight of the inbound bank must connect with the first flight of the outbound bank. Therefore, the outbound bank needs to be *(BDI + MCT)* minutes after the start of the inbound wave. Additionally, to prevent wait times longer than MaxCT, BDI and BDO must be designed in such a way that the initial flight of the inbound bank connects with the last flight of the outbound bank. For this reason, the following conditions need to hold true;

$$BDI + MaxCT \leq BDT \qquad (1) \quad \text{and}$$
$$BDI + MCT \leq MaxCT \quad \text{or} \quad BDI \leq MaxCT - MCT \quad (2)$$

Rewriting the first expression

$$BDI + MaxCT \leq BDI + MCT + BDO$$
$$MaxCT - MCT \leq BDO$$

It is implied that the maximum value of the *BDI* can be *(MaxCT – MCT),* while this number is at the same time the minimum optimum duration for the *BDO* (Intervistas, 2014). It should be noted that if all flights in the inbound bank can be connected to all flights in the outbound bank, the total number of generated hits are (Wittmer, Bieger, & Müller, 2011);

$$hit_{max} = n(inbound)\ x\ n(outbound)$$

where $n(inbound)$ is the total number of flights in the inbound bank and $n(outbound)$ is the total number of flights in the outbound bank. The final number of hits would change depending on : (Goedeking, 2010)

- The number of flights in a bank

- The number of banks in a day

- Airport infrastructure like terminal capacity

- The MCT requirement of the airport

- MaxCT

- The design of the wave: Parametric attributes of the wave-like BDI, BDO and BDT, as well as the shape of the wave like the overlap or independence of inbound and outbound banks affect the number of viable hits.

- Directionality: In order for inbound flights to connect well to outbound flights, the origin of inbound flights and the destination of the outbound flights need to be relevant. For instance, for a hub in Europe, if an inbound bank is composed of US flights and outbound flights are designed to depart for the US again, relevant connections would not be attained in the bank, reducing the number of achieved hits.

- Delay Expectations*:* MCT is an airport dictated parameter and sets the minimum duration of connecting time at the hub. However, in reality, the probability of a delay with the inbound flight's arrival to occur is not zero per cent. For Wu (2010, s. Section 2.5.4), "passengers who suffer delays lose time as well as the potential value of the delay time. In addition to the direct value of the lost time, delays cause disruptions to passenger itineraries, business activities and social arrangements". Thus, planning a connection at the limits without any t_{buffer} is risky and may cause inconveniences in the form of a step function in case a misconnection happens as the passengers would be obliged to travel with a new itinerary. Airline schedulers should estimate the expected delay for each flight and schedule the flights in reference to this information. For Dunbar et al. (2014), including additional delay information within the aircraft routing and scheduling in the form of scenarios has the potential to improve the overall solution robustness of the airline schedule. Therefore, airline schedulers need to consider several parameters to meet the requirements of an effective wave design in case they structure their business strategy for increasing transfer passenger traffic.

3.4.4.3.4. Literature on Hub Airports' Connectivity Measures

The connectivity of the hubs is an essential parameter for airline planners. Besides, according to Malighetti et al. *(2008)*, connectivity, which determines how easy an airport can reach the rest of the world, is one of the key attributes that airport managements consider. In the industry, there exist plenty of commonly used connectivity measures such as the models of ACI-Europe and Netscan. ACI's connectivity index is calculated by weighting the schedule related parameters like the frequency, MCT and t_{conn} *(ACI Europe, 2017)*. For Veldhuis *(1997)* the Netscan model considers the direct and indirect flights and use schedule, transfer time, MCT and great circle distance data to weight the connectivity units. Logothetis and Miyoshi *(2018)* introduced a new model for evaluating connectivity at hub airports which assessed both schedule and comfort related attributes of indirect flights. The authors also attempted to inject a quality perspective into the connectivity indexes which takes not only the detour factor and time-related parameters into consideration but also the aircraft type, seat supply and frequency factor.

3.4.5. Fleet Assignment Cycle

The fleet assignment is the process of assigning the right aircraft type for each particular flight in the constructed schedule. The fleet assignment is a different process than fleet planning (Clark, 2012). While fleet planning is a process of identifying capacity requirements for the airline, the fleet assignment is about addressing the fleet inventory to the relevant flights in the constructed schedule. In practice, airlines have multiple aircraft types in their fleet. Within the fleet assignment, planners need to use the right aircraft for the most appropriate flights while meeting various operational constraints (Abara, 1989). Although the number of frequencies is decided during the schedule construction phase, total capacity offered to a market at the O&D level is finalised after the fleet assignment as the number of s_f is finalised at this stage.

During the fleet assignment phase, the schedulers need to assign the right aircraft to the right destination to ensure profitability by maximising revenue and minimising costs. Various studies ensuring cost minimisation through objective functions are present in the literature. Hane et al. (1996) first modelled a fleet assignment problem that was simplified by the assumption that each flight is flown every day of the week. This approach facilitated a reasonable solution of practically sized problems. In their objective function, they minimised the total cost of assigning fleet types to segments while ensuring that one fleet type covers each leg and the flow balance at a given node in the network is ensured. As a sequel to this work, Clarke et al. (1996) generalised the basic model by inserting maintenance and crew scheduling considerations while preserving the solvability and cost minimisation objective. Lohatepanont and Barnhart (2004) as cited in Bae (2010) dealt with the immense problem size and complexity to minimise cost by employing incremental approaches to schedule design, working with a subset of candidate flight segments for fleet assignment from a given flight schedule at each step. Li et al. (2006) further elaborated on the fleet assignment problem by including belly cargo considerations in their model.

In previous literature, most of the fleet assignment problems considered leg based passenger flow. However, with the rise of HS networks and airline executives' focus on connecting passengers, as Barnhart et al. (2002) argued, as all legs in a network are interdependent, failing to capture network effect may inhibit the optimal fleet assignment problem. For this reason, they incorporated itinerary based passenger flow into their fleet assignment model. Rexing et al. (2000) considered the appointment of aircraft on flights together with departure times to improve flight connection opportunities.

3.4.6. Load Factor and Yield Management

When assigning aircraft to a flight, it is essential to ensure the highest levels of load factor. Flying aircraft with empty seats encapsulate a direct opportunity cost for the carriers. This requires a proper demand analysis and its incorporation into the fleet assignment process. Assigning larger aircraft to a low-demand market leads to low utilisation and consequently lower load factor. On the other hand, assigning small aircraft to a highly demanded leg results in passenger spill, implying that the demand exceeds the capacity offered. The spill cost is, therefore, the potential revenue of lost passengers due to insufficient aircraft capacity (Bazargan, 2004) and needs to be added to the fleet assignment problem. For Ozer & Phillips (2012), the load factor (LF) of flight *i* is defined as

$$LF_i = \frac{pax_i \ x \ m_i}{s_i \ x \ m_i} = \frac{pax_i \ x \ m_i}{ASM_i}$$

where pax_i is the total number of passengers, s_i is the number of available seats and m_i is the mileage for flight *i*. Defining revenue yield (RY), as the revenue per passenger, the yield of flight *i* is then

$$RY_i = \frac{Total\ Revenue\ of\ Flight\ i}{pax_i \ x \ m_i}$$

Multiplying RY_i with LF_i, $RASM_i$ is obtained.

$$\frac{Total\ Revenue\ of\ Flight\ i}{ASM_i} = RASM_i$$

Remembering that profit per available seat mile is the subtraction of $RASM_i$ and $CASM_i$, (Vasigh, Flemming, & Humphreys, 2015), the profitability of flight *i* is;

$$(RASM_i - CASM_i) = (LF_i \ x \ RY_i) - CASM_i$$
$$= \left[(LF_i \ x \ RY_i) - \frac{Total\ Cost\ of\ Flight\ i}{seats_i \ x \ m_i}\right]$$

As the objective function, the following profit expression of the airline needs to be maximised,

$$\sum_{i=1}^{n} \left[(LF_i \ x \ RY_i) - \frac{Total\ Cost\ of\ Flight\ i}{seats_i \ x \ m_i}\right]$$

where *n* is the total number of flight legs. The equation implies that spill passengers have to be minimised to keep LF and profitability high. The multiplication of LF with the RY is an issue of demand elasticity as the carrier can play with load factors by adjusting the fares accordingly. The process of balancing demand and yield relates to yield management. Pfeifer (1989) defines the yield management as "the process by which discount fares are allocated to scheduled flights for the purposes of balancing demand and increasing revenues". Kimes (1989) argues that yield management guides the decision of how to allocate undifferentiated units of capacity to available demand in such a way as to maximise profit or revenue. For Smith et al. (1992) yield management is used to control capacity profitably, which can lead to a great increase in revenues. Boyd (1998) alleges that the implementation of a yield management system that balances demand and capacity can improve revenues between 2 to 8 per cent or even more. From this perspective, the coordination of the yield management department with the fleet assignment department is critical for the airlines' profitability.

3.4.7. Aircraft Routing / Tail Assignment Cycle

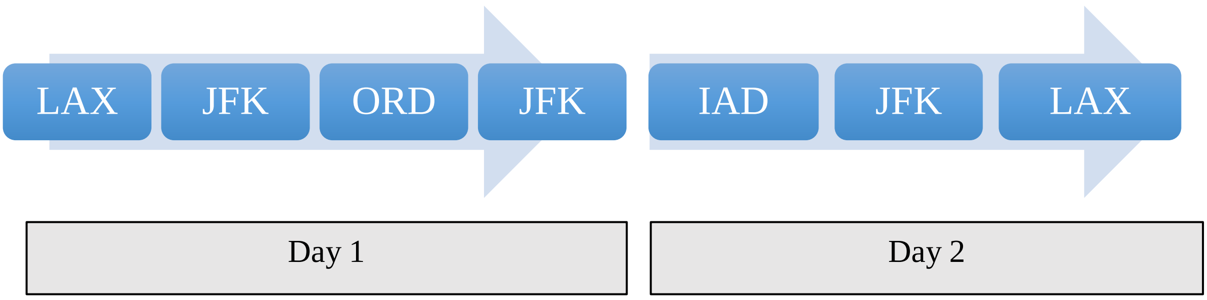
Aircraft routing is the process of addressing a particular aircraft to each flight segment. During the fleet assignment phase, it is not identified which specific aircraft from the fleet is assigned to each flight. From this perspective, aircraft routing is also named as "tail assignment" or "aircraft rotation". For Wilson et al. (2009), "the aircraft routing problem involves finding paths from a specified start point to a specified destination. Routes are composed of straight-line segments joining intermediate 'waypoints' and the problem is to position these waypoints so that the resulting path avoids certain 'hard' constraints (such as geographical features and 'no-fly zones') and has low exposure to 'soft' constraints (such as risks from military missile threats or low fuel reserves)". They define the optimality of a route based on minimising cost. Bartholomew-Biggs et al. (2003) studied the tail assignment problem as finding an optimal flight path traversing a minimal distance between a given O&D pair while avoiding obstacles in a geographical sense. From this perspective, aircraft routing has a direct impact on profitability as the optimal solution minimises unit cost through shorter distance travels and increased aircraft utilisation. For Gopalan and Talluri (1998), aircraft routing problem should minimise the operating cost with the following considerations:

- Each flight needs to be covered by an aircraft.
- The aircraft must have balanced utilisation loads.
- Maintenance requirements must be met.

Since the maintenance facilities of an airline are located either at their hub or in another contracted destination, once an individual aircraft's maintenance period is due, the aircraft has to be routed to that destination. Table 3.8 and Figure 3.16 demonstrate an example of a two-day rotation of an aircraft.

Table 3.8 and Figure 3.16: 2-day Rotation for a 738 Aircraft Originating Its Journey in Los Angeles at 5.00 Am in Day 1 and Returning to Los Angeles at 21.30 in Day 2. The Figure Is Adapted From (Airline Operations and Scheduling, 2004)

	Flight Number	Origin	Departure Time	Destination	Arrival Time
Day 1	101	LAX	05:00	JFK	13:30
	129	JFK	15:05	ORD	16:05
	109	ORD	17:10	JFK	20:10
Day 2	140	JFK	06:20	IAD	07:20
	120	IAD	14:25	JFK	15:25
	127	JFK	19:00	LAX	21:30



3.4.8. Interline and Codeshare Flight Planning

Airlines launch new flight destinations or increase flight capacity to a certain destination so long as they have adequate resources in terms of capital and labour to operate. As mentioned in earlier sections, demand in this context is the ultimate driver triggering the appointment of organic (physical) capacity that refers to the airline's self-resources. While assigning capacity to a particular O&D, the forecasted demand is estimated to be above the critical mass enabling the airline decision makers to take the flight from origin to destination with the airlines' capacity. However, it may be the case that an airline would still prefer to be present in the markets whose estimated demand figures are below the critical mass qualifying to assign physical capacity. It may also be the case that even if the demand is sufficient enough to place an organic capacity to a route, the airline may not be able to offer physical capacity due to the limited resources of the carrier in terms of capital and labour or due to the regulatory framework such as the unavailability of traffic rights, airport slot restrictions and etc. For Holloway (2008), for carriers, the choice lies between using their aircraft and outsourcing capacity provision. Serving a solution for such limitations, many airlines are now extending their commercial networks by entering into codeshare agreements. For Robinson et al. (2013), because of the rising global competition between airlines, to differentiate their products and reach as many destinations as possible which in most cases is not economically viable, airlines partner with others and enter into code-share agreements. In a codeshare agreement, the airlines share the two-lettered designation for the contracted flights. Stolzer et al. (2011) resemble the code-share agreements to a supplier agreement, that is, "the supplier provides products or services based on the service level or quality agreements". As covered in Chapter 2, marketing carriers can sell the seats on the operated flight as if those seats are at the marketing carrier's own discretion. An operating carrier may allow more than one marketing carrier on a particular flight.

Before the proliferation of code-share agreements, interline agreements were widespread. Shaw (2007) defines an interline connection whereby the inbound flight to a hub and the outbound from it are performed with different airlines. With interline agreements, consumers are permitted to travel across networks of multiple airlines with the convenience of a single itinerary, requiring operating and marketing carriers to integrate their IT systems effectively to grant passenger convenience.

Various advantages of interline and codeshare agreements exist for both the operating and marketing carriers. While the marketing carrier extends its network coverage through the partnership with a lower cost figure in comparison to the cost of organic capacity assignment, the operating carrier establishes a new channel to sell their seats by means of another airline's inventory. With the support of the marketing carrier, the operating carrier can increase the load factors. For Szakal (2013), the main advantage of interlining from the carriers' perspective is the revenue increase. The cooperating airlines have the opportunity to offer a highly competitive joint fare that attracts customers to their particular route. In case the operating airline is somewhat smaller than the marketing carrier, such an agreement would build up the operating carrier's image and credibility. From this perspective, regional carriers engage in such agreements aggressively. Almost all regional airlines operate under codeshare agreements (Lee, 2007). Through these contracts, regional airlines enable major carriers to offer additional capacity and market presence with their codes, which they would otherwise not likely be able to offer themselves profitably. In other words, the primary marketing carriers outsource some of their flights to operating carriers through code-share agreements, offering a seamless trip for passengers travelling to offline destinations, which are not organically covered.

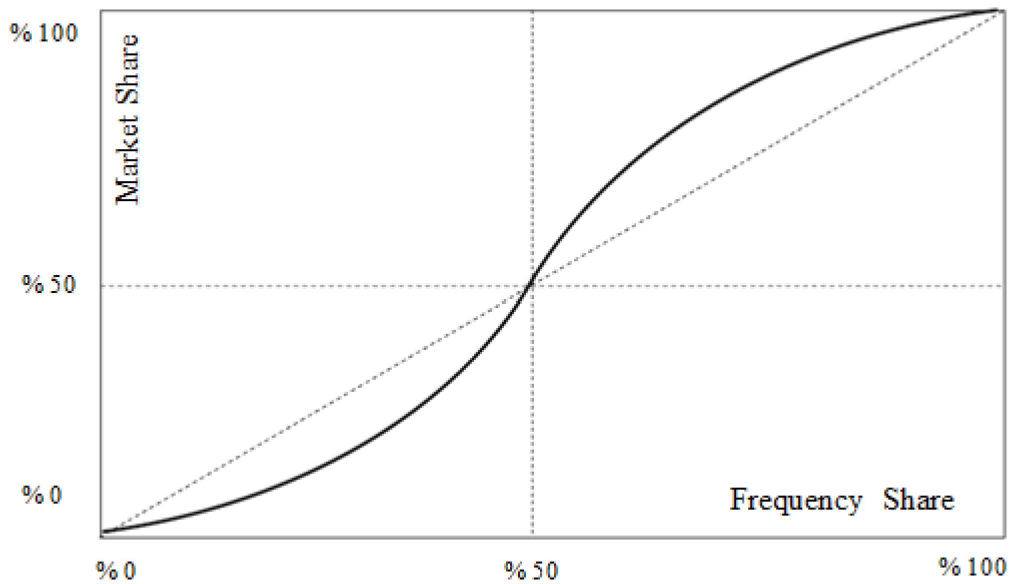
Although generating network synergies is the principal motivation behind such cooperation between airlines, it should be noted that some airlines are fierce competitors on most parts of their respective networks too. However, because of the mutual business needs, they still can construct codeshare agreements on specific routes. Brandenburger and Nalebuff (1996) formed the term ‘‘co-opetition’’ to define this kind of phenomenon. In this sense, interline and codeshare agreements prove that the airline industry is a good example of co-opetition. On the other hand, Abdelghany and Abdelghany (2009) have a more cautious view on codeshare agreements stating that "most code-share agreements are implemented based on the assumption that the agreement will generate additional demand that will fill empty seats on the participating flights. However, in some case, this additional code-share demand would displace non-codeshare passengers on the operating carriers' flights". They believe such agreements might cause revenue loss for airlines. For this reason, airline decision makers need to investigate the trade-off between the incremental revenue from a code-share agreement and the revenue loss from displacing non-code-share passengers. In this context, the coverage of the codeshare agreements is a focal point of concern.

3.5. Airline Market Share Evaluation and Quality Service Index (QSI)

Due to the commoditisation process of air travel and rising flight options available for sale, the importance of schedule convenience in the decision-making process of consumers is increasing for all traveller segments. The schedule convenience is charged by the airlines and paid by the travellers. In addition to its impact on the fare, it is also apparent that an airline’s market share expectations are correlated with their products’ schedule convenience. The following Chapter provides a literature review concerning schedule convenience and passenger choice in detail. This section covers the market share estimation mechanisms currently available in current knowledge. As addressed in Chapter 1, market share is a particular parameter of market performance as higher market shares on a given O&D imply relatively stronger market presence and thus better economic performance.

The “S-curve” relationship between airline market share and frequency share is accepted is depicted in Figure 3.16. The S-curve relation between the market share and the frequency infers that higher volumes of capacity shares lead to higher market share performance. As an example, Belobaba et al. (2009) argue that in a two-airline competitive market, if one carrier serves 60% of the non-stop flights, it is likely to capture more than 60% of the market share. Conversely, the other airline will see less than 40% market share. Button and Drexler (2005) note, it is difficult to trace the origins and evolution of the S-curve model from published literature. Early theoretical development and empirical studies for the pre-deregulation era demonstrate that higher-frequency shares are linked with disproportionately higher market shares (Taneja, 1976). For the S-curve theory, a frequency advantage-building airline is rewarded by a proportionately greater market share advantage. After deregulation, there are further references to the S-curve (Baseler, 2002). According to the IATA report (2006), with the S-Curve in mind, network managers have attempted to limit the damage in the markets in which they are disadvantaged either by matching competitors' frequencies (often triggering unnecessary overcapacity) and by focusing on connecting traffic or by withdrawing altogether. For an HS carrier, the S-curve phenomenon may assist in strengthening its competitive position at a hub. By adding frequencies on the spokes, it is expected to receive more than a proportional share of traffic, and the trend may continue until the carrier dominates these markets (Ghobrial, 1991). Skinner et al. (1999) find that, a carrier dominant at a hub may use its S-curve advantage to drive out other competitors, and that carriers use the S-curve in their decisions to adjust in terms of adding or removing capacity.

Figure 3.17: A Depiction of S-Curve. Market Share vs Frequency Share Adapted From (The Global Airline Industry, 2009)



There are different views towards the S-curve phenomenon. According to O'Connor (2001), although the S-curve approach seems to be an argument against removal of entry controls, as new entrants would "overschedule in an effort to win an adequate share of the market, while the established carriers would retaliate by expanding their schedules further". Opponents of the theory would argue that a carrier losing money because of insufficient market share and thus "flying too many empty seats will seek to correct the problem by further expanding the number of seats it is offering". Although there are various applications of the S-curve in the literature, as the work of Cheung (2004) demonstrates, market dynamics facilitated primarily by the LCCs can shape the strategy of airlines incompatible with the S-curve theory. Not all observations accept the existence of the S-curve relationship (Holloway, 2008). For example, relatively smaller competitors with a strong brand and value proposition may be able to retain a market share premium.

Capacity abundance cannot be argued to be the sole factor shaping consumer choice. Market share at O&D or airport level can be discussed through the impact of many other parameters on top of capacity and frequency supply. According to Goedeking (2010), after the analysis of the S-curve effect for 4,300 global and randomly selected O&Ds, the effect is argued to be so weak that it does not qualify as a strategic lever. In their book "Jumping the S-Curve" (2011), Nunes and Breene describe the phenomenon of "the bigger, the better" as a legend since no correlation is found between a company's relative size in an industry and business performance. They discuss that industry-leading scale is not a requirement for high performance.

Given such impairment and potential lack of justification with the general rule of thumb, as in the case of the S-curve model, there is a real need for airlines to concretely and objectively define the metrics and quantify the convenience of their product with a competitive benchmark. This process is utterly complicated as airlines have multiple numbers of products between several O&Ds and its products' schedule driven attraction can differ on different routes. If an airline is flying to n destinations from a single origin and the carrier has a PP network strategy, the number of potential indexes the airline has is in the complexity of $O(n)$. On the other extreme, if the airline connects each of its destinations via HS network strategy, the carrier has to deal with $O(n^2)$ different convenience indexes for each O&D pairs. Additionally, it is also a challenging task to set up a product convenience consistency index for all O&D pairs. Due to the vast number of product valuations, which needs to be consistent with each other, a model that is widely accepted in the airline industry to valuate products was necessary. Such a global approach would create a standardised platform to benchmark products among competing airlines.

Serving these purposes, the Quality Service Index (referred to as QSI) has become a norm in the airline industry. The QSI method provides an option to somewhat benchmark the service level of different flight options by quantifying consumer behaviour. Although there are multiple ways of computing a service index, the general practice in the industry is to employ QSI to assess the schedule related attraction. According to Intervistas report (2012), QSI is a powerful tool to forecast expected market share in the industry as it predicts consumer behaviour by quantifying the relative attractiveness of different flight options. It can assist airlines in answering questions regarding expected passenger flow, their contribution to route profitability and market share. Simultaneously, QSI can be employed to evaluate changes in quality of air service over time and against other airports. QSI models, introduced by the U.S. institutions in 1957 in the era of airline regulation associate an O&D's passenger share to its "quality" (Civil Aeronautics Board, 1970), where it is defined as a function of various itinerary service attributes and their corresponding preference weights.

The QSI computation process starts with the determination of parameters that are influential in consumer's choice, continues with assigning coefficients to each factor to generate the QSI score and completes by comparing the score of other flight alternatives (Weatherhill, 2008). The parameters that are often used during QSI calculation are weekly frequency, seat capacity - aircraft type, day/time of the flight and total journey time. There exists software that enables airlines to automatically generate QSI scores for each airline for different O&D pairs. Thus, the present QSI calculation methodology is strictly mathematical with the inputs provided to the computation are unprocessed figures obtained directly from airline schedules. The coefficients that are appointed to decision factors are mathematical too. The QSI of flight x can be formulated with the following equation where n is the number of factors associated, α's are the preference coefficients while X denotes the independent variables.

$$QSI(x) = \alpha_1 X_1 + \alpha_2 X_2 + \dots + \alpha_n X_n = \sum_n \alpha_n X_n$$

where $\sum_1^n \alpha = 1$.

The market share expectation of a flight y can then be expressed as;

$$E_y = \frac{QSI\ (y)}{\sum_{t\,\in T} QSI\ (t)}$$

where t represents the total number of competing airlines present in the O&D route of flight y. The inputs denoted by X_1 to X_n are obtained through the schedules of the airlines and are purely related to capacity. Whilst, for instance, daily availability of the flight y can be a factor for QSI computation, non-schedule related factors such as seat comfort or airline brand cannot be included in this methodology.

There are critics towards the traditional QSI computation model. Such methodological deficiencies can lead to fallacies in market share expectations that QSI generate. The arguments regarding the insufficiency of the current QSI method can be grouped into methodological and parameter related concerns. From the methodology point of view, Jacobs et al. (2012) stress two fundamental theoretical problems regarding the QSI. The first concern relates to the independent determination of coefficients α from others in the model, inhibiting observation of the interaction between factors. The second methodological issue stems from the fact that QSI models are not able to assess the underlying competitive dynamic that may exist among flight alternatives. Parameter related inability of the QSI method sources from the fact that the classic static mathematical approach is not able to catch the decision-making algorithm of the passengers due to several reasons. The listed parameters X may not entirely compose the whole factors that impact the decision of passengers. The value that a passenger might attach to a parameter can significantly differ from one passenger to another. Different passenger segments may have different needs and priorities that they seek the best alternative during the decision-making process. Adopting a global static method, in this case, would not result in the most refined outputs.

The Transportation Research Board's report on Aviation Demand Forecasting (2002) suggests that QSI's focus is centred on capacity. However, the volume of capacity cannot be the sole factor affecting an airline's realistic market share. In addition to the number of seats provided by schedulers trying to fit the demand, the quality of the supplied capacity is relevant for realistic market share estimation too. For Clark (2012), it is essential to calibrate QSI calculation with historical data employing exponents. He argues that although simple QSI methods remain attractive due to their transparency and ease of use, more sophisticated approaches such as the logit model, which is a popular probabilistic model representing the discrete band of consumer choice behaviour, would provide better predictions.

Cost is a major driver of success for each profit-oriented organisation. For Koester (2009), retaining an advantageous unit cost structure is a source of competitive advantage for firms. For him, a lower unit cost of sale figure differentiates the company and influential in bringing in a higher market share. A lower cost structure scheme can raise market share as long as the advantage is reflected to passengers. This is indeed the major philosophy behind the success of the LCC model. The QSI that is solely built on the capacity model would not be capable of apprehending cost related drivers. As a theoretical example, the total cost of transporting a passenger from City *A* to City *B* directly for Airline X can be lower for Airline Y via City C, if the following equation holds true:

$$CASM_{ABx}\ x\ m_{AB} > (CASM_{ACy}\ x\ m_{AC}) + \ (CASM_{CBy}\ x\ m_{CB})$$

where $CASM_{ijt}$ is the cost per available seat mile for airline t and m_{ij} is the mileage between *i* and *j*. The above inequality can hold true if the cost structure of Airline *Y* is more advantageous than Airline *X*. Furthermore, airline *Y* can operate large aircraft compared to Airline *X* with the higher number of seats enabling them to reduce the cost of seat per mile significantly (Duetsch, 2002). Therefore, it is probable that price sensitive passengers may prefer to take a connecting flight option via City *C*, rather than an existent point-to-point service between *A* and *B*. A static capacity perspective favouring direct flights in the QSI model may not fully reflect the market dynamics.

Therefore, parameters other than capacity need to be injected into the QSI model. In this case, individual *QSI(z)* for each facet *z* is to be individually computed with their coefficient impact of μ_z. Any additional independent facets, such as the stimulation factors mentioned in the Intervistas report dated 2012, bring a new QSI calculation along which needs to be merged to compute the final QSI (A) with the weight factor μ.

$$QSI(A) = \ \sum_{z\,\in Z} \mu_z\ QSI\ (z) \ \text{ and } \sum \mu_z = 1 \text{ where}$$
$$QSI(z) = \sum_n \alpha_n z_n \ \text{ as introduced above.}$$

An example of this could be the airfares. Farkas (1996) demonstrates that yield and revenue management has a significant impact on traffic volume and mix. Although an airline might have capacity QSI, it can increase its realistic market share by reducing fares and aim to capture a higher passenger flow. Codeshare flights can be another example of a possible facet. The computation of a codeshare flight's seat contribution on overall capacity as well as the traveller's view on codeshare flights may severely influence the actual figures of a carrier's market shares.

However, although including additional parameters would extend the QSI's coverage beyond capacity, it is still subject to the abovementioned criticisms. From the theoretical perspective, on top of the subjective coefficient α, an additional bias factor μ is introduced where both coefficients compose an essential determinant of the final *QSI(A)*. Additionally, assuming sub-*QSI (z)* forming *QSI (A)* with factor μ_z would be a flawed approach without any sensitivity analysis that captures the interrelation between *QSI(z).* From the methodological perspective, the validity of each *QSI(z)* from the standpoint of consumer behaviour requires justification.

3.6. Identification of the Gaps in the Literature Review and Implications for This Research

This chapter summarised the previous studies concerning the commoditisation process of the airline industry and elaborated on different airline business models, network structures as well as their planning processes. It has discussed how the number of passengers and rivalry among airlines has intensified, especially after the deregulation era, enabling different business models and network structures to emerge. It has also seen in the previous academic studies that the available network assessment methodologies are highly technical yet severely lack the consumers' perspectives. Christoph Franz, ex-chief executive of Deutsche Lufthansa Airlines (2010) states, "The academic literature we find on network management focuses mostly on sophisticated computerised scheduling and resource allocation, but not on fundamental strategy", clearly pointing out the strategic aspect of the network concept. Consumer satisfaction is a strategical aspect of schedule attractiveness and network assessment. Therefore, this research aims to fill this gap in the literature by addressing a strategic, consumer-oriented perspective concerning schedules and the schedule convenience of the carriers. For this reason, the technical network assessment methods referred in this Chapter will not be used for determining network efficiency of the carriers.

Airline supply (the quantity) affects market dominance and economic performance. However, amid the expansion of hub and spoke networks and non-operating products, the scope of supply has changed as the volume of connecting services and codeshare flights have risen tremendously. For this reason, a re-definition of product supply incorporating the consumers' perspectives and shifting business models is essential, which serves as the 1st Objective of the research.

The literature review has also addressed the current scarce market share estimation models considered in current research. As discussed, the existing models are highly static and mathematical yet do not comply with the realities of the airline industry since passenger profiles and their preferences are changing rapidly. Having a pre-defined static market share forecast methodology hardly captures the substituting dynamics of the industry. Besides, as an outcome of the commoditisation process, more individuals have access to the air transport product than ever before, undoubtedly forming new segments of passenger profiles. From this perspective, the estimation models to be developed in this research focus on understanding passenger profiles and their varying needs. Therefore a different, consumer-centric, perspective of realistic market share estimation procedures is a goal which serves as the Objective 3 of the research. The market share estimation model to be introduced not only uses the "quantity" of consumer-centric capacity but also the perceived quality of this capacity. For this reason, the following Chapter covers consumers' preferences in their itinerary decision-making processes to develop an understanding concerning airlines schedule quality perceptions.

Chapter 4: Literature Review – Consumer Choice in Air Transport

4.1. Introduction

Chapter 3 presented an extensive literature review on the airline industry in general as well as an overview of the carriers' business models, network structures, planning processes and current market performance estimation models. Since this research aimed to develop a passenger centric methodology for analysing the schedule and network performance of air services, understanding the theoretical background on consumer preferences was essential for designing itineraries to take into account their perceived quality and impact on purchasing decisions. For this reason, this Chapter covers an extensive literature review concerning the dynamics of consumer behaviour in the airline industry. Previous studies concerning passenger attitudes and perspectives towards certain itinerary attributes were invaluable for designing passenger survey whose results formed an integral aspect of the research's methodology.

In order to remain competitive in the market, airlines should closely watch their customers' expectations and design their services accordingly. For Reilly (1996, s. 39), "*a carrier's complete commitment to gauging, evaluating and meeting customer expectations, and the extent to which that commitment permeates every personnel layer in the organisation, is universally seen as key in customer service maintenance and improvement*". Today, airlines know that to compete effectively, they must improve the experience and value they deliver to passengers. The challenge airlines face is the identification of customer requirements and the need to develop products and services to satisfy those requirements while also producing profitable returns on investment (PWC, 2015). As explained in the previous Chapter, flying used to be a luxury in earlier decades but has become a commodity demanded by a wider spectrum of society. Furthermore, the industry has multiple segments of consumers, whom have different expectations for the air travel product and varying priorities when making purchase decisions.

The following section (4.2) discusses the basic service characteristics of air transport and analyses the link between the airline performance and consumer satisfaction. Section 4.3 focuses on the customer segments in the industry and elaborates on the variations in the preferences of different segments. The final section (4.4) reviews consumer preference factors available in literature by categorical subheadings, including airline safety & security, schedule, departure & arrival time preference, on-time performance, frequency/routing & airport, codeshare flights, fare and pre-flight & onboard services.

4.2. Air Transport Product as a Service

Kotler and Keller (2012) state that service is any act or performance that can be offered by one party to another, which is intangible and does not cause any ownership. Services represent the activities offered to consumers to fulfil their needs while ensuring satisfaction. They define satisfaction as the feeling of happiness or upset of consumers that emerges after comparing the performance of services delivered with the consumers' expectations. According to Andrew (2008), service refers to the customers' total experience from the performance of the people serving while satisfying their need. Meanwhile, Yoeti (2003) suggests that service involves economic activities whose output is not a physical product and is generally consumed at that time of production, providing added value in forms such as convenience, amusement, comfort or health. Ekinci and Sirakaya (2004) find that service quality is an antecedent of customer satisfaction and therefore the evaluation of service quality leads to customer satisfaction. Their study also indicates that consumer convenience rather than service quality is a better reflection of overall attitudes; as the link between attitudes and consumer satisfaction are reciprocal.

For Wensveen (2007), the air transport product is not a physical product, but services that passengers find useful. He points out that the service provided by the airlines is customised, meaning that each passenger may perceive and experience it entirely in a different manner. Sanyal and Hissam (2016) find that service quality and passenger satisfaction has a direct impact on passenger preference; service quality and passenger satisfaction has significance for the management of airlines, as they need to focus on improving those aspects in order to increase consumer inflow. Therefore, the demand for an airline is highly impacted by the perceived quality of their service. Zeithaml et al. (1996) state that without exception, poor service in the airline industry results in a customer's change in carrier or diminished use of the unsatisfactory line.

For many industries, creating objective metrics for benchmarking perceived quality is not a challenging task as the products and services can easily be deconstructed to objective means of sub-parameters. However, the case of the airline industry is relatively complicated. The definition of the air transportation product begins with a passenger's ticket booking and itinerary selection process, continues with their experience at the airport and on board, ending with the arrival to the final destination with all the baggage properly delivered. Thus, the service that passengers receive from an airline incorporates the processes before, during and after the flight. Passengers' experiences in all these parameters are critical when making product decisions.

Understanding the attraction of their product and relative position among their competitors is a crucial process for companies. Companies can set their revenue and performance expectation upon this positioning process. From the customer viewpoint, the positioning determines the degree of quality that they perceive and are willing to pay. Buzzell and Gale (1987) urge scholars and practitioners to embrace the marketing concept by measuring market position relative to the competition by incorporating perceived product quality into their decision making processes. Therefore, determining competitive advantages, relative superiority and performance of a product are essential both for service suppliers and for the consumers. It can also be argued that an airline's market share expectations is set by their product's relative service positioning versus their competitors.

Lawrence and Ray (1994, s. 27) state that service quality is among the vital elements affecting the competitiveness of airlines. They suggest that "if the customers' experience was better than the expectation, satisfaction (and the quality) is high. If the experience was less than the expectation, satisfaction/quality is deemed to be low. If the experience equals expectation, satisfaction is average". Having examined quality related parameters in the US regional airline industry, they generated quantitative values for effectiveness based upon the Service Quality Model using a passenger survey. They argued that satisfaction could be used as a surrogate for quality-effectiveness as perceived by the consumer. They also discovered that high levels of quality suggest an increase in the carriers' effectiveness.

4.3. Consumers in the Aviation Industry

Understanding their customer portfolio is a vital process for the airlines. According to Shaw (2007), customers are not always consumers. If travellers books through direct sales channels of the airline, they can then be seen as a customer and consumer for the carrier simultaneously. However, in case the passengers go to a travel agent who arranges the reservation and booking procedures for them, then the customer would be the travel agent, and the consumer would be those travelling.

The leisure traveller segment is a significant customer for the airline industry. Leisure travel includes families with children (Bauernfeind, 2012) and their primary motivation is to take a vacation. The characteristics of leisure travellers are that they are somewhat inexperienced compared to business travellers and may therefore seek more advice. Swarbrook and Horner (2007) find that leisure travellers are extensively engaged in the information search and consult individuals or groups such as friends and family or travel agents, organisations and media reports before making a buying decision. The impact of other people during the decision-making process can also be influential.

Business travellers who fly for business purposes form a vital customer base for airlines. Shaw (2007) defines multiple decision-making mechanisms in the business traveller segment. First of all, the business travellers themselves can make the itinerary decision. If a traveller books the flight for him or herself, they may consider various product attributes in order to make a decision. This may be time-consuming for executives with limited time to consider all flight alternatives. Alternatively, the secretaries of the executives may make the travel decision on their behalf. Therefore, they can also be regarded as customers of the carriers given their influence in the itinerary selection. In addition to secretaries and other internal travel bookers within a company, Shaw (2007) refers to the contracted travel agents handling air travel for the company as they possess some or full power in itinerary decision making. Fowkes et al. (1991) suggest that the journey planning for business travel may happen in two extremes. In the first extreme, a company executive may dictate the journey selections, whereas in the other extreme the decision may be entirely made by the travelling individual. They argue that it is unlikely that the actual decision-making mechanism will be at the extreme points. It is expected that the company may enable employees some level of autonomy in their choices, bounded by the organisation's travel policy.

There are other customer segments in the airline industry, each with different purposes of travelling and distinct evaluation and purchase approaches. For instance, budget-conscious air travellers such as students tend to be more infrequent consumers, who perceive little difference between airlines, whereas business travellers are usually price-insensitive and loyal to a brand (Market Segmentation Study Guide, 2018). Passengers may also travel to visit relatives and friends, abbreviated as the “VFR” segment. Although VFR and leisure segment can be considered to depict similar characteristics, VFR traffic is usually directed to the same route where relatives are located while leisure traffic can be routed to anywhere.

Shaw and Wright (1967) suggest that existing beliefs and perceptions about an object or product determines the future beliefs that are formed. In practice, a passenger who has previously experienced positive and good service by a carrier may be more inclined to book with the same airline. Festinger (1957) cited in Edwards (2011) mentions the cognitive dissonance theory in which conflict is thought to exists between three related cognitions (thoughts, beliefs and attitudes). To illustrate, if a consumer is strongly opposed to the business ethics of the LCC, but when booking a flight the only airline operating to the desired destination is the LCC airline that they dislike, dissonance may occur. The size and tension that cognitive dissonance procedures will be intrinsically linked to the importance that the individual attaches to it.

4.4. Parameters Influencing Consumers Itinerary Choice

Customers hold both explicit and implicit performance expectations for attributes, features, and benefits of the products. Explicit expectations are mental targets which are quantifiable and measurable whereas implicit expectations refer to established norms of performance, including comparisons and benchmarks to other product alternatives (Qualitrics, 2018). Indeed there are various parameters of choice for air travellers when making their itinerary selections. In Adler et al.'s study (2005), the application of a mixed logit approach using stated – preference survey data to produce the development of itinerary choice model is described in which the effects of itinerary choice of airline, airport, aircraft type, fare, access time, flight time, scheduled arrival time and on time performance is analysed. Their study shows that all service features included in the model has significant values to travellers. The research also suggests that current reservation and ticketing services provide information to prospective travellers on most of these itinerary features, excluding on-time-performance. Indeed today's passengers are well informed and can easily assess information on whether a product alternative meets both their explicit and implicit expectations. The choice passengers make depends on the attractiveness of available alternatives. Attractiveness is often expressed in consumer utility functions, where variables such as fare, frequency, travel times, loyalty etc. are weighted (Veldhuis, 1997). Adli et al. (2005) identifies four non-schedule related categories, including tangibility, reliability, responsiveness and assurance, of which reliability is found to be the most critical. The following sections present a detailed literature review for each major parameter feature of consumers' itinerary choice.

4.4.1. Consumers' Schedule & Time of Day Travel Preference

The schedule is among the most critical factors of choice for air travellers. This nonphysical parameter is vital as it determines not only the day and time of the flights but also the connectivity between the origin and destination, thus shaping the overall convenience for consumers. In addition to experiences before, during and after the flight, passengers are willing to choose the flight that best meets their work or travel schedules at the best price. In his work, Carrier (2003) found in his simulations that passengers are reluctant to travel on schedule – inconvenient paths, and are ready to pay a higher fare in order to travel on a more convenient frame. According to the study of Professor Wessels at Wharton University (2006), air travellers identified scheduling convenience and loyalty programs as the most important parameters in selecting an airline. Business travellers have always been asserted as one of the most schedule sensitive segment of air travellers. According to his study, even for the business traveller segment, the ability to upgrade, quality of meals and availability of first class does not matter as much as price, safety and scheduling convenience. It is also an inevitable fact that due the commoditisation process of the air transportation and subsequent rise with the flight availability and alternatives, the importance of schedule convenience in the decision-making process of the consumers is growing for all traveller segments. Even LCCs charge a higher fare for convenient flights. Thus, the convenience of flight is charged by the airlines and paid by the travellers. According to the report of UK’s Civil Aviation Authority on consumer research (2015), which conducted an extensive survey to understand consumer choice with the air travel product, the specific airline or holiday company emerged as the lowest priority overall when choosing a flight. The report suggests “flight schedule” or route to be more important than the airline/holiday company. 47% of the survey participants reported flight schedule as a crucial factor of choice while this figure was reported as 29% for the airline company.

Aircraft type is an element of an airline’s schedule and hence a parameter of choice in consumers’ decision-making process. The aircraft model, along with its amenities including seat type, legroom, in-flight entertainment systems, etc., have a definite effect on consumers’ flight convenience. De Looze et al. (2003) discuss a direct link between seat comfort and emotions. Given that aircraft passengers spend the majority of t_{flight} seated, it could be assumed that passenger comfort may also be related to emotions. Helander and Zhang (1997) show that users perceived seat comfort with factors such as aesthetics, relief, wellbeing and relaxation, while discomfort is related to fatigue, restlessness, pain and stress. Vink et al. (2012) identified factors contributing to passenger comfort and determined their importance based on Internet reports of more than 10,000 passengers in which the overall comfort scores were obtained and correlated with many factors pertaining to both the airport and aircraft experience mentioned in the trip descriptions. The results demonstrated higher correlations to two physical factors, namely legroom and seat comfort. The study also showed positive correlation of comfort with the age of aircraft, flight class and In-Flight Entertainment systems.

An itinerary's departure time from the origin and the arrival time to the destination constitutes the basic metrics of the schedule factor. The timing of the flight affects not only consumers' utilisation of the day but also the costs of travelling. For instance, a passenger may need to spend one more night in a hotel and pay extra for accommodation due to an inconvenient flight itinerary. According to Boeing research on passenger behaviour, passengers do not have a single ideal departure time; they do have a decision window which represents the time frame that the traveller considers convenient for their journey. The decision window is determined by the earliest convenient departure time and latest appropriate arrival time. Flights that are scheduled within the boundaries of the decision window are equivalent for the passengers (Boeing Airline Company, 1997). Keumi and Murakami (2012) find that the service level of access modes such as travel time, travel cost, waiting time and delay cost affects passenger's modal choice. They find that a traveller's willingness to pay to save time differs by time of day. Passengers tend to pay more in the morning time than in the afternoon. They argue that considering a traveller's willingness to pay for saving time; it would not be suitable to set the same price for flights at different times even if they have the same service attributes.

Mehndiratta (1996) investigates the effect of time of day preferences on the planning of business trips in US domestic journeys. The study involves an experimental/qualitative survey of a group of ten San Francisco-based executives' business trips. It was found through the interviews with these frequent travellers that there is always a flight that fulfils their travel schedule expectations, even in markets with limited flight options. This finding implies that business travellers are ready to adapt their journey plans to the itineraries offered by airlines, supporting the assumption that air travellers do not possess a single specific ideal schedule but rather a range of preferred travel times.

Fowkes et al. (1991) found that 95% of individuals prefer to travel by air over alternatives modes of transportation due to air travel's comparatively shorter journey times, which is still the case today. From this perspective, trip or journey time needs to be computed from the "true" origin to the "true" destination covering the flight times and the connection time at the hub airport, if the journey is a connecting one. On top of the actual t_{flight} plus t_{conn}

which yields to t_{total}, Simpson et al. (1992) introduce fixed and schedule displacement times to compute the overall trip time as expressed below:

$$T = t\ (fixed) + \ t_{total} + \ t\ (schedule\ displacement)$$

The fixed time, *t(fixed)*, includes entry and exit times to/from airports at the origin and destination. These times are not likely to change in the short term and also include airport-processing times. t_{total} , which is explained in Chapter 2, covers the block time plus the connection time at a hub. Block time refers to the time between the scheduled gate departure and arrival times for a flight and thus includes the pushback and taxi time. The schedule displacement time, *t(schedule displacement)*, is the time between a passenger's desired departure time and actual available flight time. This concept is associated with the fact that there is not likely to be a flight exactly at the time each passenger is ready to depart. For instance, if the passengers would like to leave for their destination at 12:00, and there are two flight alternatives at 11:00 and 14:30, the schedule displacement time for them would be either 1 or 2.5 hours depending on their preference. Simpson et al. (1992) assesses the schedule displacement time as;

$$t\ (schedule\ displacement) = \frac{K}{f}$$

where K is a constant expressed in hours divided by frequency, implying that the schedule displacement time would reduce as the number of frequencies and flight alternatives ascend in the market.

For Mackie et al. (2001, s. 94), if passengers diminish t_{total}, a change in the utility function is provoked because other more pleasurable or useful activities can be undertaken. "When substituting travel time, the individual will increase only the time assigned to those alternative activities which are not constrained at a minimum necessary or work." A report by Accent/Hague (1999) suggests that for the UK, the income elasticity of travel time saving is calculated as 0.5. For Stigler (1987), as GDP per capita rises, wage rates are likely to increase faster with fewer hours being worked. This implies that individuals are expected to use the time saved from journeys more for work than for leisure time. In other words, a longer journey time creates a cost for passengers given the fewer hours being worked.

According to Veldhuis et al (2002) several schedule related connection parameters are evident in their utility function such as t_{conn} and the routing factor. Routing factor *(rf)* for a journey from City A to City B is calculated as $\frac{t_{connecting\ ACB}}{t_{directAB}}$ where $t_{connecting\ ACB}$ refers to the total flight time of a connecting journey from A to B via C, whereas $t_{directAB}$ symbolises the duration of a direct flight between A and B. For Bootsma (1997), the maximum routing factor is typically 1.25 and the maximum rf excludes the backtracking routes like New York – Moscow – Chicago.

According to Theis et al.'s report (2006), network airlines traditionally attempt to minimise passenger connecting times at hub airports based on the assumption that passengers prefer minimum scheduled elapsed time for their trips. The report emphasises that the importance of t_{total} be historically attributed to three factors: The screen position of an itinerary in Global Distribution Systems (GDS), the decision window model and the passenger preferences regarding trip length and connections. Based on the ranking in the GDS and the fact that around 80% of all bookings are made from the first screen (and no fewer than 50% from the first line), many airlines feel elapsed time is essential in passenger choice. The second factor refers to the decision window of Boeing described earlier. The third rationale is the hypothesis that passengers prefer relatively shorter t_{total}. According to the report, prefer shorter connections and discount longer connections. Another study by Van Eggermond et al. (2007) finds that passengers staying at their destination only for a short period prefer itineraries both leaving and returning in the morning. Furthermore, the report also quotes that "departing in the morning is preferred by all types of passengers. Seen in the light of passenger preferences for a certain departure time and the high number of observations of passengers staying at their destination for a short period of time, this is reasonable" (Eggermond, Schuessler, & Axhausen, 2007, s. 17). They also suggest that a more convenient departure and arrival time have higher monetary values from a consumer's perspective. In Chapter 2, the departure and arrival time quality perceptions were parametrised through q_{dep} and q_{arr} respectively.

4.4.2. Consumers' Frequency, Routing & Airport Preference

According to Dixit and Stiglitz (1977), consumers demonstrate demand patterns that are increasing in the levels of variety offered. In the aviation market, passengers prefer higher frequency because such choices reduce potential delay (Douglas & Miller, 1974). Additionally, the availability of alternative frequencies increases the likelihood for consumers to choose from a wider spectrum of products. In the study of Ippolito (1981), it is demonstrated that passengers' utility increases in frequency which are also corroborated by the work of Adler and Hanany (2015), suggesting that a higher number of frequencies increases passenger utility as more preference options are presented to consumers.

The routing of the itinerary is a definite factor of choice for passengers, especially in an environment where multiple alternatives compete. The routing of the itinerary constitutes the overall t_{total} for travellers. Passengers appreciate direct routings as it significantly reduces the journey time. Naitho (2014) justifies this by contrasting consumers' utility functions for direct and connecting services, in which non-stop flights entail the utmost convenience. Having implemented a survey to consumers, Flightview in its report (2005) suggests that today's travellers report a willingness to pay more for convenience. Their survey finds that more than 75% of consumers regularly experience difficulty in finding direct flights to their desired destination from their local airport, "and the majority of those surveyed are willing to reach deeper into their pockets". According to the study, 70% of the travellers surveyed said they would be willing to pay even more for a direct flight from their local airport. Of that 70%, more than two-thirds would be willing to pay 10-15% more, with nearly a third willing to pay an additional 16% or higher. According to the report, there is also a segment which is ready to pay more than 30% for a more convenient routing. The US Government Accountability Office argues in its report (2004) that in case a market has non-stop service, this would be considered the best level of service. However, one-stop connecting services may also be a competitive alternative to non-stop in some markets.

Since connecting journeys incur the risk of misconnection and baggage loss, direct flights reduce passengers' perceived risk (Veldhuis, 1997). The report of van Eggermond et al. (2007) suggests that journey time and the number of transfers from origin to destination is a determinant of passengers' decision-making process, implying that connecting journeys have a negative effect on extending t_{total}. Moreover, the study also finds that for connecting itineraries, the t_{conn} is another critical factor of decision making. Furthermore, the detour factor (df) is another vital element of consumer satisfaction. As the df increases, the passenger travels a longer distance, and the itinerary's attractiveness diminishes. The study of Sismanidou et al. (2013) finds that passengers travelling on a smaller detoured route are less sensitive to t_{conn} with higher detour factor as they gain from total flight time.

The departure and arrival airports forms the basis of itinerary selection and therefore constitutes an integral aspect of the consumers' routing preference. For Ashford et al. (1976), airport facilities are an important element of passenger convenience as they highly impacts consumers' journey experience. They point out that the facilities of the airports may lead passengers facing delays, with procedures marking a deterioration in the overall travel experience. The study focuses on the criticalness of airport infrastructures, especially for connecting passengers who may suffer when interchanging their flights. Indeed, competition is fierce not only among the airlines but also among airports as they aim to attract passengers to maximise their revenues. For Graham (2013), airline choice was considered to be limited to particular airports because of governmental bilateral agreements; while this may still be true in few markets, there are now many opportunities for airports to compete for passengers, freight and airlines. According to Pestana and Dieke (2007), the deregulation and liberalisation of the airline industry have increased competition between airports sharing or competing in the same catchment area. The surge in demand has congested airports, resulting in slots becoming an important element of an airline’s network design. Airlines cannot always plan their flights in their desired airport and time of the day due to the slot limitations at airports. Capacity constraints at one airport cause spill-over effects and thus influence air travel demand served at other airports (Gelhausen, 2011). Furthermore, Bonzio (1996) shows that travel time to the airport plays a significant role, and that access time was more important for business passengers than for leisure travellers. Pels et al. (2001) analyses the combined choice of airport and airline, and find that airline choice is nested within airport choice, i.e. the competition between airlines departing from the same airport is more severe than between airlines departing from different airports.

The study of consumers' airport choice has long been of interest to researchers. It is generally agreed that access time and flight frequency are dominant factors explaining airport demand (Escobari, 2017). The study of Hess (2010) suggests that all else being equal, respondents prefer larger to smaller airports, with a preference for the airport closest to their home. It is inferred from this finding that even though respondents associate a higher likelihood of delay and other sorts of inconveniences with larger airports; they believe that if things go wrong, the backup options are wider and superior at the large airports in comparison to the smaller ones. Several factors, most notably flight frequency and in-vehicle access time, have a significant overall impact on airports’ attractiveness, airline and access mode transportation, while parameters such as fare and aircraft size have a considerable effect only in some population segments (Hess & Polak, 2006).

The proximity of an alternative airport can represent an appropriate choice should it offer a substitutable service. In order to assess this substitution, Frontier Economics referred to in IATA report (2013) carried out an empirical assessment to investigate how likely passengers are likely to choose an airport over the alternative substitute, and the role that relative prices play in influencing the itinerary selection decision. It is found in the study that passengers' preference to travel from their local airport is very strong. The study alleges that for every 1% increase in distance, the likelihood in passengers flying from their local airport declines by 4%. When it comes to price, the research argues that "for every 1% increase in distance, a 1% change in relative prices would be needed to persuade passengers to travel to the more distant airport."

4.4.3. Consumers' Codeshare Flight Preference

The literature discussing codeshare operations does not agree on a single perspective. The positive aspect of such agreements from the travellers' perspective is that they are not required to contact the operating carrier to handle their flight related processes, such as booking, ticketing, baggage transferring, post-flight services, etc. Additionally, travellers can earn loyalty program credits at their preferred operating airline even though a different carrier operates the journey. For Herdem (2017), there are several benefits of codeshare agreements for consumers. Coordinated schedules for easier connections, the ability to check on baggage and to obtain the boarding pass to final destination are among some benefits of codeshare agreements. Furthermore, wider international networks and easier methods to access those destinations, in addition to both the operating and marketing carriers' resources to deal in case of operational disruptions, can be counted as other major benefits of the codeshare flights.

Contrary to the above mentioned positive approaches towards the codeshare flights, there are opposite views too. In non-operating services, when expecting to travel with their preferred airline, a passenger may be obliged to travel with another carrier. This surprise is very probable as the marketing carriers display their designation in reservation systems, given a flight carrying a familiar airline code sells better than a flight carrying unfamiliar code (Goedeking, 2010). McCartney from the Wall Street Journal (2018) argues that codesharing is becoming more frustrating in many cases. The disconnects between connecting airlines have become more complicated as airlines unbundle services and create fees for things that were previously included in tickets, such as checked baggage and seat assignments. Back passing in codeshare operations is harder to manage in case of service failures with the operating airline. The European Commission Directorate General for Competition (2007) report finds that airline code-shares in general exhibit results that are overtly-competitive. According to the report, in many cases, routes with codeshare contracts have shown increasing capacity and decreasing fares, although the evidence appears to suggests that in some cases, code-share partners on parallel operated routes do not compete as much as occurs on similar routes lacking such arrangements.

Different customer segments may have varying attitudes towards non-operating services. For instance, whilst leisure passengers in markets with sufficient demand do not prefer codeshare agreements, business passengers do prefer competitive or bilateral codeshare agreements (Adler & Hanany, 2015). The study of Goh and Uncles (2002) indicates that some passengers have misconceptions concerning the ‘code-sharing’ mechanism that is commonly used by airlines. In their study, a survey was implemented to passengers in which 36% of the respondents had the mistaken belief that code-sharing meant that consumers had a better chance of flying on planes owned by their preferred airlines. Since perceptions influence consumers' expectations, it is essential to consider such misconceptions concerning codeshare operations. The brand image of an airline may be damaged if consumers are unknowingly placed on aircraft operated by alliance partners instead of their preferred airline and if standards of service among code-sharing airlines are variable (Driver, 1999). Therefore, marketing carriers should be transparent during the ticketing process and disclose the operating airline. Furthermore, they should also monitor the service offered by the operating carriers to avoid any inconvenience that may arise due to the mismatch between their customers expectations and the service delivered on the codeshare journey.

There are conflicting findings in the literature concerning the fare of codeshare flights. For example, Szakal (2013) argues that fares between the regional airport and the hub airport are often high, but an interline ticket to the final destination is normally considerably cheaper than the sum of the two local fares. However, there are studies in the literature arguing the opposite, demonstrating that the marketing carriers may charge higher prices than the operating airlines within a codeshare agreement scheme. For instance, Alderighi et al. (2004) use data on flights between the UK and European airports to study the effects of codeshare agreements on the time profile of airfares. They find that code-sharing is associated with higher fares, especially for early bookers. They also report higher fares by the marketing carriers. According to the study of Gilo and Simonelli (2014), marketing carriers involved in code sharing charge 4 per cent more than the fares set by their code-sharing partner and almost 10 per cent higher than other airlines in the same market as the marketing carriers need to generate a profit from the itinerary.

4.4.4. Fare's Impact on Consumer Choice

The fare is a key parameter for consumers when making travel decisions, as it refers to an indication of the value of air transport product. Consumers determine a willingness to pay value for each product available for sale, which is defined as the maximum amount of money they are willing to spend for their preferred brand product over other comparable brands (Cameron & James, 1987). Customers agree to pay more for a better service, which maximises their utility. That is, when consumers have a higher perceived value in relation to the cost of the product, they are willing to pay a relatively high price (Miao & Mattila, 2007). The study of Balcombe et al. (2009) reveals that in principle passengers are willing to pay a relatively large amount for an enhanced service quality. Compared to short haul flights, consumers may be ready to pay higher for enhanced service for long-haul flights. Therefore, the quality perception of the product is a determinant of the willingness to pay value. The study of Juan Carlos Martín et al. (2008) observes the willingness of customers to pay for airline service quality and estimate valuations of some service-quality attributes in an airline choice context using stated preferences methods. They find that different characteristics of the service are associated with the varying values of the service.

The existence of different customer segments having different needs and expectations from the air transport product enables the avoidance of full price competition in the market for the airline industry. Airlines intend to set the optimum product and price match for their target segments, maximising their profitability with the most appropriate product/fare positioning by correctly addressing the willingness to pay value of their customers. Lohmeier and Hess (2009) suggest that airlines should set their fare structures by analysing the market in addition to the demand of their relevant customer segments and their cost structure.

Different customer segments may have different attitudes towards airfares. On one extreme, the fare could be the sole factor of choice, especially for budget constrained travellers, whereas in the other extreme, for business travellers with no or minimal budget constraints, price may rank as the least important factor over others in the decision making process. The study of Henderson (2016) finds fare to be the most important and influential criteria for a consumer segment composed of international students in New Zealand when making the itinerary decision, followed by stopovers, flight schedule and baggage allowance. The students refer to a budget-constrained segment, therefore their fare prioritisation is within the limits of expectations. Price is the most important factor for price-sensitive passengers to choose LCCs too. As discussed in the study of Rajasekar and Fouts (2009), fare advantage is considered to be one of the strengths of LCCs over FSCs. The study of Federco and Hospodka (2018) argues that airlines should offer "better" products with higher prices in markets where business traveller segments dominate, indicating that quality of the product is a more important factor of choice than the fare for business travellers. The demand for business travellers is relatively inelastic, therefore enabling airlines to charge business travellers higher prices (Driver, Developments in Airline Marketing Practice, 1999). While the LCCs target primarily the budget constrained consumers, the FSCs address consumers prioritising service quality-related attributes.

Carrier (2006) argues that previous studies have not included fare and schedule convenience on a detailed level, which ultimately influences passenger choice and sees as a potential application area in pricing policy and revenue management. He suggests that heterogeneity of the behaviour is primarily driven by the underlying fare structure of the air transport product. Later studies have demonstrated that schedule convenience and fare quotations are correlated to the extent that schedule related parameters can even drive the demand. For instance, Escobari (2017) finds that the relatively low cross-price elasticities at the departure time level suggest that higher prices during peak times aimed at solving congestion problems are more likely to reduce the overall demand for travel than to shift passengers to less congested periods. As per Eggermond (2007), the fare is recognised as a dimension of individuals' itinerary decision making and finds that travellers have different sensitivity for fare over time and per duration of stay.

With the recent enhancements in aviation in terms of technology, comparison-shopping allowed airline offerings to be benchmarked, enabling consumers to select the most appropriate product for their need which fits their budget constraints. The improvement in distribution channels gave consumers the opportunity to find lower cost alternatives, including LCCs and new entrants, and to make trade-offs between service and price (GRA Incorporated, 2017). The internet is ideal for the tourism industry due to the characterisation of its products (McCole, 2002). Morrison et al. (2001) argue that consumers would rather book airline tickets online instead of through their local travel agent as they can access the details of the competing products on the internet transparently. Chen and Jang (2004) identify two distinct segments of web searchers according to use preferences: Bargain Seekers and Utilitarian. The bargain seekers represent those mainly utilising the Web as an information channel to find low-fare air tickets. This segment consists of younger individuals who have a lower income. On the other hand, the Utilitarians represent those requiring a fast transaction, better customer support and sophisticated price comparison functions. It is also discussed in their study that Utilitarian consumers are inclined to emphasise a flexible schedule when booking on the web. For Fuellhart (2003), with the spread of various web tools, consumers are armed with more information than ever to assess fare and service differences between competing airlines and airports. According to GRA Incorporated's report (2017), consumers can have a fair chance of finding the best air travel option available through neutral comparison shopping with the rise of web sales. Through the internet, the cost of assessing alternative services is diminished, and passengers can effectively compare each competing airline's itinerary.

4.4.5. On-Time Performance Parameter's Effect on Consumer Choice

An airline's on-time performance refers to the carrier's adherence to their published schedule or timetable. Surovitskikh and Lubbe (2008) identify on-time performance as one of the critical factors of choice for consumers, finding that on-time performance forms a crucial aspect of an airline's consistency of service. As schedule convenience is a factor of choice for consumers, any divergence from the preferred schedule is a matter of dissatisfaction. Strydom et al. (2000) indicate that "punctual flights" are an essential feature of air travel. The study of Suzuki (2000) reveals that once experiencing flight delays, passengers are more likely to switch airlines. As per the Nextor report (2010), in case of delay, passengers see increases in the time required for travel, experience inconvenience and stress, and may face additional expenses for food and lodging. The costs to passengers can be in the form of added expense on top of decreased convenience and additional misery. Douglas and Miller (1974) define the schedule delay (SD) parameter as the travellers' preferred arrival time and actual arrival time. SD is described as a cost for passengers. For Proussaloglou and Koppelman (1999), business travellers are more sensitive to SD than leisure travellers. They find that SD has a greater value for business travellers. In their study covering personal travels, not limited to air travel only, Bates et al. (2001) argue that punctuality is indeed highly valued by travellers. Therefore inadequate levels of on-time performance may affect an airline's market share due to negative passengers' experience.

There is a strong correlation between airline schedules and on-time performance. For instance, in order to adhere to scheduled arrival times, some airlines add time to their flight schedules to improve on-time performance at the expense of aircraft utilisation. Besides, while some airlines adjust schedules to be as short as possible while still allowing the flights to arrive on time, some others try to improve on-time performance by shifting frequently late flights to less-congested time slots, streamlining baggage handling, and reducing the time required to fuel and prepare their aircraft (US General Accounting Office, 1990).

On-time performance also constitutes an airline's brand image from the consumers' standpoint. According to a survey conducted in the US in 2015, 75% of the respondents identified on-time performance as an essential factor in airline brand perception (Statista, 2018). Since passengers cannot foresee if the flight would be delayed or not when selecting their itinerary, consumers would tend to base their decision regarding on-time performance in accordance to the brand perception of the competing airline fed by their previous experiences.

While delays are a key source of inconvenience, cancellation of the scheduled services is another severely disruptive experience. For many passengers, waiting at the airport when the flight has been delayed or cancelled is a negative experience as they often do not know how long they will have to wait for the service recovery (Wong, McCain, & Liu, 2015). In case of cancellations, passengers are required to make a new journey plan and adjust their programs accordingly. Therefore, cancellations cause significant dissatisfaction for the consumers and carriers to show the utmost care to avoid such inconveniences.

4.4.6. Consumers' Perceptions Toward Airlines' Pre & Post Flight, Onboard Services and Brand

Pre and post-flight-related factors are definite factors of choice for consumers as they affect the time spent at the airport. Since time is a scarce source, satisfying the time requirements of consumers has become increasingly crucial (Lovelock & Wirtz, 2004). The time lapse from airport entrance to flight departure in the origin airport and the time from landing to airport exit at the destination airport are significant parameters that passengers closely watch. In this context, the length of waiting time for the service can drive future behaviour by shaping overall service evaluations (Dubé-Rioux, Schmitt, & Leclerc, 1989). Longer waiting times before the flight, namely during the check-in process and boarding process has a negative influence on consumer utility. Moreover, baggage handling is amongst the leading factors of passenger satisfaction, both for departing and arriving passengers (Freivalde & Lace, 2008). Therefore, both the airline's and the airport's performance including check-in, boarding, baggage delivery, security, passport control, etc. influence the time spent at the airport and thus affect consumers' decision making. In cities with multiple airports, the divergences between airport processing times can be detrimental when preferring one itinerary over the other.

Airline customer loyalty programs are another factor of choice for the consumers. For Watterson et al. (2008) airlines found value in several characteristics of the loyalty programs including shaping customers' travel decisions through incentives of air miles and rewards. The major goals of a loyalty program are to establish and to foster customer loyalty, provide benefit to customers by rewarding their loyalty (Dorotic, Fok, Verhoef, & Bijmolt, 2011). Airlines with a loyalty program can boast a higher number of passengers carried than those that do not (Vilkaitė-Vaitonė & Papsiene, 2016).

Many carriers have personalised their both onboard and ground services especially from the viewpoint of retaining satisfied consumers and attracting the new ones. In this context, onboard catering facilities are regarded as part of airline marketing strategies to attract business or leisure passengers. As per Zahari et al.'s study (2011), airlines should not ignore the catering element but take the opportunity to create more attractive and acceptable in-flight meals as effective marketing tools in attracting passengers to re-flying with them. There are also contradicting studies in the literature arguing that catering's impact is very limited as a marketing tool. With the rise of the LCCs, passengers may not demand onboard meals should they wish to reduce their travel costs by choosing a no-frills airline. As per Jones (2007), food as a marketing tool has only a limited impact. His study refers to surveys suggesting that apart from the fare, passengers appear most concerned about safety, on-time performance, scheduling/ticketing issues, the aircraft's physical surroundings such as seat and leg comfort, efficient gate check-in and boarding. This means that while food is important, it is unlikely to be the deciding factor in a passenger's airline choice. However, for longer journeys, onboard dining can indeed be an important element of consumer choice. For Zahari et al. (2011) taste, freshness, the appearance of in-flight meals/food served and menu choices are essential for passengers, especially for the long haul flight.

The service delivery expectations of each carrier form an air traveller's perception towards the airline brand. Gronroos (1984) argues that service quality was perceived by consumers via a comparison between the perceptions of actual service and the expectations of that service. Bitner & Hubbert (1994) define the brand as a general impression made by a consumer regarding the relative inferiority or superiority of the service. Zeithaml (1988) defines brand perception as an evaluation made by consumers on the general inferiority or superiority of the service, which is affirmed by Kim (2007) who claims that brand image has significant positive effects on brand loyalty via marketing communication. Furthermore, the partnership and alliance relationships contribute to the attraction of airline brands through the benefits offered to consumers. For Dennis (2000), one of the major benefits of airline alliances to both carriers and passengers is the potential they offer to facilitate travel between an increased range of O&Ds around the world.

4.4.7. Air Transport Product Safety and Security

Airline safety and security are two different terms. While aviation safety refers to the efforts that are taken to ensure aircraft are free from factors that may lead to injury or loss, aviation security is only one component that may affect passenger safety. It is not so much related to the aircraft itself, but rather intelligence gathering, pre-boarding procedures and airport security personnel (Boeing, 2016). For some consumers, flying is a risk due to safety and security concerns. For Capafons et al. (1999), almost half of the population suffers some degree of fear of flying ranging from slight discomfort to very intense fear. According to their study, some of these people will not even fly at all. Van Gerwen et al. (2004) show that this has been an increasing trend related to terrorism and health concerns, September 11, 2001, being one of them. Ito and Lee, (2005) find evidence of an ongoing negative demand shift in air travel after the September 11 incident. The possible existence of a consumer's flight fear would not favour a specific itinerary over the other as such a fear would be linked with the risk of air travel phenomenon. However, the safety and reliability of a carrier are influential parameters for consumers, which are highly linked with service quality. Liou and Tzeng (2007) find that safety and reliability are the critical factors of service quality. Wen and Yeh (2010), on the basis of seven other studies of service quality, identify 18 factors as relevant to consumers in the airline industry, including safety.

In the markets lacking modern aircraft, safety can even be reported as the most critical factor of choice for the consumers. For instance, the study of Hamidi et al. (2013) finds that safety is the most effective parameter in the consumer decision-making process for a sample of 145 Iranian individuals. Due to the sanctions on the country, the Iranian state and airlines cannot acquire new, modern aircraft. Therefore, Iranian passengers are obliged to travel with old aircraft with obsolete technology when using their national carriers for their journey. On the other hand, due to flight rights, only national carriers can operate in the domestic market. Therefore, it is natural for Iranian consumers to prioritise safety first in their decision-making process. Analysts say air travel is vulnerable by nature because of all the moving parts and the potential weaknesses they create (ABC News, 2017). The study of Oyewole et al. also reveals that the safety record of the airlines is an overriding factor of choice (2007).

Due to enhancements in the aircraft technology and governmental regulations, significant progress has been achieved in the safety and security of air travel. According to an article in the Guardian (2014), as per the figures from the Bureau of Aircraft Accident Archives, aircraft accident rates are at a historic low despite high-profile plane crashes. Therefore, many passengers all over the globe may consider safety and security parameter for granted as there are very few injuries or fatalities recently caused by the air transport, leading consumers to be neutral with this factor in their itinerary choice. However, any unexpected incidents such as accidents, terrorist attacks or hijacking may prioritise safety and security parameter and may deem it as the most important factor of itinerary choice.

4.5 Identification of the Gaps in the Literature Review and Implications for This Research

This Chapter covered the parameters influencing consumer decision when purchasing their itineraries. Undoubtedly, the importance level of each parameter differs depending on the individual circumstances of the travellers. For certain traveller profiles, as suggested in the UK Civil Aviation Authority report (2015), familiarity with the carrier and its reputation for providing low-cost fares and excellent customer service are paramount considerations. For another segment prioritising price, getting good value is more important than accessing the cheapest fare. As a result, consumers do not have a single preference towards each parameter of choice but develop their individual stance. The report also finds that consumers appeared to be reasonably well-informed and equipped to make their air travel choices. Passengers can now better access information regarding the features of the rival products and can effectively benchmark them. In this context, the literature review chapter has provided an essential contribution to understanding the consumer expectations in the airline industry as well as its variations among different customer segments. Moreover, the review has formed an indispensable step in designing the passenger survey whose results will provide the input for the research’s methodology.

It is verified in the literature review that the airline schedule is an essential element of consumer convenience and has a significant role in consumers' itinerary choice, subsequently affecting the airlines' overall performance. However, the literature does not address the extent of these schedule-related parameters influence of on consumers' decision-making process. From the passengers' perspective, the value proposition of different flight alternatives may fluctuate depending on the type and routing of the itinerary. The below quadrant illustrates passengers' perceived utility values for different flights type and routing.

Table 4.1: Consumers' Perceived Value Parameters for Different Flight Modes.

	Operating Flight	Codeshare Flight
Direct Flight	u_{do} - the value of a direct and operating service	u_{dc} - the value of a direct and codeshare service
Connecting Flight	u_{co} - the value of a connecting and operating service	u_{cc} - the value of a connecting and codeshare service

It is found in literature that (i) $u_{do} > u_{dc}$ and $u_{co} > u_{cc}$; since an operating flight is preferred over the codeshare alternatives and (ii) $u_{do} > u_{co}$ and $u_{dc} > u_{cc}$; as a direct flight is better preferred compared to a connecting product. However, a commonly agreed relation between u_{dc} and u_{co} cannot be determined in literature to assess consumers' changing attitude between direct-codeshare vs operating connecting flight alternatives. On the other hand, although it is known that direct flights are desired over connecting ones, and online products are better chosen over codeshare alternatives, there exists limited studies justifying to what extent these propositions are true.

The passenger survey that has been designed using the information retrieved from the literature review has quantified how these parameters affect consumer choice in order to develop a robust methodology quantifying the quality of the competing itineraries in a given market, referring to Objective 2 of the research. Specifically, the concepts introduced in Chapter 2 including t_{buffer}, q_{dep}, q_{arr}, MaxCT, $t_{inconvenient}$, $\%_{inconvenient\_time}$, f_{split} had to be quantified through the passenger survey in order to fill the gap in the existing literature. In addition, the survey sought to identify relative values of u_{do}, u_{co}, u_{dc} and u_{cc} where those figures would be used as an input of REMSET, corresponding to Objective 3 of the research.

Chapter 5: Data Sources

As explained, this research aimed to develop a passenger-centric methodology to analyse the schedule and network performance of air services. In this context, Chapter 3 and 4 assessed previous research and identified the gaps in the literature to ensure the application of a credible and contemporary methodology that fulfils the research's aim. In addition to a robust theoretical basis backed by the literature review, the successful implementation of the research's proposed models relies heavily on using valid and credible data. For this reason, the data collection process was a crucial phase of the research. This Chapter covers an in-depth review of the data sources as well as their collection and verification processes.

Within the scope of the study, an extensive array of data from various resources were required. The data serves as the inputs of the proposed assessment methodologies and thus the reliability of the research directly links with the credibility of said input data. To determine a consumer-centric capacity share estimation model, which refers to Objective 1 of the study, the schedule information of the airlines and MCT figures of the airports were required. For fulfilling Objective 2, numerous research specific parameters such as t_{buffer}, q_{dep}, q_{arr}, $t_{inconvenient}$, u_{do}, u_{co}, u_{dc}, u_{cc} were needed to assess the supply quality. The REMSET model required both the supply shares and quality scores to estimate market performance accurately. Therefore, an extensive range of both primary and secondary data was needed within the scope, and the successful attainment of the research's aim and objectives rely on the validity and credibility of the data used. The research specific parameters referred to above, including the MaxCT, were obtained directly from consumers by means of a passenger survey, which is covered in the next Chapter. This Chapter focuses on the schedule, MCT and the demand data by addressing their retrieval process and elaborates on the verification methods of the data used.

5.1: Introduction to Schedule Data & Listed Airlines

Approximately four billion passengers fly with commercial airlines each year, implying at least four billion itinerary decisions are made annually by consumers. According to IATA (2018), 36.8 million flights were performed in 2017 operated by more than 1,400 airlines from approximately 4,000 airports. Therefore, the schedule data refers to a broad range of data. Although the network assessment models to be introduced in the proceeding Chapters can be applied globally to all carriers and regions of the world, this research focuses on major carriers in Europe, Middle East and Africa. As explained in Chapter 1, this regional focus ensured that the study is concentrated on international markets as a vital share of travel in Northern America and Asia Pacific is composed of domestic traffic and was therefore excluded from the scope of this research. Additionally, focusing on the selected regions enabled a narrowing down of the required set of schedule data.

In this context, major airlines in Europe, Middle East and Africa were identified and listed for the competitive analysis, whose network performance was benchmarked in the following Chapters. While selecting the airlines, it was ensured that all major FSCs, LCCs and hybrid carriers of the regions were all included in the dataset. As explained in earlier Chapters, only scheduled services are considered implying that charter flights were excluded from the scope. The selected 36 airlines and their two-lettered designators are: Aegean Airlines (A3), Aeroflot (SU), Air Berlin (AB), Air France (AF), Air Lingus (EI), Air Norwegian (DY), Alitalia (AZ), Austrian Airlines (OS), British Airways (BA), Brussels Airlines (SN), easyJet (U2), El Al Airlines (LY), Egyptair (MS), Emirates (EK), Ethiopian Airlines (ET), Etihad (EY), Finnair (AY), Germanwings (4U), Iberia (IB), KLM (KL), Lufthansa (LH), Middle East Airlines (ME), Pegasus Airlines (PC), Qatar Airways (QR), Royal Air Maroc (AT), Royal Jordanian (RJ), Ryanair (FR), SAS (SK), Saudia Airlines (SV), South African Airways (SA), Swiss (LX), TAP Portugal (TP), Tuifly (X3), Tunisair (TU), Turkish Airlines (TK), Wizzair (W6). This airline sample ensured a good mixture of regional and global carriers as well as FSCs and LCCs. U2, 4U, FR, PC, X3 and W6 are LCCs whereas AB and DY can be considered as hybrid carriers. The other remaining carriers are FSCs although their level of service may differ from one carrier to another. The listed airlines transport more than two thirds of the entire passenger flow in the region. Therefore inclusion of the schedule data for all 36 listed airlines was mandatory to run the proposed methodologies.

The REMSET model offers a tool for industry practitioners to assess schedule and network competitiveness of the airlines, which refers to Objective 4 of the research. Furthermore the research's model can be used to track airports' connectivity measures which refers to another implication of Objective 4. In order to accomplish Objective 4, historical schedule data of the selected carriers was required in order to observe the change in the research outputs (capacity share, quality scores and the realistic market share expectations) with respect to schedule changes. Therefore, the effect of the airline schedule related investments and initiatives, to enhance and widen their services, was quantitatively assessed through the employment of a research model using historical data in order to observe any changes from the research outputs. For this reason, obtaining historical schedule data of the selected 36 airlines was obligatory.

In addition to airlines' historical schedule information, data concerning airports' MCT figures was also essential as the MCT is an aspect of schedule data which is influential in determining not only possible connections but also their schedule quality.

5.2: Schedule Data Resources

Before the development of online platforms, it was common for carriers to print their schedules as handbooks. Passengers and travel agencies used these publications to check an airline’s timetable. Any passenger intending to purchase a ticket had to book directly with the airline or through an agency that had access to the airline’s inventory. With the rise of electronic ticketing and online sales, airlines began to post their timetables on several digital platforms. These platforms provide both a sales channel for the carriers and a vitrine to display their timetables. Through a GDS, carriers have the opportunity to reach end consumers. Subscriber agents can make bookings on an airline through GDSs by accessing their flight database. Therefore, agencies, passengers and other external parties have the opportunity to easily access airline schedule information.

Analytics and information management companies utilise the published schedule information for their data delivery services sourced from the GDS platforms. In this context, the Official Airline Guide (OAG) appears as a credible data source. “OAG provides aviation information and analytical services sourced from its proprietary airline schedules holding the current, future and historical database of more than 900 carriers and 4000 airports. On the other hand, OAG supplies flight information to the GDS, e-portal and hosts airline reservation systems” (OAG, 2014). Directly linking to the airlines’ flight database, OAG provides correct and consistent schedule information, which is also used by airline network planners to analyse a competitor’s services on certain O&Ds. As OAG links with the inventories of the airlines and obtains the information directly from the carriers' system, the data provided by the OAG system can be regarded as “secondary data”. OAG also contains the airport information including the MCT.

For this reason, the listed airlines’ schedule information is obtained from OAG data in this research. Only historical schedule data is retrieved from the OAG database as future timetables are live information with the possibility to change as airlines update their schedules. Therefore, although some airlines publish their schedule information and start selling tickets well in advance, only past schedule data from 2004 to 2016 was used throughout the research to ensure a fair and complete analysis. Having 13 consecutive years' schedule data ensured an adequate and satisfactory volume to observe the effect of capacity changes on the research outputs.

An airline's schedule data is not identical for each week of the year. An airline may increase, reduce or cancel some services to a certain destination within a year. In practice, airlines have two scheduling terms: summer and winter. The summer term continues during the Daylight-saving time commencing in the last week of March and ending in late October. Within each scheduling term, an airline's timetable is constructed on a weekly basis and repeated for the following weeks with minor variations within the weeks. It is therefore critical to determine which schedule term and specific week is referred to when discussing the schedule of a carrier for a specified year. It was mandatory to get a weekly snapshot of schedules which well represented the airline's yearly schedule. Since in summer schedules, airlines usually offer higher capacity and utilise their resources effectively to accommodate surging demand, selecting the representative week from the summer season would be a realistic approach. Although the weekly divergences with the schedules during the terms are usually limited, exceptions can be observed due to the launch of a new route or frequency increase to a certain destination. Moreover, actions such as the removal of a route from the network or deletion of certain frequencies can be the other reasons of the schedule changes within the weeks of the scheduling term. Additionally, codeshare agreements may become effective during the mid-scheduling term. Due to commercial reasons, it is to the benefit of airlines to make such timetable changes early in the scheduling term to ensure full availability of their products during the term. As a result, when selecting a representative week in the schedule term, the selection of very early or very late phases of the summer season was avoided. In this context, the weeks of April, May as well as September and October were avoided. On the other hand, July and August is the holiday season in most of the countries in the focus regions of the study with most of the listed airlines usually offering additional capacity on these months. As a result, the weeks of July and August were also excluded. Therefore, June was selected as the best representative schedule month of the yearly schedule. Since the schedule information is organised weekly, the last week of June's schedule data was used. Hence, the schedule information for each of the 36 listed airlines from 2004 to 2016 as of the relevant years' final June week was retrieved from the OAG database.

With the OAG data, the following field attributes were retrieved for each of the operating and codeshare flights from 2004 to 2016 for the listed carriers:

- Airline
- Flight Number
- Origin City
- Origin Airport
- Destination City
- Destination Airport and Terminal
- Domestic or International Flight: Indicates whether the flight is a domestic or international operation.
- Stops: Number of stops from origin to destination.
- Kilometre: O&D distance
- Flight Status: Indicates whether the flight is an operating or a codeshare flight
- Weekly Frequency: Number of weekly frequency operated for the same flight number
- Day(s) of Flight: Days of the week that the flight is operated
- Departure Time: Local departure time from the origin airport
- Arrival Time: Local arrival time to the destination airport
- Flight Time: Flight time between the aircraft's take-off and landing time from origin to destination.
- Block Time: Total time between the flight's engine start and engine off times. Block time includes the flight and taxi time.
- Aircraft Type: The assigned aircraft type for the flight. Although airlines can change the aircraft type depending on daily circumstances, the aircraft type assigned at the scheduling phase is correctly reflected to the OAG data.
- Seat Number: Total number of seats per flight. The flight's assigned aircraft type determines the physical seat count.

The below example retrieved from the OAG database illustrates the primary attributes of the schedule data. This is a snapshot of an Emirates (EK) flight as of June 2010 row retrieved from the OAG database.

1) Airline Designator Code	:	EK
2) Flight Number	:	124
3) Departure Airport Code	:	IST (refers to Istanbul)
4) Departure Terminal	:	International
5) Departure Local Time	:	16:30
6) Arrival Airport Code	:	DXB (refers to Dubai)

7) Arrival Local Time	:	21:45
8) Operating Status	:	Operating Flight
9) Total Seat Number	:	303
10) Day of Week	:	3 (Wednesday)
11) Block Time / Flight Minutes	:	255
12) Number of Stops	:	0
13) General Aircraft Code	:	772 (Boeing 770-200)
14) Direct Kilometres	:	3009

Using the data above, the following fields are added to the table by mapping the airport codes with the OAG's airport database.

15) Arrival Airport Name	:	Dubai International
16) Departure Airport Name	:	Ataturk
17) Departure City Name	:	Istanbul
18) Departure Country Code	:	TR
19) Departure Country Name	:	Turkey
20) Arrival City Name	:	Dubai
21) Arrival Country Code	:	AE
22) Arrival Country Name	:	United Arab Emirates
23) Operation Type	:	International

The above mentioned sample single row data obtained from the OAG with its 23 attributes refers to a direct operating flight of Emirates from Istanbul (IST) to Dubai (DXB) having flight number EK121, operated on Wednesday in June 2010 by a 777-200 type aircraft with an average seat capacity of 303 per flight. Since the departure country and the arrival country are not the same, it is deduced that this is an international flight. The flight departs from Istanbul at 16:30 local time and arrives at Dubai at 21:45 local time, implying a flight time of 255 minutes. Since this is a scheduled flight, Emirates operates this flight each Wednesday in the 2010 Summer timetable.

If there exist additional rows in the OAG data proving the presence of EK121 flights in the others days of the week, which is indeed the case, EK121 is then considered to be a daily flight. Accessing this data on separate rows enables the observation of daily changes with the service if any, i.e. the seating capacity of a particular day may be different from other days due to the operation of another aircraft type, or departure and arrival times may differ depending on the day of the week.

Considering that the airlines may operate more than thousands of flights per week and for each flight, the 23 attributes mentioned above were retrieved from the OAG database, an enormous volume of schedule data was required. The below table shows the number of rows referring to the number of weekly operating and codeshare flights of the listed airlines for each year's representative week (final week of June).

Table 5.1: Number of Operating and Codeshare Flights in the OAG from 2004 to 2016

Number of Flight Rows	Operating Flights	Code-share Flights	Total
2004	25,604	14,635	40,239
2005	29,680	17,619	47,299
2006	32,887	20,908	53,795
2007	34,506	21,687	56,193
2008	38,350	24,008	62,358
2009	38,656	26,512	65,168
2010	40,173	35,145	75,318
2011	42,305	44,664	86,969
2012	45,426	45,767	91,193
2013	48,841	49,308	98,149
2014	50,244	52,733	102,977
2015	51,453	54,682	106,135
2016	52,867	62,844	115,711
Total Rows		1,001,504	
Total Number of Attributes		23,011.592	

As Table 5.1 demonstrates, the schedule data of the 36 listed airlines' representative weeks from 2004 to 2016 add up to more than one million records. Considering each row contains 23 attributes, more than 23 million secondary data was fetched from the OAG database. It is also observed in Table 5.1 that for some years, the number of codeshare flights is more than the number of operating flights. As one operating carrier can contract with multiple numbers of marketing airlines, it is possible to observe higher codeshare flight frequencies than the operating services.

Since the schedule data is central to attaining the research's aim and objectives, a double check was required to ensure the accuracy, validity and credibility of the obtained data. Although OAG is a highly credible source, it is a secondary data source requiring validation controls. For this reason, ensuring the correctness of the OAG data is mandatory, and therefore the accuracy of the OAG schedule data was checked using alternative primary and secondary data sources.

There are publicly available tools that could assist in verifying the OAG data. For instance, it was possible to enquire online on the airlines' websites and check whether their displayed schedules are in line with the OAG data. Moreover, most carriers' post their timetable booklets for download online. The information accessed from the carriers' websites is primary data, referring to a credible method for validation. Undoubtedly, it was nearly impossible to crosscheck all OAG data via these resources because of two reasons. First, an airline's past schedule is not publicly available for download or viewing, as it has already expired and no longer available for sale. Second, including codeshare and operating flights, there were more than 1 million flights available from 2004 to 2016 awaiting to be checked. Therefore, validating this data was only possible through manual efforts by conducting random tests. In June 2016, the schedule information obtained through the web searches of the listed carriers' 2016 June flights was crosschecked with the OAG data. For each airline at least three pairs of O&D were selected whose schedule details were obtained from the carriers' website, which was then compared with the OAG data. The three selected O&Ds had the following characteristics to ensure diversity:

(i) A direct flight with either departure or arrival city is the base/hub of the airline (i.e. Dubai for EK or Vienna for OS at the origin or destination)
(ii) An operating connecting O&D (i.e. London to Amman via KL)
(iii) A non-stop or connecting O&D with at least one segment is a codeshare flight.

The comparison of primary data obtained through the web searches proved a 100% match with the OAG data for 2016 schedules, and hence the validation was completed successfully. Although only 3 O&Ds for each of the listed airlines were tested through this method, it was convincing that the OAG data presented credible schedule information. Indeed OAG is commonly used in the industry and academic studies without any doubt on data reliability, which was re-corroborated with the manual tests.

To accomplish a further credible schedule data validation, other data resources were explored. Similar to OAG, Innovata's joint product with IATA Schedules Reference Service (SRS) offers the carriers' schedule information too. For IATA (2014), SRS is a neutral source of airline schedules, and was created to provide a secure and high-quality service for the collection, validation, consolidation and distribution of airline schedules, also presenting robust and stable historical timetable data for more than 850 companies. Therefore, SRS was used as the second method of validating the OAG data. Similar to OAG, SRS is formed by a set of secondary data fed from various direct resources like GDS, market intelligence, airline and airport inventory data.

In order to validate OAG data and compare it with SRS outputs, certain control parameters at the aggregate level were defined. These control parameters included each of the listed airlines' 1) total weekly operating services and 2) total weekly codeshare flights. The values of these parameters were retrieved from the OAG and SRS databases separately, with the following formula calculating the match rates:

$$1 - \frac{|count(OAG) - count(SRS)|}{count(OAG)}$$

Where count (OAG) refers to the number of weekly flights fetched from the OAG database whereas count(SRS) refers to the same parameter retrieved from the SRS database. In case of count(OAG) and count(SRS) are equal to each other, it could be inferred that both databases reported the same number of frequencies for the representative week and managed 100% match rate. In order to ensure the credibility of the data sources, a high match rate was essential. The following tables (Table 5.2 and 5.3) report the representative week's total flight count in the OAG and SRS databases for the listed carriers from 2004 to 2016.

Table 5.2: Number of Operating Flights OAG vs SRS and The Match Rate

Years	count(OAG)	count(SRS)	Match Rate
2004	25,604	25,587	more than 99.9%
2005	29,680	29,646	more than 99.8%
2006	32,887	32,841	more than 99.8%
2007	34,506	34,912	98.8%
2008	38,350	38,124	99.4%
2009	38,656	38,731	more than 99.8%
2010	40,173	40,188	more than 99.9%
2011	42,305	42,300	more than 99.9%
2012	45,426	45,418	more than 99.9%
2013	48,841	49,014	99.6%
2014	50,244	50,220	more than 99.9%

2015	51,453	52,019	98.9%
2016	52,867	53,276	99.2%

Table 5.3: Number of Non-Operating Flights OAG vs SRS and The Match Rate

Years	count(OAG)	count(SRS)	Match Rate
2004	14,635	14,252	97.3%
2005	17,619	16,993	96.4%
2006	20,908	20,688	98.9%
2007	21,687	21,225	97.8%
2008	24,008	23,883	99.4%
2009	26,512	26,421	99.7%
2010	35,145	35,100	more than 99.8%
2011	44,664	44,621	more than 99.9%
2012	45,767	45,750	more than 99.9%
2013	49,308	49,002	99.4%
2014	52,733	52,688	more than 99.9%
2015	54,682	54,501	99.7%
2016	62,844	62,254	99.0%

Based on the information depicted in the tables above, count(OAG) and count(SRS) converged, implying high match rates of the data resources. The difference in operating flights was minimal, 0.4% on average whereas the figure with codeshare flights varied between 97.3% to more than 99.9%. The minor differences in codeshare flights might be sourced due to the unavailability of flight information in one of the data resource, whereas it existed in the other. However, it is also observed from Tables 5.2 and 5.3 that the match rates with codeshare flight have improved to a rate above 99.6% since 2008. As a result, it is inferred from the high match rates that both the SRS and OAG databases report almost similar flight counts and thus the credibility of the OAG data was further credited.

5.3: Minimum Connection Time (MCT) Data

As explained earlier, airport authorities determine the MCT duration, which may differ from one airport to the other. On the other hand, airports MCTs may change over time. For example, if an airport invests in its technical infrastructure to facilitate faster transfer processing, its MCTs may decrease. Therefore, obtaining up-to-date MCT data was mandatory for this research.

OAG provides a detailed MCT database for over 4,000 airports. In OAG, more than 100,000 standard and carrier exceptions are contained within the MCT database. It is the single most comprehensive source of MCT data available in the market (OAG, 2016). It should be noted that airports do not necessarily need to have a single MCT duration. The MCT of an airport may change depending on the incoming and outgoing flight terminals, which is already present in the OAG database. For this reason, if the airport has more than one MCT, multiple MCTs were needed along with the terminal information. An example of London Gatwick is disclosed in Table 5.4

Table 5.4: MCT Figures of the London Gatwick Airport

Terminal	Operation Type	MCT
South Terminal	Domestic to Domestic	40 minutes
South Terminal	Domestic to International	45 minutes
South Terminal	The Channel Islands to Domestic	50 minutes
South Terminal	International to Domestic	60 minutes
South Terminal	International to International	55 minutes
North Terminal	Domestic to Domestic	45 minutes
North Terminal	Domestic to International	45 minutes
North Terminal	International to Domestic	45 minutes
North Terminal	International to International	45 minutes
Between Terminals		75 minutes

The MCT values of 2,455 airports, valid as of 2016, were obtained from the OAG database and used throughout the study. This data covered all hub airports in which the listed carriers offer connecting services. While determining the exact MCT of an airport with multiple MCTs for a given itinerary, schedule data was used to clarify the specific value. For example, domestic flights are identified in case the departure and arrival countries are the same and the corresponding MCT of domestic flights in London Gatwick airport is 45 minutes as shown in Table 5.4. Furthermore, the departure and arrival terminals of the flights are already contained in the schedule data easing to determine the specific MCT value for a particular itinerary. In case the terminal information was not specified in the schedule data, the highest MCT value of the connecting airport was used throughout the research.

Although OAG confirms the actuality and accuracy of its MCT database, its credibility needed to be also cross-checked as the MCT information is a secondary data source too. For this reason, 20 airports were selected and their MCT values were obtained from other various resources, which were then compared with the OAG data. The selected airports were: Istanbul Ataturk (IST), Geneva Cointrin (GVA), London Heathrow (LHR), New York - John F Kennedy (JFK), Frankfurt International (FRA), Dubai International (DXB), New Delhi Indira Gandhi (DEL) and Johannesburg O.R. Tambo (JNB) airports. The other 11 airports were Milano Malpensa (MXP), Tehran Imam Khomeini (IKA), Baku Heydar Aliyev (GYD), Chicago O'Hare (ORD), Tokyo Narita (NRT), Bangkok Suvarnabhumi (BKK), Amsterdam Schiphol (AMS), Cairo International (CAI), Tel Aviv Ben Gurion (TLV), Singapore Changi (SIN) and Barcelona (BCN).

The alternative resources for obtaining the MCTs of the selected airports included a mixture of primary and secondary data. Public MCT information available on airports' official web pages and other secondary data sources, including airline announcements, blogs and magazine/newspaper articles, were helpful in this context. However, not all of the selected airports disclosed their MCTs transparently through their official web pages and other sources. As an alternative solution, the airports were contacted through e-mail and phone asking for their MCT for academic purposes, and five of them kindly responded. As a result, OAG data successfully passed all validity and credibility tests, and the MCT accuracy was verified through alternative primary and secondary data resources.

5.4: Demand Data

As discussed earlier, this research was dedicated to comprehending air service providers' schedule and network performance, for which certain methodologies were introduced utilising consumer-centric supply and quality metrics as the input. Moreover, the study sought to introduce the REMSET model, enabling a comparison of the market performance for competing airlines. Therefore, demand was not a key driver of the research's approach.

Although demand information was not employed as an input to the research's methodology, it was required to validate the accuracy of the study's outputs. For example, the REMSET model yields a realistic market share estimation of the rival carriers on an O&D. In order to measure the accuracy of these forecasts, actual demand figures were required to be compared with the REMSET models' estimations. In case of convergence with the forecasted and actual market shares, it could be claimed that the methodology produced credible estimations. For this reason, Marketing Information Data Tape (MIDT) data was employed. MIDT obtains data via the booking transactions generated by the GDSs and represents the true total market figure and carrier performance (OAG Analytics, 2018). However, MIDT datasets do not capture passengers booked directly with an airline. Given the fairly low market penetration of the GDSs in some regions, an O&D's true booking natures may not be accurately reflected in MIDT figures. Despite such drawbacks, MIDT data provides valuable competitive information enabling industry practitioners to make well-informed decisions (Devriendt, Derruder, & Witlox, 2013).

This Chapter has addressed the data sources for the schedule and the MCT information that was used throughout the research. The validity and credibility of the data sources was discussed in detail. It could be safely concluded that OAG is a credible data source for schedule and MCT data. Additionally, MIDT data has been chosen as a resource to perform the accuracy tests of the REMSET model. Besides, the research demands an extensive array of consumer preference data to incorporate passengers' perspectives into the research's methodologies. In order to obtain the most relevant information, primary data obtained directly from the passengers through a survey was used. The following Chapter addresses the survey design and implementation procedure in detail.

Chapter 6: Passenger Survey Design and Implementation

This research contributed to academic knowledge by including a passenger perspective on airline schedule assessment, which has not previously been quantitatively addressed in the academic literature. Such an extension has enabled a calculation of the ‘quality’ of itineraries competing on a given O&D and has made it possible to benchmark their relative performance, referring to Objective 2 of the study. It was therefore mandatory to develop an understanding of the passenger’s perception of a “good” or “bad” schedule. Although the literature review has identified specific factors with a particular impact on consumer choice, those parameters needed to be re-validated by passengers as the expectations and priorities of consumers may change over time. The relative superiorities of the factors influencing the passenger purchasing decisions had to be comprehended, especially in the presence of alternative products with varying characteristics. Moreover, Chapter 2 recognised certain research-specific factors that may be influential in consumers’ schedule convenience perception. As the research-specific parameters were not available in the academic literature, they required justification and verification by the passengers. Hence, a passenger survey was conducted in order to [i] verify the factors addressed in the literature review Chapters that influence consumers’ itinerary choice (i.e. total journey time, departure and arrival time, routing, itinerary type, etc.), [ii] corroborate the research specific parameters effect on passengers’ decision making and [iii] quantitatively assess the relevant parameters impact on the schedule convenience. It was intended through the survey to gather key market intelligence information to determine relative schedule quality scores of the competing products in a market. By comprehending the priorities and preferences of consumers on schedule related metrics, the survey looked to translate qualitative concepts of schedule convenience into quantitative factors to accurately measure and benchmark a carrier’s network attraction. Therefore, the survey’s role in reaching the research’s aims and objectives was key, requiring a separate chapter to addresses its design and implementation procedures. This Chapter elaborates on the implementation method of the questionnaire, as well as the representative sample selection and each asked question. The survey results are analysed in Chapter 7, and how they were used in the consumer-centric capacity, quality and REMSET are discussed in Chapter 8 and 9.

6.1. Selection of Sample Population and Method of Implementation

Although the research was focused on network attractiveness of the carriers in the Middle East, Europe and Africa, it is an inevitable fact that the perceptions and schedule preferences of consumers are global and beyond the regional level. With the further rise of globalisation, demand for international travel and the expansion of HS networks, today an airline in the Middle East, Europe and Africa can be a choice for a passenger residing in the Americas or Australia. Therefore, it was essential to execute the survey not only in the research focus regions but at a worldwide level.

The survey intended to receive feedback directly from the travellers who recently made an itinerary decision. For this reason, it was considered that the best venue of the survey implementation would be the airport departure terminals, where passengers are processed for check-in and boarding. In order to access a broader spectrum of respondents all around the world, airports in different continents were identified to conduct the survey. The selected airports included busy global hubs and regionally strong. The chosen airports were New York John F. Kennedy (JFK), Delhi Indira Gandhi (DEL), London Heathrow (LHR), Istanbul Ataturk (IST), Dubai International (DXB), Geneva Cointrin (GVA), Frankfurt International (FRA), Hong Kong International (HKG) and Johannesburg OR Tambo (JNB). These airports host a larger volume of international passenger movement each day. Moreover, when picking these airports, a mix of curfew-implementing and curfew-free airports was achieved. In order to achieve a satisfactory survey result set, it was concluded that collecting nearly 100 survey responses at each of these selected airports would be more than sufficient to report an adequate population set.

The implementation of the survey across 9 different airports was a challenge in terms of logistics and organisation. For this reason, a detailed implementation strategy was adopted. First, survey administrators (or assessors or interviewers) assisted in implementing the survey at each airport by distributing the surveys to participants and collecting the responses. The assessors were chosen from the airline employees whom had access to the passenger terminal. Survey administrators had no contribution in the questionnaire design and analysis. The interviewers, were experienced in communicating with passengers regarding their itineraries, were the researcher’s colleagues and provided assistance voluntarily. From late January to March 2015, the assessors in the international terminals of the selected airports approached prospective respondents and asked if they would be willing to contribute to an academic research with their valuable responses. Second, the survey administrators received a comprehensive presentation regarding the aim and objectives of the research, and were due-diligently informed about the importance of the survey responses to the quality of the research's output. The presentation also covered the principles of the survey implementation strategy.

Only one assessor approached passengers in each airport, and they did not delegate their responsibility to anyone else. Although the survey took approximately 5 minutes to complete, in case the subjects were observed to be in a rush to catch their flight, they were excused from participating as the questions required participants' concentration. Since conducting the questionnaire only at a particular time of the day might bias the analysis (for example morning flights may have been largely preferred by businessmen), the assessors working in shifts paid attention to approach passengers at different time intervals to ensure a good representative participant set. In order to further enhance the diversity on the participant set, the administrators implemented the survey on different days of the week. For instance, while a large share of weekend travellers could be leisure travellers, business travellers may dominate the airport early in the weekdays. For these reasons, survey administrators sought to collect between 100 – 120 responses over a period of 4 to 5 weeks. This target corresponded to 4 – 6 surveys per day-shift on average. As each survey implementation took roughly 5 minutes, the interviewers' duty at the airport was not severely interrupted, and their focus on the survey was ensured.

As explained, the assessors received their brief by way of a presentation regarding the survey implementation procedures. In the presentation, they were trained to approach a balanced mix of respondents. For instance, they were instructed to approach all levels of age groups including senior passengers, youngsters and middle-aged adults. Passengers observed to be younger than 18 years were excluded from participation. Moreover, they were encouraged to have an equal split of male and female subjects. Although the age and sex of the passengers were not asked directly in the survey, the assessors showed extra care in achieving a good mix as they only approached 4 to 6 participants per day, easing the process. Airline employees travelling on stand-by tickets with concessional fares were also denied from participation since seat vacancy is the ultimate determinant of their journey rather than their travel plan.

The survey was prepared and implemented in English. The survey administrators, who were fluent in English, excused participants who may have difficulty in understanding the survey due to limited understanding of the English language. In case participants demanded clarification about the questions, the assessors replied with the language in which they were asked, mainly the local language of the city where the survey was undertaken. It should also be noted that the assessors approached not only to local passengers but also to foreign nationals. Therefore, the survey did not intend to analyse the results based on the nationality of the respondents.

The survey participants were expected to be familiar with basic aviation related concepts such as connecting flights, connect time, codeshare operation, etc. to ensure full comprehension of the questions. Although the survey questions were drafted in a simplistic manner to avoid complex technical language, if the interviewers observed that the respondents had difficulty in understanding the questions despite their clarifications, it was regarded that the interviewee was unfamiliar with basic aviation-related terms and thus their responses were eliminated so as not to adversely influence the results set.

It was highlighted to potential survey participants that their responses would be used for academic purposes only, not commercial. Assessors observed that the respondents appreciated this explanation, which increased their willingness to participate. As some airport authorities required pre-approval processes for survey implementation as part of their internal regulations, the assessors informally updated the airport management regarding the academic purpose of the survey.

6.2. Preparation of Survey Questions

Before distributing the questionnaires to assessors and starting the implementation, a pilot survey was carried out to enhance the effectiveness of the survey. The purpose of the pilot study was to test the appropriateness and language of the survey questions. The pilot survey was implemented directly by the researcher to 30 participants. Based on the feedback received from the pilot participants, the survey questions were finalised. The responses of the pilot participants were not included in the survey analysis.

The survey included a set of questions in different categories. The first category of the questionnaire intended to segment the passengers. This categorisation enabled the participants to be profiled and an assessment to be made of how the responses to questions varied among different passenger segments. The next group of questions was about time-related parameters which were designed to develop an understanding concerning the respondents' departure and arrival time quality perception, MaxCT tolerance and buffer time request. The next set of questions addressed the respondents' relative appreciation for different flight type and routing combinations whereas the final category was designed to comprehend consumers' flight time split preference. A final version of the passenger survey is available at Appendix A.

6.2.1. Passenger Segmentation & Profiling Questions

The survey contained four questions to segment and profile the respondents. The profiling questions intended to evaluate the participants' (i) frequency of flights, (ii) previous positive experiences and (iii) preference priorities. The inclusion of each segment's responses into the analysis invaluably contributed to the survey results and enabled an observation of the divergences of the findings for different segments. Additionally, as part of the profiling process, the jurisdiction on passenger's itinerary selection was also asked due to the fact that in some cases not the individual travellers but someone else (like the company travel agency, the secretary or the spouse) make the travel decision. Profiling questions required the respondents to pick the attribute that best reflected their circumstance and positive experience. Therefore, they were not stated preference questions. The fourth question shown below is a conjoint ranking scale question in which the respondents were asked to rank the alternatives from most important to least preferred. The profiling questions with their remarks are shown in Table 6.1 with correct questioning order. The remark column clarifies the rationale behind the inclusion of the corresponding question into the survey.

Table 6.1: Survey Profiling Questions – Q1–3

Question	Remarks
Q1- How many flights have you taken in the last 12 months? Travelling to one destination and back count as 1 round trip. ☐ No flights ☐ 1 round-trip flight ☐ 2 – 5 round-trip flights ☐ 6 – 9 round-trip flights ☐ More than 10 round-trip flights	Helped to address how frequently the respondent travelled. The more the passenger travels, the more itinerary decisions were made.
Q2- To what extent you are able to decide or influence the decision makers of your flight plans? ☐ I make or influence my ALL flight decisions. ☐ I make or influence MOST of my flight decisions. ☐ I make or influence SOME of my flight decisions. ☐ I RARELY make or influence my flight decisions. ☐ I NEVER make of influence my flight decisions.	Measured to what extent the respondents had influence and authority on their travel decision.
Q3- Have you taken any of these air trips in the past 5 years? ☐ Connecting flight ☐ Connecting flight with limited connection time (due to short connection time or late arrival of the first flight) ☐ Codeshare flight (booked in one airline but flown with another one) ☐ Long haul flight (more than 8 hours) ☐ Business or first class flight ☐ Premium economy class flight ☐ Low-cost airline flight ☐ Domestic flight	Enabled understanding if the passenger had ever experienced and tested different flight alternatives stated in the question as they would be replying to questions in the proceeding sections that were directly associated with those experiences.

Table 6.1 (continued): Survey Profiling Questions – Q4

Q4- Please rank the factors shaping your travel decision from the most important one to the least from 1 to 10. (1 / most important, 10 / least important) Use each number once only. __ Date and time (schedule) convenience __ Fare __ Duration of the journey __ Frequent flyer programme __ Airline reputation __ Departure and/or arrival airport __ On-board services (catering, in-flight entertainment, cabin service etc.) __ Before and after flight services (CIP lounge, shuttle services etc.) __ Availability of flight alternatives (such as higher frequency per day) __ On-time performance and consistent schedule times	Enabled understanding the preference priorities of the respondents. The question also clarified the extent that the schedule related factors were prominent in the traveller's decision-making process.

Consistent schedule time refers to identical departure and arrival times of a flight under the same flight number. For instance, if XY101 departs 10:00 on Tuesdays and Thursdays but departs at 10:40 in the remaining days of the week, XY101 is assumed not to have consistent schedule times within a week.

6.2.2. Departure and Arrival Time Quality Determination Questions

As discussed in the literature review, passengers have preferences regarding their ideal departure and arrival times. Therefore, it was intended in the survey to develop an understanding concerning the most appreciated time intervals of the day to depart from the origin and arrive at the destination. Additionally, it was aimed to comprehend the relative superiorities in terms of preference among different time zones of the day. Thus, the objective with these questions was to understand the departure and arrival time qualities (q_{dep} and q_{arr} respectively) of the itineraries.

As the initial step, time intervals of the day were identified. The smaller the duration of each interval, the more precise the views of the travellers but the higher the number of responses needed. For instance, if the time intervals were determined to be 1 hour, passengers would need to respond to 48 (24 for departure, 24 for arrival) questions. However, although this approach would offer a clear picture about the attractiveness of each hour to depart and arrive, having an excess number of questions might distract passengers' concentration and thus the quality of the responses. On the other hand, over stretching time intervals would lead to the precision with the response quality, despite fewer questions. For this reason, fixing time intervals to two hours was found optimal. The first time interval started from the midnight and ended at 01:59 am, followed by other eleven time periods, resulting with 24 intervals to be rated by the participants.

The next decision factor involved rating each time interval to be assessed. Higher numbers of scales were avoided, as it would influence the concentration and justification process of the respondents. Furthermore, odd numbers of scales were avoided to prevent passengers from ticking the middle-value option, implying complete indifference. Since the survey aimed to quantify relative superiorities of each time zone, passengers' responses should move away from being neutral. For this reason, a four-scale rating was utilised. The scales were titled “worst”, “poor", "good" and "best". This approach in a sense forced the survey participants to decide on the attractiveness of each time zone as a neutral-indifferent option was absent. Since q_{dep} and q_{arr} can have any numerical number and a standard definition is required to construct a common base for further references, the following standard q_{dep} and q_{arr} values were introduced.

Table 6.2: The q_{dep} and q_{arr} Factors with Min and Max Values and Inferences of Their Values.

Parameter	Min. Value	Max. Value	Explanation
q_{dep}	1	4	1 refers to the worst departure time score; the least preferred departure time and 4 is the highest and best alternative.
q_{arr}	1	4	1 refers to the poorest arrival time score; the least preferred arrival time and 4 is the highest and best alternative.

6.2.3. Maximum Connection Time (MaxCT) Determination Question

Although the MCTs of the airports are fixed parameters which are pre-defined by the airport authority, MaxCT is a subjective factor indicating the extent of passengers' maximum tolerance for connecting time at the connecting airport. In other words, while the MCT is an absolute figure, MaxCT is a subjective, passenger-specific parameter deeming it a primary interest of the survey. For this reason, a direct question was placed on the survey asking the respondents' MaxCT. It is an indispensable fact that there exist various factors shaping the MaxCT tolerance of the individuals such as airport amenities, smoking facilities, airline lounges, passengers' age and purpose of travel. However, for the sake of this question, the passengers were merely asked their maximum tolerance, free from these factors, concentrating only on their perceived maximum. To ascend the lucidity of the question, a case was exemplified in parenthesis. The answer options were designed at the hour-level forcing the respondent to make an educated decision. The last answer option was for the subject for whom the MaxCT was not a critical parameter in their overall thought process.

6.2.4. Buffer Time (t_{buffer}) Request Question

Although the MCT refers to the minimum connection time at the hub airport, it was claimed in Chapter 2 that passengers might demand additional buffer time to reduce their stress and make their journey more comfortable. In order to verify the existence of this buffer time preference and its duration in case of its presence, a direct question was asked in the survey. The question was explained in detail to introduce the case explicitly. The 'buffer time' concept was not used in the question text but rather the idea was outlined with an explanation. Passengers were asked how much minimum additional time they would demand to make their connection less stressful through a stated preference model enquiry. The phrase 'stress' was intentionally used in the question to encourage subjects to determine the additional time required to minimise their stress and maximise their convenience. The reply options were set to start with no additional time requirement to 1 hour with 15-minute intervals. The final option was included for passengers demanding more than an hour-long additional time.

Table 6.3 shows above mentioned departure and arrival time quality questions whereas Table 6.4 displays the MaxCT and buffer time request determination questions. The question numbers proceed precisely as printed on the survey.

Table 6.3: Departure and Arrival Time Quality Question of the Survey (Q5-6)

Q5 and Q6. For each time interval below, please state the degree of convenience for departures and arrivals. 1 referring to the worst, 2 poor, 3 good, 4 the best time of the day. For example if you believe departing a city at 5 am in the morning is terrible please tick ☑ option "1" for row 04:00 – 05:59 for departure time section on the left, and if you believe it is good to arrive at the city at 5 am in the morning, please tick ☑ option 3 for the arrival time section on the right.

	Departure Time	1 Worst	2 Poor	3 Good	4 Best		Arrival Time	1 Worst	2 Poor	3 Good	4 Best
Departure Time	00:00-01:59	☐	☐	☐	☐	Arrival Time	00:00-01:59	☐	☐	☐	☐
	02:00-03:59	☐	☐	☐	☐		02:00-03:59	☐	☐	☐	☐
	04:00-05:59	☐	☐	☐	☐		04:00-05:59	☐	☐	☐	☐
	06:00-07:59	☐	☐	☐	☐		06:00-07:59	☐	☐	☐	☐
	08:00-09:59	☐	☐	☐	☐		08:00-09:59	☐	☐	☐	☐
	10:00-11:59	☐	☐	☐	☐		10:00-11:59	☐	☐	☐	☐
	12:00-13:59	☐	☐	☐	☐		12:00-13:59	☐	☐	☐	☐
	14:00-15:59	☐	☐	☐	☐		14:00-15:59	☐	☐	☐	☐
	16:00-17:59	☐	☐	☐	☐		16:00-17:59	☐	☐	☐	☐
	18:00-19:59	☐	☐	☐	☐		18:00-19:59	☐	☐	☐	☐
	20:00-21:59	☐	☐	☐	☐		20:00-21:59	☐	☐	☐	☐
	22:00-23:59	☐	☐	☐	☐		22:00-23:59	☐	☐	☐	☐

Table 6.4: MaxCT and t_{buffer} Request Question of the Survey (Q7-8)

Questions and Remarks	Remarks
Q7. If you need to take a connecting flight, what would be your maximum tolerance to wait in the connecting airport from the landing of your first flight until the departure of your second flight? (E.g. You are travelling from New York to Rome via Heathrow. How long would you be willing to spend in Heathrow airport maximum?) ☐ Up to 2 hours ☐ Up to 3 hours ☐ Up to 5 hours ☐ Up to 8 hours ☐ Connection time is less important than other factors	MaxCT determination question - The question text asks passengers maximum tolerance duration at the intermediary airport while connecting for the next flight.
Q8. There is a minimum time required for each airport to connect from one flight to another. Some people find the minimum time challenging as with any irregularity such as the late arrival of the first flight, they may misconnect or feel stressed. How much minimum additional time would you prefer to have to make the connection less stressful? ☐ No extra time required ☐ Minimum time + 15 minutes ☐ Minimum time + 30 minutes ☐ Minimum time + 45 minutes ☐ Minimum time + 1 hour ☐ Minimum time + more than 1 hour	t_{buffer} request question – The question text initially informs respondents regarding the existence of each airports MCT value and then asks their additional time demand on top of this pre-defined duration.

6.2.5. Codeshare Flight Convenience Question

Quantifying and benchmarking the value of a codeshare flight compared to an operating service is vital to determine the relative network positioning and performance of the carriers. Although the codeshare flights widen the airline network and offer a broader range of products, their value perceived by the passengers has to be well identified and reflected into the research's model. As discussed in the literature review, consumers may have varying tendencies to prefer codeshare flights as the booked airline is not the operating carrier implying the utility of a codeshare flight may significantly diverge from that of an operating service. While for some consumers the airline operating the flight is the utmost factor of choice, some others might be apathetic as long as they enjoy a convenient journey. Furthermore, codeshare flights can even be a preference factor for some like frequent flyers aiming to gain incremental miles for their loyalty account.

To address the dynamics of consumers' attitude towards codeshare flights, the survey asked a question for assessing the circumstances when travellers' make a non-operating itinerary preference. The answer options were designed to be mutually exclusive with clear distinctions. The first option was drafted for respondents with no tolerance to codeshare flights in their itineraries. The second alternative was for those who would only select the non-operating service in case of the operating carriers' service absence to the final destination. The third option was for the respondents who would only choose the codeshare flight if it is "more convenient". The final option was for passengers with complete indifference to codeshare flights.

Table 6.5: Codeshare Flight Convenience Question of the Survey – Q9

Question
Q9. There are two flight alternatives to your destination, one operated by the airline of your choice and the other a codeshare flight where you book with the airline of your choice but travel on a different airline. Under which conditions would you choose the codeshare flight? ☐ I would never choose a codeshare flight. ☐ I would only choose it if I had no other choice. ☐ I might choose a codeshare flight if it is more convenient. ☐ It really does not matter to me.

6.2.6. Fare, Schedule Convenience and Flight Type Related Questions

One of the primary objectives of this survey was to numerically quantify and benchmark the value of flight alternatives from the consumers' standpoint. As discussed in the literature review, consumers' willingness to pay values is a definite indicator of a product's value. All parameters that are instrumental in the decision-making process of the consumer are elaborated in their thought process and translated into a fare that they intend to pay for the proposed flight. Therefore, the maximum fare that could be accepted by consumers can be used as a reference to assess their perceived value of the itinerary.

The survey asked questions about travellers' willingness to pay in dollars for different flight cases. Initially, a broader inquiry was made in Question 10 to sort the subjects' tendencies between fare, flight type (operating or codeshare) and routing (direct or connecting). In Question 11, the interrelation between core product attributes and their relative monetary values were intended to be captured by referencing to a base case. Question 10 and 11 were drafted using stated preferences and choice modelling techniques in which the respondents were presented a rich set of preference as they were asked to choose between more than two alternatives. According to the Centre for International Economics Report (2001), this model allowed the analyst to estimate the extent to which individuals are prepared to trade off one attribute against another. Since the attributes were measured in monetary terms, it was possible to estimate the amount of money that the subject was prepared to pay for improving a non-monetary attribute by one unit.

Table 6.6: Fare, Schedule Convenience and Flight Type Question of the Survey – Q10

Question
Q10. Which of the flight itinerary would you prefer for your travel from City A to City B? $ signs are a depiction of the flight cost factor where more number of $ signs refers to a more expensive option. □ A direct flight of my favourite airline costing $$$$ □ A codeshare direct flight operated by an airline other than my choice costing $$$ □ A connecting (longer) flight of my favourite airline costing $$$ □ A connecting (longer) flight of an airline other than my regular choice costing $$

Question 10 assisted to understand to what extent the respondents would compromise convenience in the presence of better fares. Although the number of dollar signs depicted in the options did not signal an exact proportional fare level, it was easily inferred by the respondents that the higher number of dollar signs implied a comparably higher fare. The selection of the first option categorised the passenger to be product quality oriented with no or limited price sensitivity. If the second or third option were selected, the participant provided a clear preference: prioritisation of a direct flight at the expense of a codeshare flight OR an operating flight of his choice airline at the expense of an inconvenient connecting flight. In case the final response was picked, the respondent was categorised to be price sensitive.

Although Question 10 was instrumental in mapping itinerary characteristics in relation to fare in defining their relative priorities, its role remained solely conceptual and qualitative. The question did not assist in developing the quantitative relationship for competing itineraries based on their routing and type, in other words, inadequate to compute u_{do}, u_{co}, u_{dc} and u_{cc}.

Question 11 intended to measure the numerical value of different itinerary scenarios for quantifying schedule convenience by introducing a reference base case. In theory, with research employing stated preference, techniques rely on "hypothetical baselines" which describes a current state or a reference point. The researcher then poses a valuation question or choice task that is contingent, not on the existing status quo, but rather on the state of the world described in this new hypothetical baseline (Whittington & Adamowicz, 2011). For Question 11, the base scenario flight was determined to be an operating connecting service with 18 hours of total journey time for which the participant was assumed to pay 500 USD. In the proceeding set of questions, by consecutively altering the variables tested, passengers were requested to decide how much maximum they would agree to pay, referencing to 500 USD. The scales were determined in 50 USD intervals where the most expensive scale referred to was more than 700 USD and the cheapest one was less than 400 USD. The tested parameters were i) flight routing – (direct / connecting) ii) flight time convenience (convenient / inconvenient) and iii) type (codeshare /online). It was expected through this question to crystallise the extent the passengers would pay more for the relatively advantaged (or less for the disadvantaged) itineraries compared to the base case and therefore to draw a roadmap for clarifying relative superiorities. Therefore, through this question, a concrete quantitative relation between the relative values of u_{do}, u_{co}, u_{dc} and u_{cc} could be constructed.

Table 6.7: Relative Value Determination Question of the Survey – Q11

Question

Q11. Let's suppose you will fly from City A to City B by connecting through City C. This is a long haul connecting flight with *INCONVENIENT* departure and arrival times taking *18 hours* for the whole journey. You paid 500 USD or this flight. Please answer the below questions taking 500 USD as the reference fare.

How much would you pay for the below-mentioned flight alternatives from City A to City B referencing the above case costing 500 USD? Please tick ☑ the value in USD or each case below. The leftmost column refers to less than 400 USD, where rightmost column refers more than 700 USD.	< 400 $	401 – 450 $	451 – 500 $	501 – 550 $	551 – 600 $	601 – 650 $	651 –700
A connecting flight with *convenient* flight times lasting 18 hours	☐	☐	☐	☐	☐	☐	☐
A direct flight taking 12 hours with convenient flight times	☐	☐	☐	☐	☐	☐	☐
A direct flight taking 12 hours with inconvenient flight times.	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with convenient flight times taking 18 hours	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with inconvenient flight times taking 18 hours	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with convenient flight times taking 15 hours	☐	☐	☐	☐	☐	☐	☐
A codeshare direct flight with inconvenient times taking 12 hours	☐	☐	☐	☐	☐	☐	☐

6.2.7. Connecting Flight Split (f_{split}) and Flight Time Percentage ($\%t_f$ or $\%t_c$) Questions

As discussed in Chapter 2, for connecting flights, in addition to the total travel time, the split of the journey between the first and proceeding legs may considered to be necessary as the existence of a relatively more extended segment would allow passengers to rest or sleep, limiting the stress caused by either changing or terminating the flight soon. On the other hand, an equal split, not ultimately stretching the duration of a leg might be a choice especially for smokers, rushing to find a permitted space to smoke soon after their disembarkation from the aircraft or for travellers having phobia avoiding excess flight times. The amenities of the hub airport might be detrimental to decide within this context, but the respondents were encouraged to reflect their general perspective concerning their best-preferred journey split for connecting itineraries through stated preference model questions.

To ensure the clarity of the question, a connecting itinerary case with 10 hours of t_{total} was illustrated where t_{conn} was determined to be 1 hour. The reply options were indicated to have a different duration for the first and second segment where t_{flight} summed 9 hours for each case. Answer options started with the first leg lasting 8 hours and the latter an hour. The complete symmetric with the interchanged duration of 1 hour and 8 hours for the first and second flight consecutively was listed in the fourth option. The second and third reply option involved symmetric 6 and 3 hours of flight time for the first or second flight respectively. The final answer alternative was placed for indifferent respondents viewing the split of the journey not as a vital parameter in their decision making. Respondents' potential answers among symmetrical options were expected to offer an insight about their preference whether they would favour taking the longer or shorter flight first.

The final survey question intended to understand if passengers favoured waiting at the hub airport rather than spending that time flying on board. This was achieved by fixing the total journey time and altering the t_{conn} in the response options. The respondents were requested to choose between 1 hour and 3 hours of connecting time in which both routings in the itineraries had 12 hours of total journey time. The question assessed whether passengers would prefer spending 2 hours difference at the hub airport or onboard. Each option had certain advantages and disadvantages. Passengers preferring rather to be at the airport could enjoy more freedom and activities at the hub. On the other hand, some passengers could choose to stay onboard as they could sleep, work, watch a movie if the aircraft had an In Flight Entertainment (IFE) system or eat in case the airline offered free meal. Alternatively, business class passengers could enjoy lounge facilities at the airport and therefore could prefer waiting at the hub airport rather than flying. In other words, the question aimed to understand, whether a higher $\%t_f$ or $\%t_c$ was appreciated by the participants among itineraries having equal t_{total}.

Table 6.8: Connecting Flight Split and Flight Time Percentage Questions of the Survey – Q12–13

Questions and Remarks	Remarks
Q12. For a different journey, which of the connecting flight itineraries would you prefer for your travel from City D to City E? Total duration of the journey from D to E is 10 hours. ☐ First flight leg lasts 8 hours, the second leg lasts 1 hour and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 6 hours, the second leg lasts 3 hours and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 3 hours, the second leg lasts 6 hours and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 1 hour, the second leg lasts 8 hours and the connection time at the connecting airport is 1 hour. ☐ It does not matter to me at all.	Question intended to determine the ideal split between the duration of connecting flight legs, having the same journey duration.
Q13. Which of the connecting flight itineraries would you prefer for your travel from City F to City G. (Assuming all other parameters of choice like fares, airline preference, schedule are identical) ☐ A connecting flight with a total 12 hours of journey time of which 3 hours are spent at the connecting airport ☐ A connecting flight with a total 12 hours of journey time of which only 1 hour is spent at the connecting airport	Identified whether a passenger would like to spend more on board or in the airport among two itineraries having identical total travel time.

Totalling thirteen questions, the survey was printed on a two-sided page; fitting on a single sheet at the expense of using a smaller font. Avoiding multiple sheets was an intentional strategy to persuade subjects to participate in a short questionnaire. Considering that the survey was performed at the airport and potential respondents would take off for their destination soon, the pressure of outstanding passport and other formalities could have averted their participation unless they were convinced regarding the brevity of the survey. Soon after passengers completed the survey, the interviewers double-checked if any responses were missed or inappropriately responded. By establishing a proper coordination between the researcher and the survey administrators, the overall quality of the survey responses was increased. The survey administrators were well informed concerning the implementation strategy, and they approached a balanced mix of respondents on different days of the week and different times of the day. Such a well-informed, trained and interactive method was beneficial and hence significantly contributed to obtaining good quality responses.

The survey intended to assess parameters including MaxCT, t_{buffer}, q_{arr}, q_{dep}, u_{do}, u_{co}, u_{dc}, u_{cc}, f_{split},$\%t_f$, $\%t_c$ which all together formed an essential input to schedule quality determination and the REMSET model. The following Chapter discusses the survey results and analysis.

Chapter 7: Passenger Survey - Results and Analysis

As discussed in the earlier Chapters, the passenger survey had a central role in attaining the research's aim and objectives with the incorporation of passengers' perspective into the consumer-centric capacity determination, quality score computation and market share estimation processes. For this purpose, the survey was designed to let passengers around the world to present their independent and objective views concerning schedule attractiveness. The questionnaire addressed numerous critical factors and provided valuable results, which are discussed throughout this Chapter in detail. Moreover, a number of statistical tests were implemented on the survey data to validate the robustness of the results.

7.1. Number of Participants and the Determination of Valid Survey Responses

As addressed in Chapter 6, to ensure an acceptable level of confidence with the survey results, it was targeted to have a large sample size. Each interviewer in 9 selected airports was asked to complete approximately 100 surveys from late January to March 2015. As securing additional responses would assist in granting lower error margins, the survey administrators were even encouraged to exceed 100 responses per airport as long as their shift enabled them to do so.

As the initial step, the criteria for accepting valid survey responses were identified and a preliminary check was performed to observe whether the responses met the primary criteria for inclusion in the analysis. In order for the responses to be included into the accepted survey set, two criteria were determined: (i) The respondents had to have a recent flight experience in the past 12 months and (ii) they had to report at least some interest in schedule convenience. Passengers without a recent flight experience were assumed to be unable to suggest credible and up-to-date responses as they made their most recent itinerary decision more than a year ago. Furthermore, as the objective of the survey was to examine schedule convenience, it was required that respondents place at least some degree of importance on schedule quality. The percentage of survey participants placing at least some importance on schedule convenience is an indicator of the research's relevance, which is reported in the proceeding sections, so the responses of the interviewees with no interest in schedule convenience were eliminated from the analyses. The respondents' flight experience was asked in the first question whereas their attitude towards schedule convenience was examined in the third question. Furthermore, inconsistent replies (i.e. selecting more than one option for a single response question) and incomplete forms were also eliminated from the final set. Table 7.1 summarises the total number of surveys mailed by the assessors and the amount of valid surveys obtained after the completion of the above-mentioned procedure.

Table 7.1: Number of Surveys Returned by the Survey Administrators and Valid Surveys to Be Included in the Results Analysis

Airport	Number of Surveys Returned	Number of Valid Surveys
Delhi (DEL)	110	98
Dubai (DXB)	112	105
Frankfurt (FRA)	130	109
Geneva (GVA)	113	113
Hong Kong (HKG)	132	114
Istanbul (IST)	110	105
Johannesburg (JNB)	123	101
London (LON)	112	108
New York (NYC)	111	109
Total	1,053	962

As the table illustrates, among the 1,053 questionnaires mailed, a total of 962 valid survey responses were obtained for the analyses. Therefore, the accepted survey set which was used in the analysis offered more than an adequate level of confidence to ensure the validity and credibility of the survey findings. Among the 91 eliminated survey responses, 38 of them were excluded as the respondents had no flight experience in the past 12 months. Furthermore, 25 of the passengers marked schedule convenience as the least important factor when making itinerary decisions, which excused their responses from the results set. This figure implies that among 1,053 participants, only 25 of them reported no interest to schedule convenience contributing to 2.37%. In other words, for the remaining 97.63% of the respondents, schedule convenience was found to be significant. Furthermore, 28 responses were disqualified because of incomplete or unreadable replies.

The following sections discuss the survey findings by incorporating the replies of 962 valid questionnaires. The results were also analysed at the airport breakdown, whose results are disclosed in Appendix B. It should be noted that the survey did not address the nationality or residence country of the participants. Therefore, the responses at the airport breakdown does not reflect the findings that are specific to the country or residents of the city where the survey was conducted. Undoubtedly the survey venue airport might have affected the variances with the responses, but it cannot be argued as the single reason of any divergence.

7.2. Frequency of Flights

The first question of the survey addressed respondents' flight frequency in the past 12 months. Higher frequencies implied a greater number of itinerary decisions made, enabling passengers to provide more credible justifications towards survey questions. Table 7.2 summarises the breakdown of the responses.

Table 7.2: Replies to Question 1 of the Survey

Options	Number of Respondents Marked	Per cent share
1 round-trip (RT) flight	181	18.81%
2 RT flights	224	23.28%
3 - 5 RT flights	344	35.76%
6 – 9 RT flights	145	15.07%
More than 10 RT flights	68	7.08%
Total	962	100.00%

The above table demonstrates that, 81.19% of participants had multiple flight experiences in the past 12 months and the largest portion of the respondents took between 3 to 5 RT flights. Assuming "3 - 5 RT flight" option contributes to 4 flights whereas "6 - 9 RT flight" maps to 7.5 flights and "more than 10 RT flights" refers to 12 RT flights, the average RT flights taken by respondents is calculated as follows:

$$\frac{((1\ x\ 181) + (2\ x\ 224) + (4\ x\ 344) + (7.5\ x\ 145) + (12\ x\ 68))}{962} = 4.06$$

Therefore, an average survey participant took 4.06 RT flights in the past 12 months. This figure is convincing in the sense that an average respondent had at least 8 flight experiences, as a round-trip involves 2 flight segments minimum. The breakdown of the flight frequency per airport is disclosed in Appendix B.

7.3. Itinerary Decision Making

Although it is not a prerequisite for consumers to have full control over their travel plans, a higher degree of influence in their itinerary decision making would mean more time spent on product choice, adding up to the credibility of the findings. Table 7.3 demonstrates the responses to this question.

Table 7.3: Replies to Question 2 of the Survey

Options	Number of Respondents Marked	Per cent share
I make / influence ALL decisions.	153	15.91%
I make / influence MOST decisions.	401	41.69%
I make/influence SOME decisions.	297	30.87%
I RARELY make / influence decisions.	87	9.04%
I NEVER make / influence decisions.	24	2.49%
Total	962	100.00%

57.6% of the respondents had a substantial degree of control over their journey plans, i.e. making or influencing either all or most of their travel decisions. A significant share of the respondents, contributing to nearly 31% of all participants, mentioned that they have some control over their itineraries. Less than three per cent of the surveyed individuals reported no power in decision making. These results added further credibility to the survey analysis in the sense that the survey participants had more than adequate level of control over their itinerary choices. The responses of the participants who completely lacked control on their itinerary selection were also included in the analyses of the proceeding questions as their opinions concerning schedule convenience matters. The responses to Question 2 at the airport breakdown are also displayed in Appendix B.

7.4. Previous Positive Experiences

Comprehending the travellers' previous positive flight experiences was crucial for the accuracy of the survey findings as the proceeding questions of the questionnaire intended to develop an understanding concerning the relative values of different flight options. Therefore, learning about the previous positive experiences of the travellers was a valuable piece of information in order to conduct many various useful analyses. Table 7.4 summarises the responses to Question 3.

Table 7.4: Previous Positive Experiences of the Respondents

Options	Number of passengers with a positive experience	Positive experience % share
Connecting flight	714	74.22%
Connecting flight with limited connection time	305	31.70%
Codeshare flight	286	29.73%
Long haul flight	611	63.51%
Business / First class flight	359	37.31%
Premium economy flight	388	40.33%
Low-cost airline flight	814	84.61%
Domestic flight	793	82.43%

As the table suggests, almost 3/4 of respondents had experienced a connecting flight, of which 305 of them had a connection with limited t_{conn}. Almost 30% of the participants tried codeshare flights. 359 passengers flown business class, and 388 had a premium economy itinerary in the past five years. 63.51% of survey participants' confirmed their positive long-haul experience whereas domestic and low-cost flights were experienced by more than 80% of the participants. Therefore, the respondents reported an adequate volume of positive experiences, implying that they could adequately justify the relative values of the competing itineraries in the following questions. Among 962 valid respondents, 93 passengers had positive experiences in all of the flight options surveyed.

Among 359 passengers who had had a business or first class experience in the past five years, 304 of them, contributing to more than 84%, had tried a low-cost flight too. This finding proves that consumers may alter their product choice depending on their specific circumstances. For this reason, any income related segmentation of the travellers could not solely be attained through the responses of this question. The airport breakdown of this question is also available in Appendix B.

7.5. Importance Ranking

Question 4 sought to rank the factors that are influential in consumers' decision making based on their relative level of importance. Additionally, as the prior positive experience of the respondents cannot be a litmus indicator of their segmentation, the question enabled the profiling of the respondents by analysing their most influential determinants of the itinerary choice. Table 7.5 shows the raw distribution of the results for each decision parameter. Participants marked factors between 1 (most important) and 10 (least important), with each score only used once. The weighted index is calculated by multiplying the factors' importance values by the number of respondents giving the same rating, summed together and later divided by the total number of valid survey responses.

Among 962 participants, 322 of them marked "fare" as the most important decision factor (score "1") when choosing their itinerary; this had the lowest weighted average score of 3.27. Therefore the fare was marked as the most influential factor of itinerary choice. Passengers rated date and time (schedule) convenience as the second most vital factor of itinerary choice, followed by the on-time performance with 4.73 and 4.98 weighted index scores respectively. These findings confirmed that while schedule attractiveness indeed plays an important role in consumer decision after fare, how well and punctual airlines deliver their promised services also plays a crucial role in consumers' choice. Airline reputation ranked fourth and therefore found to be "less important" in comparison to fare and schedule convenience factors, signifying that consumers could be flexible with their airline choice if a better fare and schedule combination is available.

Table 7.5: Passengers Importance Ranking – Collected Straight from Survey Results (1- Most Important, 10- Least Important Factor)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Weighted Index**
Date and Time (Schedule) Convenience	140	132	124	126	88	80	38	82	88	64	4.73
Fare	322	131	171	75	85	45	50	58	12	13	3.27
Duration of Journey	37	75	70	121	105	139	96	111	88	120	6.02
Frequent Flyer Programme	32	75	93	104	98	82	100	113	109	156	6.24
Airline Reputation	132	109	73	97	75	99	75	70	95	137	5.44
Departure and/or Arrival Airport	45	50	79	93	121	92	85	133	145	119	6.30
Onboard Services	40	99	119	87	99	88	96	130	106	98	5.83
Before and After Flight Services	41	54	23	92	85	123	201	105	95	143	6.53
Availability of Flight Alternatives	48	105	107	67	115	158	98	60	144	60	5.65
On-Time Performance and Consistent Schedule Times	125	130	105	100	91	56	123	100	80	52	4.98

1st important factor: Fare

2nd important factor: Date and Time (Schedule) Convenience

3rd important factor: On-Time Performance and Consistent Schedule Times

4th important factor: Airline Reputation

5th important factor: Availability of Flight Alternatives

6th important factor: Onboard Services

7th important factor: Duration of the Journey

8th important factor: Frequent Flyer Programme

9th important factor: Departure and/or Arrival Airport

10th important factor: Before and After Flight Services

Availability of flight alternatives ranked fifth, outperforming onboard services, frequent flyer programme (FFP) as well as before & after flight services (BAFS) implying that the variety of flight options in a market was found to be more critical than the airlines' product-related attributes. Total journey time ranked seventh, also outpacing FFP and BAFS. Indeed, BAFS was nominated as the least important factor in travellers' choice. To summarise, it is easily inferred from the analyses that passengers place more importance on fare, schedule convenience and alternative flight options in comparison to airline reputation and product-related attributes involving FFP and BAFS. As per the responses, schedule convenience was even found to be a crucial factor among price-sensitive passengers. According to 322 passengers who chose fare as the most crucial determinant of their itinerary decision-making process, the weighted averages of the other factors surveyed were computed as follows:

Table 7.6: Weighted Index of Other Parameters for 322 Price Sensitive Passengers for Whom Fare Was Ranked as the Most Important Factor of Their Itinerary Choice

Date and Time (Schedule) Convenience	4,82
Duration of Journey	5,97
Frequent Flyer Programme (FFP)	6,56
Airline Reputation	6,12
Departure and/or Arrival Airport	6,44
Onboard Services	5,92
Before and After Flight Services (BAFS)	7,03
Availability of Flight Alternatives	6,24
On-Time Performance and Consistent Schedule Times	5,44

The above table demonstrates that, after fare, date and time convenience was more important than any other factor even for the price-sensitive segment. Schedule convenience was followed by on-time performance and duration of the journey. This finding affirmed that schedule convenience related factors were found to be critical factors of choice even for the price-sensitive segment. It should also be noted that, the index values obtained from this survey question are not used as part of the REMSET model. Therefore, the exact rankings of the analysed factors are not critical as part of the research model and results. Although, examining the cross-factor effects would provide insightful findings concerning consumers' behaviour, it is not examined as part of this research.

7.6. Departure Time Quality (q_{dep})

The survey asked respondents to rate the quality of each departure time interval throughout the day. Passengers rated departure time quality as follows:

Table 7.7: Departure Time Quality Score (q_{dep}) of Each Time Interval of the Day

	Worst (1)	Poor (2)	Good (3)	Best (4)
00:00 – 01:59	313 (32.5%)	445 (46.3%)	139 (14.4%)	65 (6.8%)
02:00 – 03:59	434 (45.2%)	376 (39.1%)	120 (12.4%)	32 (3.3%)
04:00 – 05:59	735 (76.4%)	108 (11.2%)	112 (11.7%)	7 (0.7%)
06:00 – 07:59	125 (13.0%)	211 (22.0%)	412 (42.8%)	214 (22.2%)
08:00 – 09:59	89 (9.2%)	101 (10.5%)	303 (31.5%)	469 (48.8%)
10:00 – 11:59	23 (2.4%)	85 (8.8%)	504 (52.4%)	350 (36.4%)
12:00 – 13:59	137 (14.3%)	378 (39.3%)	340 (35.3%)	107 (11.1%)
14:00 – 15:59	242 (25.2%)	285 (29.7%)	211 (21.9%)	224 (23.2%)
16:00 – 17:59	80 (8.3%)	109 (11.3%)	518 (53.9%)	255 (26.5%)
18:00 – 19:59	38 (4.0%)	43 (4.5%)	388 (40.3%)	493 (51.2%)
20:00 – 21:59	87 (9.1%)	73 (7.6%)	358 (37.2%)	444 (46.1%)
22:00 – 23:59	84 (8.7%)	115 (12.0%)	412 (42.8%)	351 (36.5%)

The table shows that respondents strongly preferred morning and early evening departures. Afternoon and mid-day flights were not found to be attractive most probably because such timings would disrupt the utilisation of the day. As expected, respondents did not welcome late night departures. Table 7.8 below shows the consolidated view of the q_{dep} scores from 1 to 4 for each time interval. It is observed from the table that the worst quality time interval continues for 4 hours within the day, whereas poor, good and best times last 6, 8 and 6 hours respectively.

Table 7.8: Consolidates View of the q_{dep} Scores

Worst (Score 1)	Poor (Score 2)	Good (Score 3)	Best (Score 4)
02:00 – 03:59 04:00 – 05:59	00:00 – 01:59 12:00 – 13:59 14:00 – 15:59	06:00 – 07:59 10:00 – 11:59 16:00 – 17:59 22:00 – 23:59	08:00 – 09:59 18:00 – 19:59 20:00 – 21:59

7.7. Arrival Time Quality (q_{arr})

The survey asked respondents to rate the quality of each arrival time interval throughout the day. Passengers rated arrival time quality as follows:

Table 7.9: Arrival Time Quality Score (q_{arr}) of Each Time Interval of the Day

	Worst (1)	Poor (2)	Good (3)	Best (4)
00:00 – 01:59	411 (42.7%)	358 (37.2%)	122 (12.7%)	71 (7.4%)
02:00 – 03:59	753 (78.3%)	174 (18.1%)	30 (3.1%)	5 (0.5%)
04:00 – 05:59	813 (84.5%)	105 (10.9%)	41 (4.3%)	3 (0.3%)
06:00 – 07:59	202 (21.0%)	416 (43.3%)	233 (24.2%)	111 (11.5%)
08:00 – 09:59	18 (1.9%)	224 (23.3%)	331 (34.4%)	389 (40.4%)
10:00 – 11:59	9 (0.9%)	243 (25.3%)	434 (45.1%)	276 (28.7%)
12:00 – 13:59	78 (8.1%)	233 (24.2%)	299 (31.1%)	352 (36.6%)
14:00 – 15:59	80 (8.3%)	179 (18.6%)	398 (41.4%)	305 (31.7%)
16:00 – 17:59	84 (8.8%)	133 (13.8%)	336 (34.9%)	409 (42.5%)
18:00 – 19:59	18 (1.9%)	255 (26.5%)	382 (39.7%)	307 (31.9%)
20:00 – 21:59	162 (16.8%)	366 (38.1%)	288 (29.9%)	146 (15.2%)
22:00 – 23:59	172 (17.9%)	393 (40.9%)	305 (31.7%)	92 (9.5%)

The table suggests that passengers largely preferred morning and afternoon arrivals, and they found late night arrivals unpopular. Factors such as day utilisation, hotel check-in time, availability of public transport facilities were influential in determining the attractiveness of each arrival time interval. Table 7.10 below shows the consolidated view of the q_{arr} scores from 1 to 4 for each time interval. It is observed in the table that the day is split evenly among scores.

Table 7.10: Consolidates View of the q_{arr} Scores

Worst (Score 1)	Poor (Score 2)	Good (Score 3)	Best (Score 4)
00:00 – 01:59	06:00 – 07:59	10:00 – 11:59	08:00 – 09:59
02:00 – 03:59	20:00 – 21:59	14:00 – 15:59	12:00 – 13:59
04:00 – 05:59	22:00 – 23:59	18:00 – 19:59	16:00 – 17:59

7.8. Maximum Connection Time (MaxCT) Determination

The survey asked passengers to indicate their maximum connection time tolerance when connecting from one flight to another at the hub airport. The split of responses was as follows:

Table 7.11: Respondents MaxCT Preferences

	Number of Respondents Marked	Per cent share
Up to 2 hours	127	13.2%
Up to 3 hours	202	21.0%
Up to 5 hours	465	48.3%
Up to 8 hours	138	14.4%
Connection time is less important than other factors	30	3.1%
Total	962	100%

As per the results, almost half of the participants, 48.3% of the whole set, stated their maximum tolerance to be 5 hours at the hub airport, while 13.2% of passengers ticked a very short MaxCT duration of 2 hours. 3.1% of the participants indicated that MaxCT could not be an influential factor in their decision-making process. The weighted average technique was used to calculate the average MaxCT of the whole respondents as follows: (nominal value of 12 hours is assumed for the last option in which 30 respondents stated no MaxCT preference.)

$$\frac{((2\ hrs\ x127)+(3\ hrs\ x202)+(5\ hrs\ x465)+(8\ hrs\ x138)+(12\ hrs\ x30))}{962} = 4.83\ hours$$

Translating 4.83 hours into minutes, it was found that passengers on average could tolerate an approximate maximum of 290 minutes of t_{conn} at the hub airport. In case the nominal value of “connection time is less important than other factors” option was determined to be 9 hours, the average MaxCT would be calculated as 284.3 minutes. On the other hand, if it was set to be 15 hours, the global average MaxCT would be equal to 295.5 minutes. In the extreme case, if all the respondents ticking the “connection time is less important than other factors” option can tolerate to wait 24 hours at the hub airport, which is very unlikely, the global average MaxCT would be computed as 312.4 minutes. As the survey question text refers to “up to 8 hours” in the previous option, participants ticking this choice are expected to wait between 9 and 24 hours. Therefore, the calculated global average of MaxCT could range between 284.3 and 312.4 minutes and it is likely that the maximum tolerance of the 30 participants ticking this option would not converge to 24 hours, but rather towards 9 hours. Since the text of the question’s last option does not specify an exact maximum time, 12 hours can be regarded as a credible assumption and 290 minutes of global MaxCT can appropriately be used.

Although airport-related factors like duty-free stores, CIP lounges and other amenities could extend or shrink the MaxCT, 290 minutes could be defined as the global average MaxCT value as the question did not refer to any such parameters. Furthermore, itinerary or passenger-specific reasons like travel purpose, flight duration and etc may shape the MaxCT tolerance of the consumers. The survey results have shown that 14.4% of the respondents state a longer MaxCT tolerance than the calculated 290 minutes and 3.1% of the passengers do not actually seem to attach any importance to that parameter. Since the REMSET model, whose methodology is covered in Chapter 8 and 9 requires the MaxCT as an input parameter it was essential to come compute a global average MaxCT figure. However, as the REMSET model is designed with an adaptable scheme implying that the model could be re-run with varying input factors including MaxCT, the calculated global average MaxCT of 290 minutes is to be used as the default value of the model, as to be explained in Chapter 10.

It would be beneficial to perform the same analysis for different passenger profiles in order to examine how their responses differed from the global average MaxCT value. The below table demonstrates the computed weighted average MaxCT figures for different passenger groups.

Table 7.12: Weighted MaxCT for Different Consumer Profiles

Segment	Weighted MaxCT	Minutes
Passengers who had connecting flight experience in the past five years	4.77 hours	~ 286
Passengers who had a connecting flight with limited connecting time experience in the past five years	4.92 hours	~ 295
Passengers who travelled in business and premium economy class in the past years	4.17 hours	~ 257
Passengers for whom fare is the most or second important decision parameter (Response 1 or 2 for the fare in Question 4)	5.03 hours	~ 302
Passengers for whom schedule convenience is the most or second important decision parameter (Response 1 or 2 for date and time convenience in Question 4)	4.79 hours	~ 287
Standard deviation (including global MaxCT)	15 minutes	

The table suggests that there was no significant divergence (standard deviation of 15 minutes) between the global average MaxCT and the weighted MaxCT of the introduced segments. The calculated MaxCT for those prioritising flight convenience within their decision-making process was reported to be very similar to the global average, lasting 287 minutes. On the other hand, passengers who had a business class and premium economy flight experience indicated a relatively smaller MaxCT, totalling to 257 minutes. Naturally, with 302 minutes, the price sensitive segment reported a higher tolerance for longer connection times.

7.9. Buffer Time (t_{buffer}) Request

The survey asked respondents a direct question to investigate whether they required a buffer time on top of the airports' official MCT. The responses were as follows:

Table 7.13: Responses to t_{buffer} Request Question

	Number of Respondents Marked	Share
No extra time required	97	10.1%
MCT + 15 minutes	216	22.5%
MCT + 30 minutes	414	43.0%
MCT + 45 minutes	132	13.7%
MCT + 1 hour	60	6.2%
MCT + more than 1 hour	43	4.5%
Total	962	100%

Table 7.13 suggests that approximately 90% of the passengers demanded additional time on top of the airports' MCT. This is indeed a critical finding, implying that a vast majority of the passengers did not find the airport's official minimum connection time adequate enough to ensure a smooth and hassle-free connecting flight experience. A buffer time would enhance passenger's convenience by inhibiting the stress they would feel due to a potential late arrival of the inbound flight to the hub or due to any disruption at the intermediary airport like passport clearance, transfer facilities, boarding pass re-printing and other formalities.

According to the results, 22.5% of the respondents demanded 15 minutes buffer time while 43% required at least half an hour. The share of the passengers demanding more than half an hour was around a quarter of the whole set (13.7% demanded 45 minutes, 6.2% one hour and 4.5% asked for more than an hour). Assuming the last option stating more than one hour refers to 75 minutes, the weighted average of the demanded t_{buffer} was calculated as;

$$\frac{((0\ min\ x 97) + (15\ min\ x\ 216) + (30\ min\ x\ 404) + (45\ min\ x\ 132) + (60\ min\ x\ 60) + (75\ min\ x\ 43))}{962}$$

$$= 29.2\ minutes$$

If the last option was assumed to refer to 90 minutes (instead of 75 minutes), the weighted average t_{buffer} would increase to 29.8 minutes. It is therefore possible to conclude that the survey respondents demanded approximately half an hour more than the airports' official MCT, on average, to mitigate the risks of missing a connecting flight and boost journey convenience. Similar to the discussion in MaxCT determination, although a global average of

29.2 minutes of t_{buffer} is calculated, as per the survey results, almost a quarter of the respondents demand at least 45 minutes buffer time. Consumers' preference for buffer time request may vary depending on their individual circumstances and their itineraries such as journey purpose. However, for the sake of using a default t_{buffer} value as part of the REMSET model, t_{buffer} = 29.2 minutes is employed. Table 7.14 presents the calculated t_{buffer} value for different passenger groups.

Table 7.14: Weighted t_{buffer} for Different Consumer Profiles

	t_{buffer}
Passengers who had a connecting flight experience in the past five years	29.7 minutes
Passengers who had a connecting flight with limited connecting time experience in the past five years	30.1 minutes
Passengers who travelled in business and premium economy class in the past five years	26.3 minutes
Passengers for whom fare is the most or second important decision parameter (Response 1 or 2 for the fare in Question 4)	29.8 minutes
Passengers for whom schedule convenience is the most or second important decision parameter (Response 1 or 2 for date and time convenience in Question 4)	28.8 minutes
Standard deviation (including global t_{buffer})	1.39 minutes

Table 7.14 reports limited divergence within the segments; with a standard deviation of 1.39 minutes only. Passengers who experienced a connecting journey with a limited connection time demanded the highest t_{buffer} duration of 30.1 minutes, a figure not far off the global average.

7.10. Codeshare Flight Convenience

In order to benchmark and quantify the value of a codeshare flight compared to an operating service, passengers were asked to mark under which of the following circumstances presented in the table below they would favour the codeshare flights. The replies are summarised in Table 7.15.

Table 7.15: Responses to Codeshare Flight Convenience Question

	Number of Respondents Marked	Per cent share
I'd never choose a codeshare flight	316	32.9%
I'd only choose if I had no other choice	238	24.7%
I might choose a codeshare flight if more convenient	227	23.6%
It does not matter to me	181	18.8%
Total	962	100%

The results suggested that almost one-third of all respondents did not have a positive attitude towards the codeshare flights, indicating that it could never be a choice in their itinerary. On the other hand, 18.8% of participants stated that they are indifferent to codeshare flights. Approximately one-fourth of the whole set expressed that they would only prefer a codeshare flight in their itinerary if there were no other option whereas 23.6% of the passengers took a pragmatic perspective and specified that if it is more convenient, they could pick a codeshare flight. The below figures demonstrate the responses of the different consumer segments.

Figure 7.1. Passengers with an Experience of a Codeshare Flight in the Past Five Years.

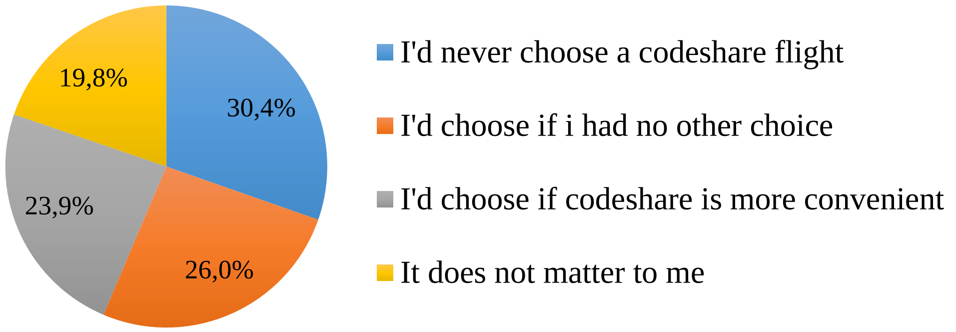


Figure 7.2. Passengers for whom Schedule Convenience is the Most or Second Important Decision Parameter (Response 1 or 2 for date and time convenience in Question 4.)

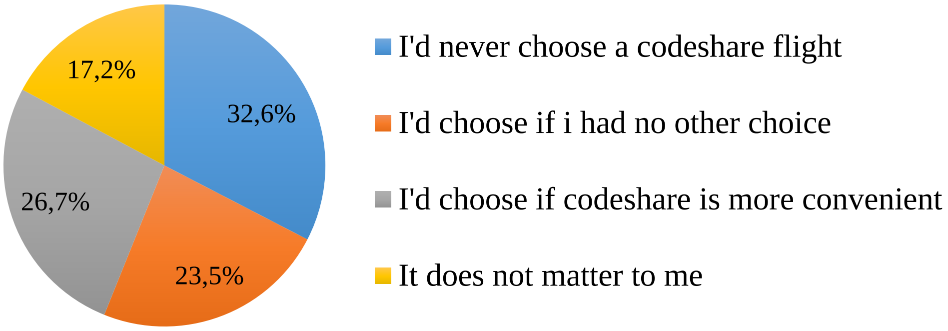


Figure 7.1 and 7.2 indicate that passengers who had experienced codeshare flights in the past five years were not as unwilling to have such flights in their itineraries. While 34% of the respondents lacking a codeshare flight experience indicated that they would never choose a codeshare flight, this figure was 30.4% for those who had previously travelled on a codeshare flight. Furthermore, participants who ranked schedule convenience as one of the top essential decision factors of itinerary choice reported a 26.7% preference for the codeshare flights, a share higher than the general average of 23.6%, if it was more convenient.

It is clear from the results that compared to an online/operating flight, passengers do not have an equal degree of appreciation for codeshare flights. In sum, only less than half of participants were sympathetic to travelling on codeshare flights under limited circumstances. Therefore, from the consumers' standpoint, it can be stated that the perceptional value of a codeshare flight is not equal to the value of an operating flight.

7.11. Fare, Schedule Convenience and Flight Type Relation

To develop a high-level understanding concerning the passengers' preference over fare, routing and type combination, Question 10 was asked whose responses are disclosed in Table 7.16 below.

Table 7.16: Responses to Question 10 – Preference on fare, routing and type combination

	Number of Respondents Marked	Per cent share
A direct flight with my favourite airline costing $$$$	207	21.5%
A codeshare direct flight operated by an airline other than my choice costing $$$	216	22.4%
A connecting (longer) flight with my favourite airline costing $$$	294	30.6%
A connecting (longer) flight with an airline other than my regular choice costing $$	245	25.5%
Total	962	100%

As per the table, only 21.5% of all participants would pay the highest fare for a direct and operating flight whereas 25.5% of the passengers marked the cheapest option offering longer connecting and non-operating service. Among two flight options with the same fare level, 294 of them contributing to 30.6% of all participants picked a longer flight operated with passengers' favourite airline, whereas 22.4% of the consumers preferred the shorter codeshare flight. This finding crystallised that the majority of respondents would accept travel on a longer operating flight even though a direct codeshare alternative was present at the same price level. In Table 7.17, different customer groups within the participant set were identified, and their responses to question 10 reported to observe if any variation existed among different profiles.

Group 1 – Passengers for whom fare was the most or second important decision parameter (Response 1 or 2 for fare in Question 4)

Group 2 – Passengers for whom schedule convenience was the most or second important decision parameter (Response 1 or 2 for date and time convenience in Question 4)

Group 3 – Passengers who had a codeshare flight experience in the past five years

Group 4 – Passengers who had a codeshare AND connecting flight experience in the past five years.

Table 7.17: Above Defined Groups' Responses to Question 10

	Group 1	Group 2	Group 3	Group 4
A direct flight with my favourite airline costing $$$$	%19.1	%25.8	%20.6	%22.0
A codeshare direct flight operated by an airline other than my choice costing $$$	%21.4	%23.4	%21.7	%21.9
A connecting (longer) flight with my favourite airline costing $$$	%31.0	%28.7	%31.9	%29.8
A connecting (longer) flight with an airline other than my regular choice costing $$	%28.5	%22.1	%25.8	%26.3

The results show that even for the group prioritising schedule convenience over the other factors, barely more than 1/4th of respondents chose the most expensive direct and operating flight alternative. On the other hand, the cheapest connecting codeshare flight option was chosen by 28.5% per cent of the price-sensitive participants prioritising fare. These results imply that passengers' preferences did not accumulate to their segments' suitable flight alternative, deeming the itinerary details in terms of routing and type to be quite crucial during their decision-making process. Furthermore, it was apparent with the results that for all customer profiles, at the same price level, a connecting but operating flight was comparably preferred over a direct but codeshare alternative.

7.12. Values of Different Flight Options (u_{do}, u_{co}, u_{dc}, u_{cc})

As explained in Chapter 4, the perceived value of a flight alternative can be best reflected by the maximum fare the passengers are willing to pay for that product. Therefore, referencing a base scenario in which the price of a connecting flight from City A to City B via City C with inconvenient departure and arrival times, taking 18 hours, was fixed as 500 USD; respondents were asked to mark the maximum fare they would be willing to pay for different itinerary scenarios. The choices were presented as fare intervals where the cheapest option was shown as "< 400 USD", implying less than 400 USD and the most expensive option as "> 700 USD", implying higher than 700 USD. In between 400 USD and 700 USD, each option was determined with 50 USD intervals. The monetary value while calculating the weighted average fare of each alternative was assumed as follows:

Table 7.18: Monetary Values of the Options for Q11

Options	Monetary Value
< 400 USD	350 USD
400 USD - 450 USD	425 USD
451 USD - 500 USD	475 USD
501 USD - 550 USD	525 USD
551 USD - 600 USD	575 USD
601 USD - 650 USD	625 USD
651 USD - 700 USD	675 USD
> 700 USD	750 USD

As Table 7.18 demonstrates, with exception to the smallest and highest fares, the monetary value of the preferred option was assumed to be the median value in the range. For the cheapest option depicted by "< 400 USD", the value was fixed as 350 USD whereas for the most expensive shown by "> 700 USD", 750 USD was used. The respondents were asked to rate following flight cases:

Case 1: A Connecting Flight with Convenient Departure and Arrival Times Taking 18 Hours: The only variation from the base scenario was the convenience of departure and arrival times. This product was still a connecting itinerary with a total travel time of 18 hours, as in the base case.

Table 7.19: Participants Responses to Case 1

Options	# Marked
< 400 USD	1
400 USD - 450 USD	16
451 USD - 500 USD	12
501 USD - 550 USD	253
551 USD - 600 USD	578
601 USD - 650 USD	64
651 USD - 700 USD	32
> 700 USD	6
Total	962

Weighting the participants' responses with the identified monetary values of the options depicted in Table 7.18, the average fare, and thus the value of this flight scenario, was calculated to be 565.61 USD. This finding implied that respondents were ready to pay 65.61 USD more, contributing to 13.1% of the base case value, for an itinerary with better departure and arrival times.

Case 2: A Direct Flight Taking 12 Hours with Convenient Flight Times: This itinerary deviated from the base scenario, as it was a direct flight rather than a connecting one and therefore offered a shorter t_{total} which was 6 hours less. On the other hand, unlike the base case, this itinerary was seen to have a better departure and arrival time quality. The maximum fares that respondents would be willing to pay for this itinerary are depicted in Table 7.20.

Table 7.20: Participants Responses to Case 2

Options	# Marked
< 400 USD	0
400 USD - 450 USD	3
451 USD - 500 USD	2
501 USD - 550 USD	22
551 USD - 600 USD	79
601 USD - 650 USD	281
651 USD - 700 USD	332
> 700 USD	243
Total	962

Weighting the above responses with the assumed monetary values of the options shown in Table 7.18, the average fare and thus the value of this flight scenario was calculated to be 666.50 USD. It is deduced from this finding that passengers were ready to pay 166.50 USD more than the base case, contributing to a 33.3% rise in fare for a direct flight with better q_{dep}, q_{arr} and shorter t_{total}.

Case 3: A Direct Flight Taking 12 Hours with Inconvenient Flight Times: This itinerary only differed from the previous scenario with respect to worse q_{dep} and q_{arr}. The respondents' maximum fare mapping is illustrated in Table 7.21 below:

Table 7.21: Participants Responses to Case 3

Options	# Marked
< 400 USD	4
400 USD - 450 USD	13
451 USD - 500 USD	79
501 USD - 550 USD	96
551 USD - 600 USD	167
601 USD - 650 USD	299
651 USD - 700 USD	187
> 700 USD	117
Total	962

The weighted average value of this flight option was computed as 615.09 USD. This fare was 51.41 USD less than the previous itinerary, which presented more convenient departure and arrival times. These finding implied that for direct flights, the survey respondents were ready to pay 8.4% more for better departure and arrival times (calculated by contrasting the result of Case 2 with Case 3).

Case 4: A Codeshare-connecting Flight with Convenient Flight Times Taking 18 Hours: In order to assess the divergence of a codeshare flight's perceived value in comparison to online flights, survey participants were presented with a scenario in which the journey would be carried out by a codeshare connecting flight with convenient flight times. The duration of the travel was presented to be identical with the base case, 18 hours. The results were retrieved as follows:

Table 7.22: Participants Responses to Case 4

Options	# Marked
< 400 USD	110
400 USD - 450 USD	705
451 USD - 500 USD	122
501 USD - 550 USD	4
551 USD - 600 USD	11
601 USD - 650 USD	3
651 USD - 700 USD	7
> 700 USD	0
Total	962

Weighting the above responses with the assumed monetary values of the options shown in Table 7.22, the average fare and thus the value of this flight scenario was calculated to be 427.33 USD. Comparing this figure with the computed value of an online connecting and conveniently scheduled itinerary (Case 1), respondents would pay 138.28 USD less for a codeshare flight, contributing to 24.4%.

Case 5: A Codeshare-connecting Flight with Inconvenient Flight Times Taking 18 Hours: This itinerary deviated from Case 4 in the quality of departure and arrival times, offering a relatively unappreciated schedule. The maximum that respondents would be willing to pay for such itinerary was shown in the table below:

Table 7.23: Participants Responses to Case 5

Options	# Marked
< 400 USD	401
400 USD - 450 USD	483
451 USD - 500 USD	70
501 USD - 550 USD	5
551 USD - 600 USD	3
601 USD - 650 USD	0
651 USD - 700 USD	0
> 700 USD	0
Total	962

These replies corresponded to an average value of 398.36 USD for a codeshare connecting itinerary taking 18 hours with inconvenient q_{dep} and q_{arr}. This figure was 101.64 USD less than the base case, corresponding to 20.3%, where the flight was operated by the airline of choice, with all other parameters such as the duration and route identical, and in both case's q_{dep} and q_{arr} were unattractive.

Case 6: A Codeshare Direct Flight Taking 12 Hours with Convenient Flight Times: Participants' responses for this itinerary was collected as shown in Table 7.24 below:

Table 7.24: Participants Responses to Case 6

Options	# Marked
< 400 USD	57
400 USD - 450 USD	196
451 USD - 500 USD	155
501 USD - 550 USD	414
551 USD - 600 USD	117
601 USD - 650 USD	12
651 USD - 700 USD	11
> 700 USD	0
Total	962

The weighted average value of this flight option was calculated as 495.24 USD. This value was considerably lower than what respondents would pay for a direct online service. However, it is worth emphasising that the value attributed to this itinerary was 15.9% higher than Case 5, a connecting codeshare flight with a convenient schedule.

Case 7: A Codeshare Direct Flight Taking 12 Hours with Inconvenient Flight Times: Participants' responses for this itinerary was reported as follows:

Table 7.25: Participants Responses to Case 7

Options	# Marked
< 400 USD	117
400 USD - 450 USD	658
451 USD - 500 USD	101
501 USD - 550 USD	52
551 USD - 600 USD	30
601 USD - 650 USD	3
651 USD - 700 USD	1
> 700 USD	0
Total	962

The weighted average of the above responses corresponded to 432.09 USD which was 12.7% less than the previous case that presented a codeshare direct flight itinerary case with more convenient q_{dep} and q_{arr}.

The respondents' answers to the seven cases outlined above presented a clear picture concerning the relative values of different flight alternatives. The respondents offered the opportunity to assess the incremental changes in the value of a scenario when the itinerary changed from an inconvenient q_{dep} and q_{arr} to a convenient one. On the other hand, the difference in the value between connecting vs direct and operating vs codeshare flights could be assessed quantitatively. Since the flight times in whole connecting journeys were set to 18 hours and 12 hours for the direct trips, a clear benchmark was made to assess the relative superiorities and values of different flight choices. Therefore, the relative values of u_{do}, u_{co}, u_{dc}, u_{cc} were identified for convenient and inconvenient departure and arrival times seperately. Table 7.26 demonstrates the perceived value of flights based on the responses above.

Table 7.26: Consolidated View of the Calculated Weighted Average Fares

	Connecting Flight		Direct Flight	
	Operating	Codeshare	Operating	Codeshare
Convenient Time	565.61	427.33	666.50	495.24
Inconvenient Time	500.00	398.36	615.09	432.09

Indexing base case to 1.00, the above table was translated to determine the values of u_{do}, u_{co}, u_{dc}, u_{cc} for convenient and inconvenient departure and arrival times separately as shown in Table 7.27 below.

Table 7.27: u_{do}, u_{co}, u_{dc}, u_{cc} Determination for Convenient and Inconvenient q_{dep} and q_{arr}

	Connecting Flight		Direct Flight	
	Operating (u_{co})	Codeshare (u_{cc})	Operating (u_{do})	Codeshare (u_{dc})
Convenient Time	1.131	0.854	1.333	0.990
Inconvenient Time	1.000	0.796	1.230	0.864

7.13. Flight Time Split of the Connecting Journey

For connecting journeys, the phase at which the journey is split at the connecting airport was argued to be a potential determinant of passenger choice. This statement was tested through a question in the survey in which a long haul connecting travel case with 10 hours of t_{total} was introduced and the t_{conn} at the hub airport was fixed to be 1 hour. The reply options, whose results are presented Table 7.28 below, indicated to have varying durations for the first and second legs where the total flight time summed to 9 hours and the total journey time was fixed to be 10 hours for each option.

Table 7.28: Responses to Question 12 – Flight Time Split of the Connecting Journeys

	Number of Respondents Marked	Per cent share
First leg 8 hours, second leg 1 hour	392	40.7%
First leg 6 hours, second leg 3 hours	72	7.5%
First leg 3 hours, second leg 6 hours	54	5.6%
First leg 1 hours, second leg 8 hours	335	34.8%
It does not matter to me at all	109	11.3%
Total	962	100%

It is inferred from Table 7.28 that more than 88% of the respondents care how their itinerary was shaped in terms of first and second leg duration split, therefore affirming the hypothesis that connecting travellers care when their journey is interrupted by the connection. Survey participants reported a tendency to prefer itineraries that are interrupted by the connection either at the very initial phases or towards the very end of their journey. For a journey of 10 hours in which the sum of first and second legs' flight time to be 9 hours, 40.7% of the respondents marked that they would prefer the first leg's duration to be 8 hours while the second segment's is 1 hour. This was probably so that they could get sleep or work uninterruptedly on the first leg with no hassle of changing aircraft soon. On the other hand, more than one-third of participants preferred changing flights at the very early stages, by taking the 1-hour flight first and 8 hour-long one later. The share of respondents who preferred the split towards the middle phases of the journey was found to be reasonably lower.

7.14. Flight Time or Connecting Time (%t_f or %t_c)

In order to determine whether passengers would favour waiting at the hub airport rather than spending time on board, the survey presented a case in which the respondents chose between two alternatives. Both itineraries offered 12 hours of t_{total} , where one option had 1-hour t_{conn} and the other 3 hours. The results were obtained as displayed in Table 7.29.

Table 7.29: Participants' Response to Question 13

	Number of Respondents Marked	Per cent share
Connecting flight total 12 hours of journey time of which 3 hours are spent at the hub airport	498	51.8%
Connecting flight total 12 hours of journey time of which only 1 hour is spent at the hub airport	464	48.2%
Total	962	100%

It is clear from the responses that the participants did not present a clear perspective whether they preferred waiting at the airport rather than flying as the preference percentages of both options were found to be close to each other. It would also be beneficial to observe the variation of those responses for different segments to observe if any tendency existsed. For this purpose, the following groups were identified and their responses to this question was assessed in Table 7.30:

Group 1 – Passengers for whom fare is the most or second important decision parameter (Response 1 or 2 for fare in Survey Question 4)

Group 2 – Passengers who travelled in business and premium economy class in the past years

Group 3 – Passengers for whom schedule convenience is the most or second important decision parameter (Response 1 or 2 for date and time convenience in Question 4)

Table 7.30: Above-Defined Groups' Responses to Question 13

	Group 1	Group 2	Group 3
Connecting flight total 12 hours of journey time of which 3 hours are spent at the hub airport	231 (51.0%)	195 (54.3%)	139 (51.1%)
A Connecting flight total 12 hours of journey time of which only 1 hour is spent at the hub airport	222 (49.0%)	164 (45.7%)	133 (48.9%)

The table above confirms that there was only limited divergences within the preferences of the defined groups. Therefore, it can be concluded that respondents did not report a particular preference towards $\%t_f$ or $\%t_c$ given the same total travel time. Appendix B includes the results of the survey venue airport breakdown.

7.15. General Comments on Survey Results

This Chapter has addressed the survey findings. The questionnaire revealed plenty of useful information, which was utilised as part of the research's proposed methodologies that are covered in the following Chapters.

The survey analyses have also validated that schedule convenience is indeed an essential factor of consumers' itinerary decision. Indeed, this finding asserted the necessity of this research, as the study aimed to assess schedule and network efficiency from a consumer-centric perspective. Furthermore, the goal in conducting the survey was attained as the values of the investigated parameters were successfully measured and quantified. Although the exact value of some parameters like MaxCT and t_{buffer} may change from one passenger to another depending on the specific circumstances of the consumer and the itinerary such as fare, length of haul, journey purpose and etc., the survey results have offered valuable insights to come up with single values of those parameters that are to be utilised as input factors of the REMSET model. As REMSET model is designed to be parametric, the impact of those parameters to the research outputs would easily be assessed by changing the relevant input parameters. Therefore, such parameter results obtained from the survey analyses have offered the default values of the factors that would be used as part of the REMSET model as to be covered in Chapter 10. The value of the analysed paramaters and the final decision concerning the inclusion of those parameters in the research models are summarised in Table 7.32 below.

Table 7.32: Summary of the Key Survey Findings

Parameter	Survey Finding	Used in the models?
MaxCT	290 minutes	Yes
t_{buffer}	29.2 minutes	Yes
q_{dep}	1 (Worst) → 02:00 – 03:59, 04:00 – 05:59 2 (Poor) → 00:00 – 01:59, 12:00 – 13:59, 14:00 – 15:59 3 (Good) → 06:00 – 07:59, 10:00 – 11:59, 16:00 – 17:59, 22:00 – 23:59 4 (Best) → 08:00 – 09:59, 18:00 – 19:59, 20:00 – 21:59	Yes
q_{arr}	1 (Worst) → 00:00 – 01:59, 02:00 – 03:59, 04:00 – 05:59 2 (Poor) → 06:00 – 07:59, 20:00 – 21:59, 22:00 – 23:59 3 (Good) → 10:00 – 11:59, 14:00 – 15:59, 18:00 – 19:59 4 (Best) → 08:00 – 09:59, 12:00 – 13:59, 16:00 – 17:59	Yes
u_{do}	Varies between 1.230 – 1.333 depending on schedule convenience	Yes
u_{co}	Varies between 1.000 – 1.131 depending on schedule convenience	Yes
u_{dc}	Varies between 0.864 – 0.990 depending on schedule convenience	Yes
u_{cc}	Varies between 0.796 – 0.854 depending on schedule convenience	Yes
f_{split}	Passengers preferred their journey to be interrupted by the connection either at the very early or late stages of the flight	Yes
$\%t_f$ and $\%t_c$	Not found to be critical parameters given the same t_{total}	No

Although the survey results have provided indispensable information concerning consumer preferences, they are not completely free from potential biases. First of all, as a significant majority of the survey administrators were working for Turkish Airlines, they primarily approached the carrier’s customers in the check-in queue when asking their willingness to participate. Although other carriers’ passengers were also surveyed, a large majority of the participants were Turkish Airlines customers. As the survey did not ask whether the participants were a loyal customer of any airline, any probable over dominance of one carrier's (loyal) passengers' responses in the result set might have biased the survey results. On the other hand, the language of some questions could be considered as a source bias. For instance, Question 8 contains unneurtral terms like "challenging", "irregularity", "late arrival", "misconnect", "stressed" and "stressful". These strong and perceptionally "negative" terms might have biased the responses of the participants. Additionally, this question is predicted on passenger knowledge on the MCT value for the corresponding airports. Although the survey administrators ensured that the participants have knowledge concerning the MCT, it is extremely likely for passengers not to know the exact MCT of the airports which might raise concerns regarding potential biases on the results.

However, such sources of bias do not change the fact that the survey results have provided insightful and credible information which are to be used as integral input parameters of the research models. It should be noted that, the models to be introduced in this research in the following Chapters are highly adaptable and therefore the survey results are to be used as default values of the adaptable variables, demonstrating proof of concept, rather than being strictly definitive in a dynamic market. Therefore, the survey responses are used to determine the default input parameters of the REMSET model which could later be adapted to other values. The next chapter focuses and elaborates on how these findings are incorporated into the schedule attractiveness assessment methodology.

Chapter 8: Network Performance Model Development – Capacity Share

8.1. Introduction

This research aimed to develop a consumer-focused methodology to analyse the schedule and network performance of air services. In this context, the study has contributed to knowledge by introducing a unique passenger perspective to the schedule efficiency analysis models. The previous Chapter covered the results of the passenger survey which formed an essential basis of the design of this research's models. The analyses retrieved from surveying 962 respondents in 9 different airports have provided essential inputs for an effective and customer-centric methodology design.

The Objective 1 of this research involved the determination of a consumer-centric capacity share estimation model that uses airline schedule information and "consumer perspectives" as the input to produce consumer-centric capacity shares for each O&D as the output. The resulting capacity shares are not an indicator of competing airlines' physical supply performance but illustrate relative performance in "sellable capacity" by identifying the "feasible" and "viable" products from a consumer's perspective. The Objective 2 of the study was to quantify schedule quality of air services, which also required a separate methodology demanding the airline schedules as well as "consumer perspectives" as the input in order to yield schedule quality scores of each carrier as the output. The ability to compute quality scores enables a benchmarking of each itinerary's relative schedule quality performance and translates the abstract concept of "convenient" or "inconvenient" schedule quality into numbers. Using consumer-focused capacity shares and quality scores, realistic market shares of airlines competing in a market could also be forecasted, which serves as the Objective 3 of the research. The realistic market share estimation tool, the REMSET, assesses the relative performance of an airline's schedule & network efficiency. It is therefore a concrete parameter of consumers' appreciation towards airlines' services on certain O&Ds. Thus, the accuracy of the REMSET model plays a central role in attaining the research's aim.

The intended outputs from the introduced models of the research were (i) passenger-centric supply shares, (ii) quality scores and (iii) realistic market share estimations for each carrier operating on an O&D. The Objective 4 of this research was built upon these outputs and intended to guide industry practitioners by offering them an effective decision support tool. The following diagram illustrates the research's methodology concerning its input variables and the outputs.

Figure 8.1: The Input and Outputs of the Consumer-centric Supply Share and Quality Score Determination Models

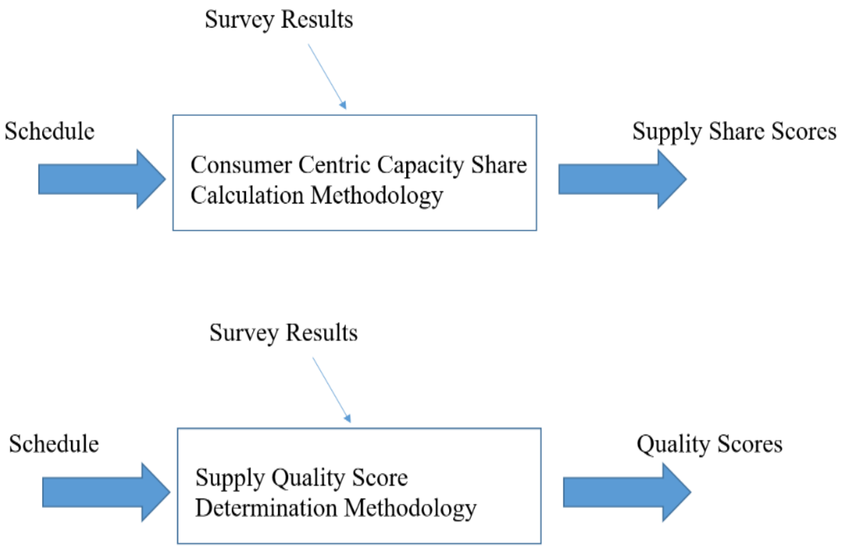
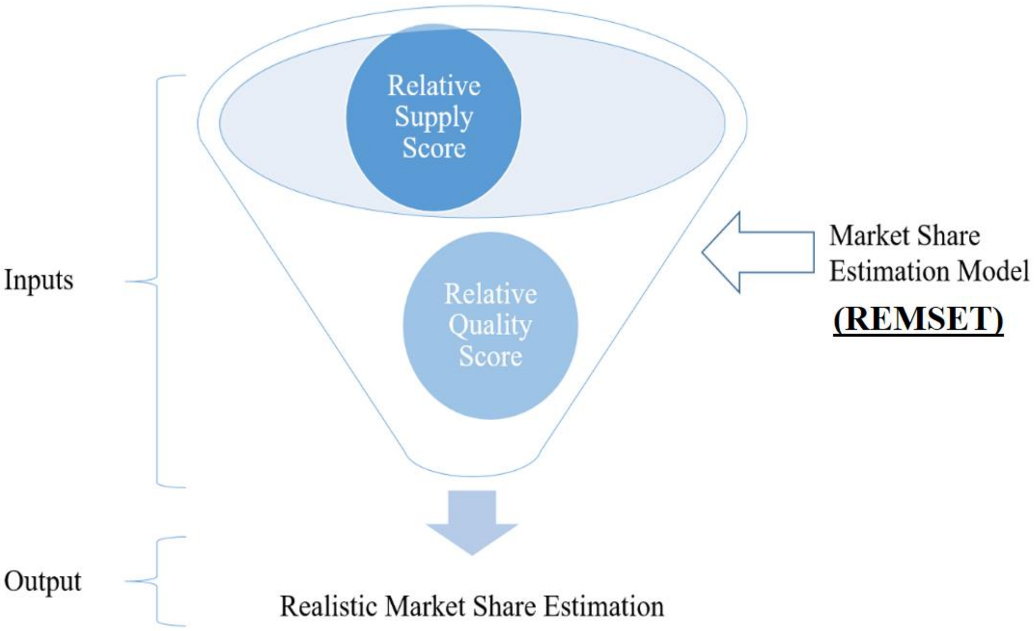


Figure 8.2: The Input and Outputs of the REMSET Model



As depicted in Figures 8.1 and 8.2, three methodologies were introduced in this research. The first methodology serves for the fulfilment of Objective 1 which results with the consumer-centric supply shares, whereas the second methodology serves to fulfil Objective 2 by returning the relative quality scores of the competing itineraries. The third methodology, the REMSET, produces realistic market share estimations, aiming to accomplish the Objective 3.

The survey results confirmed that the schedule convenience is the most critical factor in passenger choice after fare. It was discussed in the literature review that the traditional schedule efficiency measurement methods, such as QSI, are mainly mathematical models severely lacking a consumer perspective, with their outputs potentially proving to be far from being realistic. This and the following chapter together address and introduce all of the models depicted in Figures 8.1 and 8.2 which are expected to yield realistic schedule convenience assessments that better reflect market dynamics. Chapters 8 and 9 together iterate through the design steps of the proposed methodologies by employing sample schedule data. While this chapter elaborates on the first model by producing supply share scores of the competing itineraries in an O&D, the proceeding chapter covers the second model and the REMSET.

The capacity share computation procedure elucidated upon in this chapter is considerably different from traditional methods and far from being strictly mathematical. It involves plenty of consumer preference metrics while defining the products available for sale in the market. This chapter commences by introducing quantification of available supply and moves forward with capacity share calculation for each of airline contending in a market.

8.2. Determination of Available Products in an O&D

There may be multiple air services of different carriers on a particular O&D. As long as a product is available for sale in a market, it has a capacity share which is analysed in this Chapter. Moreover, each available capacity in a market has a particular quality score and market share estimation, as presented in Chapter 9. Therefore, the definition of the itineraries that could be regarded as an available product on an O&D was a crucial commencement point of the model. In the proceeding sections, each available product in a market is categorised by its routing (direct or connecting) or operation type (operating or codeshare).

As previously explained, a product is only available in a market if there exists either a direct flight or a connecting service with a connecting time (t_{conn}) larger than or equal to the minimum connecting time (MCT) of the hub airport. Technically, so long as t_{conn} is greater than the MCT, a hit is attained, enabling the connecting service. Although theoretically the maximum waiting time at a hub airport (MaxCT) for connecting journeys is not bound by a threshold, it would not be appropriate to expect itineraries with a very long t_{conn} to be an available product in the market as such flights would not be appreciated nor preferred by passengers. The literature review suggested that there is an upper bound of MaxCT tolerance at a hub airport. The passenger survey validated this argument and calculated MaxCT to be 4.83 hours or 290 minutes. Therefore, connecting itineraries that requires passengers to wait more than 290 minutes at a hub were found to be unattractive and not welcomed by the consumers. For this reason, the set of available connecting products competing in a market were needed to be adjusted to include this finding. Therefore, as part of the supply share determination model, although all connections that have a t_{conn} greater than or equal to the MCT are valid itineraries, connections having t_{conn} greater than 290 minutes had to be eliminated from the available products set. This is a major deviation of the model from the existing product determination methods used in the industry. Consequently, a product is valid (i) for all direct services and (ii) for all connecting services via a hub in which t_{conn} is greater than the hub airports' MCT and less than 290 minutes. A flight combination with t_{conn} more than or equal to the hub airport's MCT and less than 290 minutes is referred as a valid "hit" or “combination”. Only valid hits were included in total frequency and seat count computation.

The survey results have suggested that more than 90% of respondents preferred a buffer time (t_{buffer}) on top of the airports' official MCTs. The global average of the requested t_{buffer} was calculated to be 29.2 minutes. It could be argued that when determining hits, rather than using $t_{conn} >= \text{MCT}$ criteria, $t_{conn} >= (\text{MCT} + t_{buffer})$ could be used. However, although t_{buffer} is undoubtedly a vital matter of passenger convenience, it is a quality factor rather than a condition of attaining a hit. Any connection which is higher than the MCT but lower than the (MCT + t_{buffer}) is still a valid hit and available for sale by the airlines. Such connections may even be displayed in the higher rankings of the GDS systems. Therefore, t_{buffer} was used in defining the quality of connecting journeys rather than being used in supply determination. On the other hand, in case t_{conn} is greater than the MaxCT, although a connection is still technically achieved and such itineraries could be sold in the reservation systems, they were not counted as valid products as part of this model, as the MaxCT was defined as the maximum acceptable cut-off limit of t_{buffer}. Therefore when identifying relevant hits, MaxCT was used but t_{buffer} was not. t_{buffer} was used in the quality assessment of connecting itineraries.

8.3. Capacity Assessment

The consumer-centric capacity share calculation methodology was expected to return adjusted supply shares of the carriers contending in the market among the available products in an O&D, abbreviated by $\%_{a\_s}$. Letter "a" within "$\%_{a\_s}$" refers to the "adjustment" in the parameter, while "s" relates to seat supply and "%" denotes that it is a percentage parameter. The following sections iterate through the computation steps of $\%_{a\_s}$. Although at first glance, the capacity determination regarding frequency and seat supply seems like a straightforward mathematical process, insertion of the consumer perspective moderately complicates the procedure. All capacity supply assessments were made at the weekly level. Since an airline's schedules is planned and repeated weekly, the performance assessments and fair market share estimations had to be made at the weekly level too.

8.3.1. Determination of Hits/Combination & Frequency

An airline's frequency in a market is simply the sum of its physical operating flights and the codeshare frequencies offered on behalf of the carrier. Therefore, for an airline *i*, the weekly frequency on an O&D is formulated as:

$$f_{i\_O\&D} = f_{op\_i\_O\&D} + f_{codeshare\_i\_O\&D}$$

where $f_{i\_O\&D}$ is the sum of weekly frequencies for airline *i* on the O&D, of which $f_{op\_i\_O\&D}$ refers to the number of operating weekly frequencies for the carrier *i* and $f_{codeshare\_i\_O\&D}$ is the weekly codeshare frequencies marketed by the airline i on the same route. The total weekly frequency available in a market for all airlines, $f_{O\&D}$, is then formulated as

$$f_{O\&D} = \sum_{i=1}^{n} f_{(i\_O\&D)}$$

where *n* denotes the total number of airlines serving the selected O&D. In other words, the sum of distinct weekly services of all carriers in a market adds up to the total frequency count of the market. The following sections iterate through the calculation of operating and codeshare frequencies which together add up to $f_{O\&D}$.

8.3.1.1. Determination of Operating Frequencies

The total weekly operating frequency of an airline *i* on an O&D is the sum of its direct and connecting frequencies, formulated as;

$$f_{op\_(i\_O\&D)} = f_{op\_direct\ (i\_O\&D)} + f_{op\_connecting\ (i\_O\&D)}$$

The total operating frequency of all airlines $f_{op\_(O\&D)}$ in the market is $\sum_{i=1}^{n} f_{op\_(i\_O\&D)}$ where *n* refers to the total number of airlines operating on that particular O&D. Direct operating service frequency of airline *i*, $f_{op\_direct\_(i\_O\&D)}$, denotes the number of weekly distinct direct frequencies from origin to destination.

The computation of operating connecting service frequency, $f_{op\_connecting\_(i\_O\&D)}$, is relatively different as the frequencies of the inbound and outbound flights within an itinerary may differ, as one inbound flight may be connected to multiple outbound flights. As previously referred to, for a connection to be a successful "hit" or "combination", t_{conn} must be lower than the MaxCT, which is equal to 290 minutes, and higher than the MCT to get involved in the $f_{op\_connecting\_(i\_O\&D)}$ computation. Hence, only connections meeting t_{conn} >= MCT and t_{conn} <= 290 minutes (MaxCT) criteria, are included in the frequency calculation process. In Table 8.1, an example connecting flight is displayed, assuming all combinations satisfy the t_{conn} >= MCT and t_{conn} <= MaxCT criteria.

Table 8.1: Case - Connecting Frequency Determination (Operating Flight Case)

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)	Connecting Hits (From origin to destination)
XX1 XX2 XX3 Total frequencies : 3	YY1 Total Frequency: 1	XX1/YY1 XX2/YY1 XX3/YY1 Total Hits : 3
AA1 AA2 Total Frequencies: 2	BB1 BB2 BB3 Total Frequencies : 3	AA1/BB1 AA1/BB2 AA1/BB3 AA2/BB1 AA2/BB2 AA2/BB3 Total Hits: 6

Although in the first case (row), the outbound flight numbered YY1 is the only available flight that can take passengers to the destination, for a traveller at the origin, the airline can display three different flight options and possibly three different flight fares for sale: they are XX1–YY1, XX2–YY1 and XX3–YY1 combinations. On the other hand, for the second case, the airline can display six different combinations and possibly 6 different fares as there are two inbound and three outbound frequencies. Supposing that one of the hits fails to meet t_{conn} >= MCT and t_{conn} <= 290 minutes (MaxCT) criteria for the second case (row), then it would not be considered as a valid hit and the total number of combinations would fall to 5. Therefore, the total number of operating connecting hits can be denoted as:

$$\sum_{x\,=\,1}^{x\,=\,count(f\_op(i\_origin/hub))} \sum_{y\,=\,1}^{y\,=\,count(f\_op(i\_hub/destination))} \begin{cases} 1, \text{if } MCT_{hub} <= t_{conn(x\_y)} \text{ and } t_{conn(x\_y)} <= 290 \\ 0, \text{otherwise} \end{cases}$$

where $count(f\_op(i\_origin/hub))$ is the count of operating inbound frequencies from origin to hub, $count(f\_op(i\_hub/destination))$ is the number of operating outbound frequencies from hub to destination, MCT_{hub} is the minimum connecting time at the hub airport where the inbound and outbound flights are connected, and $t_{conn(x\_y)}$ is the connection time between flight x and y.

Different from the number of hits, the physical frequency for connecting journeys is the minimum of the first or second leg's physical frequency count. For the examples given in Table 8.1, in the first case, only YY1 can take the passenger to the destination, limiting $f_{op\_connecting\_(i\_O\&D)}$ to one. For the second case, although there are 6 hits present, the physical frequency from origin to destination is limited to 2 as there are only two distinct flights from the departure city while there are three flights from hub to destination.

As previously explained, capacity related parameters are calculated on a weekly basis. Therefore, to assess the weekly frequency, the calculations mentioned above need to be performed for each day of the week and later summed up. The total weekly operating frequency for an airline *i* can be formulated as

$$\sum_{day=Monday}^{day\,=\,Sunday} f_{op\_(i\_O\&D\_day)}$$

where the operating frequencies of the seven days of the week for airline *i* are summed together. Furthermore, the total weekly frequency of all airlines competing in a market can be formulated as

$$\sum_{i=1}^{n} \sum_{day=Monday}^{day\,=\,Sunday} f_{op\_(i\_O\&D\_day)}$$

which is equal to

$$\sum_{i=1}^{n} \sum_{day=Monday}^{day\,=\,Sunday} f_{op\_direct\,(i\_O\&D)} + f_{op\_connecting\,(i\_O\&D)}$$

where *n* refers to the total number of airlines competing in the market.

For direct flights, the simple sum of each day's physical frequencies determines the weekly count of $f_{op\_direct\_(i\_O\&D)}$. However, to calculate the weekly $f_{op\_connecting\_(i\_O\&D)}$, a more in-depth analysis is mandatory as it is essential to identify the days of the week that successful hits are attained. Revisiting the examples in Table 8.1, to determine the weekly connecting frequency, let's suppose for the first case, XX1, XX2, XX3 and YY1 are all operated once a day, each offering seven frequencies per week. For the second case, it is assumed that BB1, BB2 and BB3 are operated once daily too, but AA1 is operated twice a week on Mondays and Tuesdays while AA2 is operated once a week only on Fridays. Table 8.2 shows the connecting frequency and hit assessment under these circumstances assuming that all connections are valid, satisfying t_{conn} >= MCT and t_{conn} <= 290 minutes (MaxCT) criteria.

Table 8.2: Case - Connecting Frequency and Hit Determination (Operating Flight Case)

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)	Connecting Hits (From origin to destination)
XX1 - operated daily XX2 - operated daily XX3 - operated daily	YY1 - operated daily	XX1/YY1 - connected daily XX2/YY1 - connected daily XX3/YY1 - connected daily Distinct Hits : 3 Total Weekly Hits: 21 Total Weekly Frequency: 7
AA1 - Monday, Tuesday AA2 - Friday	BB1 - operated daily BB2 - operated daily BB3 - operated daily	AA1/BB1 - Monday, Tuesday AA1/BB2 - Monday, Tuesday AA1/BB3 - Monday, Tuesday AA2/BB1 - Friday only AA2/BB2 - Friday only AA2/BB3 - Friday only Distinct Hits: 6 Total Weekly Hits: 9 Total Weekly Frequency: 3

In the first case, 21 different product combinations can be sold to passengers per week. However, since YY1 is the only available flight to the destination daily, the weekly

$f_{op\_connecting\_(i\_O\&D)}$ is equal to seven. For the second case, although BB1, BB2 and BB3 are all operated daily, AA1 is operated twice and AA2 once per week, only three successful frequencies per week is achieved as there are no available connecting products on Wednesdays, Thursdays and the weekends. Since on Monday and Tuesday, AA1 can be connected to all three outbound flights whereas AA2 can connect them only on Fridays, 9 different flight combinations can be offered to passengers every week. Moreover, as the inbound flight frequency is limited to three, the total weekly frequency is also computed to be three.

8.3.1.2. Determination of Codeshare Frequencies

The frequency calculation procedures for operating and codeshare flights are identical. From a scheduling professional's standpoint, a service can either be in the form of an online flight or a codeshare one. Therefore, the methodology for assessing the non-operating flight frequency is indifferent in comparison to online flights and thus can be formulated as follows for an airline *i*:

$$f_{codeshare\_(i\_O\&D)} = f_{codeshare\_direct\ (i\_O\&D)} + f_{codeshare\_connecting\ (i\_O\&D)}$$

It is essential to note that a codeshare frequency of a carrier is at the same time an operating frequency of another airline. On the other hand, an operating frequency of a carrier may at the same time be the codeshare frequency of one or multiple carriers. The partnered frequencies are displayed both in the operating and marketing carriers' inventories on the reservation systems. Since the total number of available frequencies in a market is composed of the operating and codeshare frequencies, the resulting total frequency would be more than the physical number of frequencies if at least one codeshare frequency is present on an O&D. In other words, because codeshare frequencies are simultaneously the operating frequencies of another carrier, the existence of at least one codeshare frequency in a market would result in $f_{O\&D}$ being higher than the physical frequency supply.

In case at least one segment in a connecting itinerary is a codeshare flight, then the whole journey was defined as a non-operating (codeshare) service by this research. As 32.9% of the survey respondents stated that they would not choose a codeshare flight and 24.7% suggested that they would only choose such flights if there were no other choice, such a definition would be relevant as the findings implied that consumers do not appreciate non-operating services. Therefore, the existence of at least one codeshare leg in a connecting itinerary would deem the entire journey to be a non-operating service. Table 8.3 demonstrates the journey type based on the status of the first and second leg.

Table 8.3: Journey Type Mapping Table

Leg 1: Org. to Hub (Inbound Flight)	Leg 2: Hub to Des. (Outbound Flight)	Whole Journey
Codeshare	Codeshare	Codeshare
Codeshare	Operating	Codeshare
Operating	Codeshare	Codeshare
Operating	Operating	Operating

As Table 8.3 implies, all codeshare-codeshare, codeshare-operating and operating-codeshare hits are all included in total codeshare connecting frequency count formulated as;

$$\sum_{x=1}^{x = count(f\_code(i\_origin/hub))} \sum_{y=1}^{y = count(f\_code(i\_hub/destination))} \begin{cases} 1, if\ MCT_{hub} <= t_{conn(x\_y)}\ and\ t_{conn(x\_y)} <= 290 \\ 0, otherwise \end{cases}$$

$$+ \sum_{x=1}^{x = count(f\_code(i\_origin/hub))} \sum_{y=1}^{y = count(f\_op(i\_hub/destination))} \begin{cases} 1, if\ MCT_{hub} <= t_{conn(x\_y)}\ and\ t_{conn(x\_y)} <= 290 \\ 0, otherwise \end{cases}$$

$$+ \sum_{x=1}^{x = count(f\_op(i\_origin/hub))} \sum_{y=1}^{y = count(f\_code(i\_hub/destination))} \begin{cases} 1, if\ MCT_{hub} <= t_{conn(x\_y)}\ and\ t_{conn(x\_y)} <= 290 \\ 0, otherwise \end{cases}$$

Similar to the procedure with the operating flights, non-operating frequency count is determined at the weekly level where the fewer number of frequencies limit the physical frequency supply in the O&D formulated as $\sum_{i=1}^{n} \sum_{day=Monday}^{day = Sunday} f_{codeshare\_(i\_O\&D\_day)}$ which is equal to $\sum_{i=1}^{n} \sum_{day=Monday}^{day = Sunday} f_{codeshare\_direct\ (i\_O\&D)} + f_{codeshare\_connecting\ (i\_O\&D)}$

8.3.1.3. Determination of Total Frequency Count

As the total number of frequencies available in a market should be reported on a weekly basis, it can formulated as

$$\sum_{i=1}^{n} \sum_{day=Monday}^{day = Sunday} f_{(i\_O\&D\_day)}$$

which is equivalent to

$$\sum_{i=1}^{n} \sum_{day=Monday}^{day\,=\,Sunday} f_{op\_(i\_O\&D\_day)} + \sum_{i=1}^{n} \sum_{day=Monday}^{day\,=\,Sunday} f_{codeshare\_(i\_O\&D\_day)}$$

where n is the total number of airlines operating in that particular O&D. The example in Table 8.4 demonstrates the total connecting frequencies for two different cases for a specific day where both operating and non-operating services are present. It is assumed that all connections are valid hits, meeting the MCT and MaxCT criteria.

Table 8.4: Total Frequency and Hit Calculation for Two Cases (Shown in Each Row)

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)	Connecting Hits (From origin to destination)
BB1 - operating CC1 - codeshare BB2 - operating Total frequencies : 3	YY1 - operating Total Frequency: 1	Operating Hits : BB1/YY1, BB2/YY1 Codeshare Hits : CC2/YY1 Total Hits: 3 (2 operating, one codeshare)
EE1 - codeshare EE2 - codeshare Total frequencies: 2	UU1 - operating TT1 - codeshare TT2 - operating Total Frequency: 1	Operating Hits : None Codeshare Hits : EE1/UU1, EE1/TT1 EE1/TT2, EE2/UU1 EE2/TT1, EE2/TT2 Total Hits: 6 (All codeshare hits)

As illustrated in Table 8.4, although there exists two physical operating frequencies in the first case and none for the second case, there are 3 and 6 hits available for sale within the carriers' inventory respectively. Assuming all flights in the table are operated daily from Monday to Sunday, the total weekly frequency would be 7 for the first case with three hits present each day. For the second case, total weekly frequency count would be 14 available for sale via 6 hits each day.

8.3.2. Determination of Seat Supply

Total seat capacity refers to the sum of available seats for sale on a specific O&D. Airlines offer seats in a market through one or multiple direct frequencies in addition to successful connecting hits. The physical seat supply in the market is equal to the number of seats supplied through the operating frequencies. However, there are also codeshare seats for the marketing carriers. Although codeshare seats are already included in the operating seat count, they are still counted in the overall seat supply count of the O&D because of the reasons outlined in section 8.3.2.2. Therefore total seat supply in a market for airline *i* is formulated as

$$s_{(i\_O\&D)} = s_{op\_(i\_O\&D)} + s_{codeshare(i\_O\&D)}$$

where $s_{op\_(i\_O\&D)}$ refers to the operating seat supply of the airline *i* and $s_{codeshare\_(i\_O\&D)}$ denotes its codeshare seat supply.

8.3.2.1. Determination of Operating (Physical) Seat Supply

The total physical/operating seat capacity of an airline in an O&D is the sum of its operating-direct and operating-connecting services' seat supply. Therefore, the total operating seat supply of an airline *i* in a market for a specific day is calculated as follows:

$$s_{op\_(i\_O\&D\_day)} = s_{op\_direct\,(i\_O\&D\_day)} + s_{op\_connecting\,(i\_O\&D\_day)}$$

The total operating seat count of all airlines competing in an O&D for a given day is $\sum_{i=1}^{n} s_{op\_(i\_O\&D\_day)}$ where *n* refers to the total number of airlines operating in that particular market.

For direct flights, the total seat supply from a particular origin to destination can be extracted through available seat capacity per frequency (s_f) times the frequency. The formulation of operating direct seat supply for an airline *i* on an O&D can be formulated as:

$$s_{op\_direct\,(i\_O\&D\_day)} = f_{op\_direct\,(i\_O\&D\_day)} \text{ x } s_{f\,(i\_O\&D)}$$

However, the determination of seat supply for the connecting journeys is a relatively complex process. The challenge in the determination of $s_{op\_connecting\,(i\_O\&D)}$ stems from the fact that there is no physical capacity commitment of a connecting hit from origin to destination as there are no direct services between those routes. Thus, the allocation of seat capacity of each leg composing the itinerary is a matter of subjectivity for connecting flights. Moreover, $s_{f\,(i\_O\&D)}$ can be different for the first and second leg of a connecting itinerary. For instance, a wide-body aircraft can perform the inbound flight from origin to hub while a narrow-body aircraft with relatively fewer number of seats per frequency can be assigned to the outbound flight from hub to destination.

In order to address the capacity allotment challenge for the connecting itineraries, as previously addressed in Chapter 2, a coefficient, named *connecting seat factor* symbolised with s_{conn}, was introduced. s_{conn} is a value between 0 and 1, denoting the maximum percentage of capacity that could be allocated for a connecting destination. If s_{conn} is zero, no seating capacity is assigned to connecting passengers, where in the other extreme if it is 1, all capacity is allocated to them. For the sake of the proposed model, a single s_{conn} could be defined for all O&D pairs. It is essential to state that the capacity allotted for connecting itineraries is rather a definitive assumption within physical capacity which does not take away from the capacity allotted to direct services. For example, a flight from Oslo to Rome can welcome passengers from Helsinki who travelled to Oslo for a connection to Rome. The same flight can host passengers originating from Hamburg or elsewhere, whose intention is to fly Rome via Oslo. Each flight from multiple origins arriving in Oslo and attaining a successful connection to Rome can get a seat in the Oslo-Rome flight. Seats allocated to connecting itineraries would surge the calculated seat supply since the connecting capacities are not defined to take away from the physical capacity of the flight from Oslo to Rome.

Supposing a connecting journey from City A to City B with the following seat supply for the first and second leg which are connected to each other as valid hits, the connecting seat capacity calculation is performed as shown in Table 8.5.a, 8.5.b and 8.5.c.

Table 8.5.a. Available Seats of the Legs Composing the Hits from City a to City B

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)	Connecting Hits (From origin to destination)
XX1 - total seat: 100 XX2 - total seat: 120 XX3 - total seat: 150	YY1 - seat: 70	XX1–YY1 XX2–YY1 XX3–YY1

Assuming s_{conn} to be 10% or 0.1, the available seats for the connecting passengers travelling from City A to B is 10 for flight XX1, 12 for XX2, 15 for XX3 and 7 for YY1, as summarised in the table below:

Table 8.5.b: The Seats Allotted to Connecting Journeys Under s_{conn} = 10% Assumption

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)
XX1 - connecting seat: 10 XX2 - connecting seat: 12 XX3 - connecting seat: 15	YY1 - connecting seat: 7

It is clear from the above table that the outbound flight YY1 only has seven-seat capacity for passengers arriving from City A through XX1, XX2 and XX3, while in these flights a total of 37 (10+12+15) travellers could have arrived in a hub airport waiting to be transported to City B via YY1. However, as shown in the table below, the seating capacity of YY1 is only limited to 7, creating a bottleneck in the O&D capacity, therefore limiting the $s_{op\_connecting\ (A-B)}$ from City A to B to only 7.

Table 8.5.c: Final Connecting Seat Capacity for the Itinerary of the Sample Case

Connecting Hits (From origin to destination)	Total Connecting Seats
XX1 – YY1 : connect seat = 7 XX2 – YY1 : connect seat = 7 XX3 – YY1 : connect seat = 7	= 7 as YY1 forms the capacity constraint

Additionally, the connecting physical frequency count from A to B is only one, as YY1 is the sole frequency to City B. Therefore, one physical frequency is available for sale via three different combinations offering a total of 7 seats in the market.

The seat computation of another example for a connecting journey from City C to City D is shown in Table 8.6, with multiple numbers of inbound and outbound flights where all connections are assumed to be valid hits and s_{conn} = 0.1. As per the case, two inbound flights with different seat capacities which can be connected to three distinct outbound services.

Table 8.6: Available Seats from City C to City D

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)	Connecting Hits (From origin to destination)
AA1 - total seats : 100 AA2 - total seats : 120 -- AA1 - connect seats : 10 AA2 - connect seats : 12	BB1 - total seats : 200 BB2 - total seats : 250 BB3 - total seats : 110 -- BB1 - connect seats : 20 BB2 - connect seats : 25 BB3 - connect seats : 11	AA1–BB1 : connect s = 10 AA1–BB2 : connect s = 10 AA1–BB3 : connect s = 10 AA2–BB1 : connect s = 12 AA2–BB2 : connect s = 12 AA2–BB3 : connect s = 11

For the first three hits (AA1–BB1, AA–BB2 and AA–BB3), the seat capacity of AA1 forms the capacity-constraint. Therefore these combinations contributes by only 10 seats to the supply from City C to D. Although BB1, BB2, BB3 flights have adequate seats to accommodate more passengers to City D, AA1 can only host 10 connecting passengers maximum to City D. In the following two combinations, (AA2–BB1, AA2–BB2), the seat capacity of AA2 forms a seat constraint, limiting the maximum supply of these hits to 12 seats. Whilst for the AA2–BB3 hit only 11 seats can be allotted for passengers intending to travel from City C to City D, it does not form a bottleneck since the remaining passenger of AA2 could either be transported by BB1 or BB2, which already has a space to accommodate the passenger. In sum, all those six hits offer $s_{op\_connecting\,(C-D)}$ = 22 available seats from City C to City D.

Supposing AA2–BB1 and AA2–BB2 combinations are NOT valid hits in which a successful connection is not attained, the capacity of BB3 would be the capacity constraint for AA2–BB3 combination, limiting its seat supply to 11. Including the hits of AA1 flights, where their connecting seat supply was calculated to be 10 for three combinations, the available seat count in the market would be reduced to 21. In other words, AA2–BB1 and AA2–BB2 hits contribute to seat availability by only one passenger.

Moving from the examples illustrated above, the pseudo formulation of an operating connecting seat supply for airline *i* on a specified O&D, $s_{\text{operating\_connecting (i\_O\&D)}}$ for a given day can be summarised as follows:

```
determine if the number of outbound frequencies is less than or equal to outbound flights for
airline i
    if the above statement is true
        for each outbound frequency  j
            for each inbound frequency k
                take    a = minimum (s_j * s_conn, s_k * s_conn)
                put     list(x) = a
            next
             find the maximum value in the list(x)
                add this number to connecting seat supply
        next
    end if
    else
        for each inbound frequency    j
            for each outbound frequency k
                take    a = minimum (s_j * s_conn, s_k * s_conn)
                put     list(x) = a
            next
             find the maximum value in the list(x)
                add this number to connecting seat supply
        next
end if
```

In this pseudo formulation, s_j refers to operating seat from origin to hub, and s_k refers to the operating seat amount from hub to destination.

Similar to the frequency calculation, total seat supply is also reported on a weekly basis. Therefore, in order to calculate the weekly seat supply, the above calculations should be performed for each day of the week and later summed up. The total operating weekly seat supply of an airline *i* on a specified O&D can then be denoted as

$$\sum_{\text{day=Monday}}^{\text{day = Sunday}} \mathrm{s}_{\text{op\_(i\_O\&D\_day)}}$$

where the operating seats of the seven days are summed together. The total weekly operating seat supply of all airlines competing on a route is $\sum_{i=1}^{n} \sum_{day=Monday}^{day\,=\,Sunday} s_{op\_(i\_O\&D\_day)}$ where *n* is the total number of airlines operating on that particular O&D. Making the substitution, the total available operating seats in a market can alternatively be stated as follows:

$$\sum_{\text{i=1}}^{\text{n}} \sum_{\text{day=Monday}}^{\text{day = Sunday}} \mathrm{s}_{\text{op\_direct(i\_O\&D\_day)}} + \mathrm{s}_{\text{op\_conn(i\_O\&D\_day)}}$$

Supposing flight XX1, XX2, XX3 and YY1, illustrated in Tables 8.5.a are operated daily under the same s_{conn} = 10% assumption, available seats per week would be equal to 7 x 7 = 49. Table 8.7 adjusts the case in 8.5 by assuming flights on different days of the week.

Tables 8.7: Weekly Timetable and Seat per Frequency for Flights from City C to D.

Inbound flights (From origin to hub)	Outbound flight (From hub to destination)
AA1 - total seats: 100 (operated Mo, Tu, Sa) AA2 - total seats : 120 (operated Fri, Sa) -- AA1 - connect seats: 10 AA2 - connect seats : 12	BB1 - total seats: 200 (operated Mo, We, Fri, Sa, Su) BB2 - total seats: 250 (operated Mo, Tu, We, Fri, Sa) BB3 - total seats: 110 (operated Mo, Tu, We, Fri, Su) -- BB1 - connect seats: 20 BB2 - connect seats : 25 BB3 - connect seats : 11

Using the information above, Table 8.8 is constructed to demonstrate the number of hits, frequencies and seat count for each day of the week. As Table 8.8 shows, 54 weekly seats are offered from City C to City D in 6 distinct hits in 5 different frequencies, sold in 14 weekly combinations.

Table 8.8: Daily Summary of Hits, Frequencies and Seat Supply for Services from City C to D

	Combinations	Frequency & Seats
Monday	AA1/BB1, AA1/BB2, AA1/BB3	1 frequency (AA1 bottleneck) 10 seats (AA1 bottleneck) 3 hits
Tuesday	AA1/BB2, AA1/BB3	1 frequency (AA1 bottleneck) 10 seats 2 hits
Wednesday	N/A	No frequency, seat and hits
Thursday	N/A	No frequency, seat and hits
Friday	AA2/BB1, AA2/BB2, AA2/BB3	1 frequency (AA2 bottleneck) 12 seats (AA2 bottleneck) 3 hits
Saturday	AA1/BB1, AA1/BB2, AA1/BB3 AA2/BB1, AA2/BB2, AA2/BB3	2 frequencies (AA1, AA2 bottleneck) 22 seats 6 hits
Sunday	N/A	No frequency, seat and hits
Total	6 hits- (AA1/BB1,AA1/BB2,AA1/BB3,AA2/BB1,AA2/BB2, AA2/BB3) 5 weekly frequency (Mo: 1, Tu: 1, Fr: 1, Sa: 2) 54 weekly seats 14 combinations available for sale per week (Mo: 3, Tu: 2, Fr: 3, Sa: 6)	

8.3.2.2. Determination of Codeshare Seat Supply

As explained in earlier Chapters, determining the seat supply for codeshare flights is not a straightforward process as it is merely impossible for third parties to access and extract the details of codeshare agreements among carriers, which are most of the time bilateral. Although it is possible to determine on which routes and frequencies airlines share the capacity, as the marketing carriers place their designated code on the operating carriers' flights, the number of seats allocated to the marketing airline cannot be known by the third parties. As covered in Chapter 2, it is assumed that the marketing carrier cannot sell more than a pre-specified percentage of the operating flights' seat inventory. Therefore, a coefficient, s_{code} was introduced, whose value can vary between 0 and 1. A zero s_{code} implies no seat allocation for the marketing carrier, whereas if s_{code} is equal to 1 all seat capacity of the operating flight is allotted for sale by the marketing airline. Therefore, while the seat supply on the operating carrier is equal to the actual physical capacity, the supply offered by the marketing carrier is a virtual supply that is available for sale.

The codeshare agreements can be in soft-block space format, in which the marketing carrier can return the unsold seats to the operating carriers' inventory, or in hard-block space scheme, where the marketing carrier cannot concede the unsold seats back and are therefore required to pay for each allotted seat. As such details of the codeshare agreement are not publicly known, when analysing the airlines' total codeshare seat supply, the capacity allotted to a marketing carrier cannot be deducted from the physical inventory. Since both carriers can sell the same capacity on codeshare flights and could even practice overbooking, seats distributed to a marketing airline cannot be subtracted from the operating carrier's physical seat supply set when calculating the total seat supply available for sale in the market.

8.3.2.3. Total Seat Count Calculation & Case Studies

The sum of all seats available for sale for an airline *i* in a given market is $s_{(i\_O\&D\_day)} = s_{direct\ (i\_O\&D\_day)} + s_{connecting\ (i\_O\&D\_day)}$ where,

$$s_{direct\ (i\_O\&D\_day)} = f_{op\_direct\ (i\_O\&D\_day)} * s_{f\ (i\_O\&D)} + \sum_{k=1}^{k=m} (f_{code\_direct\ (i\_O\&D\_day)} * s_{f\ (k\_O\&D)} * s_{code})$$

and,

$$s_{connecting\ (i\_O\&D\_day)} = s_{op\_connecting\ (i\_O\&D\_day)} + s_{code\_connecting\ (i\_O\&D\_day)}$$

where $f_{op\_direct\ (i\_O\&D)}$ refers to the operating frequency for airline *i* on the specified O&D, $s_{f\ (i\_O\&D)}$ is the average seat per frequency, $f_{code\_direct\ (i\_O\&D)}$ is the codeshare frequency amount, $s_{f\ (k\_O\&D)}$ is the average seat supply of operating carrier *k* in the given O&D, and *m* is the number of codeshare flights on the given O&D. Additionally, the pseudo formulation for codeshare connecting seat supply calculation is identical to operating connecting seat calculation except the fact that the result has to be multiplied by the s_{code} factor.

To address the total seat supply on a weekly basis for all flights, including both online and codeshare operations, seat supply must be individually calculated for each day of the week and later summed up, which can be formulated as

$$\sum_{day=Monday}^{day\,=\,Sunday} s_{(i\_O\&D\_day)}$$

denoting the total seat count available for sale for airline *i*, including both operating and codeshare services. Therefore the total seat supply for all airlines contending in a market is equal to $\sum_{i=1}^{n}\sum_{day=Monday}^{day\,=\,Sunday} s_{(i\_O\&D\_day)}$, where *n* is the total number of airlines operating on that particular O&D. The examples below were obtained from the real schedules of the listed airlines and iterate through the steps of the weekly frequency and seat supply computation for various cases:

Case 1: Lufthansa Flights from Geneva (GVA) to Dubai (DXB) as of 2016 - There were no direct flights of Lufthansa from GVA to DXB. However, connecting products were present in the market via Frankfurt (FRA), which has an MCT value of 45 minutes. Under MaxCT = 600 minutes assumption, three hits were identified: 1) LH1213–LH630, 2) LH1215–LH630 and 3) LH1229–LH630 connections as shown in the table below. LH1213, LH1215 and LH1229 flights were operated daily whereas LH630 was operated six times per week, each day excluding Wednesdays. Therefore, the weekly frequency count of these combinations was limited to 6 as all hits are connected via the LH630 flight.

Figure 8.3: Flight Combination from GVA to DXB Under MaxCT = 600 Minutes Assumption.

Flight Combin	Origin	Via (MCT)	Waiting Time	Destination	Freq.	1st Leg	2st Leg	Seats
1213 / 630	Geneva	Frankfurt (45')	03:15	Dubai	6	Op	Op	166
1215 / 630	Geneva	Frankfurt (45')	01:55	Dubai	6	Op	Op	167
1229 / 630	Geneva	Frankfurt (45')	05:50	Dubai	6	Op	Op	167

For the LH1213–LH630 connection, passengers were required to wait 3 hours and 15 minutes in FRA whereas for the LH1215-LH630 connection they needed to spend 1 hour and 55 minutes. For the LH1229–LH630 connection, the transfer time at the hub was 5 hours and 50 minutes. All these durations meet t_{conn} >= MCT as they are all greater than 45 minutes, which is the MCT of FRA, and t_{conn} <= MaxCT criterion as the t_{conn}'s is less than 600 minutes.

The average seats offered in LH1213, LH1215 and LH1229 were 138, 139 and 139 per frequency respectively, whereas the average number of seats on the LH630 flight was 216. Therefore, the inbound service to the hub is capacity constrained in terms of seats offered. Assuming s_{conn} to be 20% or 0.2, the total weekly available seats offered by Lufthansa (LH) on the LH1213–LH630 combination was 166 (138 x 0.2 x 6 = 165.6 rounded to 166) and for LH1215–LH630 and LH1229–LH630 combinations, it is 167 (139 x 0.2 x 6 = 166.8 rounded to 167). However, each combination could only be connected from hub to destination via LH630 which is the capacity-constrained service. Therefore, when counting the total seat supply of LH from GVA to DXB, it is NOT possible to sum up each hit's seat supply individually. Therefore, under s_{conn} = 0.2 assumption, the total weekly seat supply between Geneva and Dubai can at most be 167, which could be sold across 18 different weekly flight combinations.

By changing the MaxCT to 290 minutes, which was our finding in the passenger survey, only two hits could attain a connection from GVA to DXB via FRA, as illustrated in the image below:

Figure 8.4: Flight Combination From GVA to DXB Under MaxCT = 290 Minutes Assumption.

Flight Combin	Origin	Via (MCT)	Waiting Time	Destination	Freq.	1st Leg	2st Leg	Seats
1213 / 630	Geneva	Frankfurt (45')	03:15	Dubai	6	Op	Op	166
1215 / 630	Geneva	Frankfurt (45')	01:55	Dubai	6	Op	Op	167

A reduction in the number of hits would not diminish total seat supply in the GVA-DXB market of LH, as LH630 is the sole capacity from the LH's hub (FRA) to DXB. Therefore, under MaxCT = 290 minutes assumption, the total seat supply in the market would not be reduced but the number of hits that the seats could be sold would fall from 18 to 12. Under the new MaxCT assumption, the number of connecting frequencies in the market would also remain unchanged. Therefore, the summary table of LH services from GVA to DXB under both MaxCTs were as follows:

Table 8.9: Consolidated Frequency and Seat Supply Table From GVA to DXB of LH Flights.

	Operating	Non - operating
Direct	N/A	N/A
Connecting	6 frequency - 167 seats	N/A
Total	6 frequencies and 167 seats	

Case 2: KLM (KL) Flights from Amsterdam (AMS) to Barcelona (BCN) as of 2016 - The direct services of the airline between AMS to BCN are displayed in the table below:

Figure 8.5: Direct Services of KL from AMS to BCN

Flight Number	Origin	Destination	Frequency	Operating
1665	Amsterdam	Barcelona	7	Op
1671	Amsterdam	Barcelona	7	Op
1673	Amsterdam	Barcelona	7	Op
1675	Amsterdam	Barcelona	7	Op
1681	Amsterdam	Barcelona	7	Op
2594	Amsterdam	Barcelona	1	Non Op

As of 2016, there existed 35 direct weekly online frequencies under 5 distinct flight numbers and one codeshare frequency per week. Therefore the total direct frequency between AMS to BCN was 36. The average direct seat capacity per frequency for KL in the AMS–BCN market, $s_{op\_dir\_(KL\_AMS/BCN)}$ was equal to 157 whereas the physical capacity on the codeshare flight, KL2594 was 189. Assuming s_{code} to be 0.3, $s_{code\_direct\_(KL\_AMS/BCN)}$ is obtained to be 56 (189 x 0.3 = 56.7 rounded down to 56). As a result, direct seats of KLM available for sale in the market as of 2016 was 157 x 35 + 56 = 5,551 per week, which could be sold in 36 distinct frequencies.

In 2016, there were also connecting services of KLM from AMS to BCN. Through the codeshare agreements, the airline could connect the two cities via Palma de Mallorca (PMI). Assuming s_{code} = 0.3, s_{conn} = 0.2 and MaxCT = 290 minutes, the connecting hits were found as follows:

Figure 8.6: Connecting Services of KL from AMS to BCN.

Flight Combin	Origin	Via (MCT)	Waiting Time	Destination	Freq.	1st Leg	2st Leg
2673 / 3320	Amsterdam	Palma de Mallorca (45')	04:15	Barcelona	1	Non Op	Non Op
2673 / 3334	Amsterdam	Palma de Mallorca (45')	01:20	Barcelona	1	Non Op	Non Op
2673 / 3352	Amsterdam	Palma de Mallorca (45')	02:00	Barcelona	2	Non Op	Non Op
2675 / 3334	Amsterdam	Palma de Mallorca (45')	01:30	Barcelona	1	Non Op	Non Op
2675 / 3352	Amsterdam	Palma de Mallorca (45')	02:40	Barcelona	1	Non Op	Non Op
2677 / 3334	Amsterdam	Palma de Mallorca (45')	01:10	Barcelona	1	Non Op	Non Op
2679 / 3320	Amsterdam	Palma de Mallorca (45')	04:40	Barcelona	2	Non Op	Non Op
2679 / 3352	Amsterdam	Palma de Mallorca (45')	01:30	Barcelona	2	Non Op	Non Op

As observed in the table, KLM offered codeshare connecting services from AMS to BCN via PMI using 8 different combinations, each having different weekly frequency amount. In order to compute the weekly frequency and seat count, the operations had to be evaluated on a daily basis by taking the s_{code}, s_{conn} and the capacity-constrained flights into consideration. For instance, in the KL2673–KL3320 hit, the physical seats on KL2673 was 189, whereas the figure was 186 for KL3320. Therefore, the seats for this connecting codeshare hit $s_{code\_connecting\_(KL\_AMS/BCN)\_day}$, was 186 x 0.2 ($s_{conn}$) x 0.3 ($s_{conn}$) = 11 (rounded down from 11.16). The following table summarises the services and available seats of the hits for each day of the week.

Table 8.10: Connecting Flights of KL from AMS to BCN – daily view.

Day	Combinations & Connecting Seats
Monday	KL2675–KL3352 - 11 seats
Tuesday	KL2673–KL3334 - 11 seats
Wednesday	KL2673–KL3352 - 11 seats
Thursday	KL2675–KL3334 - 11 seats KL2679–KL3320 - 9 seats KL2679–KL3352 - 9 seats
Friday	KL2677–KL3334 - 11 seats
Saturday	KL2679–KL3320 - 9 seats KL2679–KL3352 - 9 seats
Sunday	KL2673–KL3320 - 11 seats KL2673–KL3352 - 11 seats

As depicted in Table 8.10, on Mondays, Tuesdays, Wednesdays and Fridays, there existed one connecting frequency per day with 11 seats available for sale. For Thursdays, although three hits were present, KL2679 was the capacity constrained flight, therefore limited the availability to 2 frequencies with a total of 20 seats for that day (11 from KL2675/KL3334 and 9 from KL2679/KL3320 & KL2679/KL3352 hits). Although there were two combinations on Saturdays and on Sundays; KL2679 and KL2673 were the single flights from origin to the hub respectively. Therefore, only one connecting frequency was offered at the weekends per day where 9 seats were available for sale on Satudays and 11 seats on Sundays. Therefore, from AMS and BCN, KLM offered eight connecting frequencies with a total of 84 seats available for sale on 11 distinct combinations. The summary supply table of KLM services in the market under $s_{code} = 0.3$, $s_{conn} = 0.2$ and MaxCT = 290 minutes assumptions is as follows:

Table 8.11: Consolidated services table of KLM from AMS to BCN airport.

	Operating	Non - operating
Direct	35 frequency – 5,495 seats	1 frequency - 56 seats
Connecting	N/A	8 frequency - 84 seats
Total	44 frequencies and 5,635 seats. available for sale in 35 direct and 11 connecting combinations	

8.3.2.4. Seat Share Calculation

The per cent physical frequency ($\%_{f\_i}$) and seat ($\%_{s\_i}$) share of an airline *i* competing on a route can be calculated by identifying its per cent supply in the market. A case is illustrated in the table below.

Table 8.12: Frequency, Frequency Share, Available Seat and Seat Share of Airline A and B.

Airline	Frequency	Frequency Share ($\%_f$)	Available Seats	Seat Share ($\%_s$)
A	5	26.3% (= 5/19)	180	39.1% (=180/460)
B	14	73.7% (=14/19)	280	60.9% (=280/460)
Total	19	100%	460	100%

The above table shows the weekly frequency and seat supply for Airline A and B on a particular route and assumes no other airline offers products in the market. As per the case, it is assumed that Airline A serves 5 frequencies per week, once in the weekdays, while Airline B flies twice per day. Airline A holds 26.3% of the frequencies available in the market and 39.1% of the seats. The remaining 73.7% of frequencies and 60.9% of the available seats are offered by the Airline B. Assuming no schedule quality, fare and airline brand differences exist between Airline A and B, it would be natural to expect the market share of Airline A to be 39.1% and Airline B to be 60.9% in an unlimited demand scenario, as the seating capacity would be the sole indicator of the market performance. However, the lack of Airline A's daily services in the market would lead the carrier to lose some market share in case the demand is split to different days of the week. In this case, Airline A would gain no market share for the unserved days, which would be taken by its rival. Therefore, for the sake of capacity matters, an adjustment needs to be performed from the daily service availability perspective.

8.3.2.5. Seat Capacity Share Adjustment Process and Methodology

Not all services from an origin to destination are operated daily. Airlines may prefer not to offer certain flights on particular days of the week due to several reasons, such as demand, aircraft availability, traffic rights, etc. In case the demand is distributed uniformly among each day of the week, and all other parameters shaping the market share of airlines except the capacities are identical, it would not be natural to expect carriers not offering daily services to report proportionate market shares parallel to their seat supply. If an airline does not offer a service on a particular day of the week, the demand would shift to the other airline or airlines serving that day. In case no carriers perform flights on a specific day or days of the week, the demand would shift to other days of the week when the flights are available. Otherwise, if more than one carrier operates on the route, demand would not shift to other days of the week given the existence of alternative product. Therefore, an adjustment needs to be performed with the seat supply shares depending on daily service availability. The adjusted seat shares are denoted as $\%_{a\_s}$ which is the final output parameter of the consumer-centric supply share model, the Objective 1 of this research. The adjustment can be performed using two distinct methodologies.

8.3.2.5.1. Adjustment by Using Daily Seat Shares

The first capacity adjustment method can be performed by using the daily seat shares. If at least one airline offers daily service on an O&D and one or more airlines do not offer daily flights, the seat shares of the non-daily serving airlines need to be transferred to the daily-serving carriers for the non-served days in proportion to serving carriers' seat supply. In the above case shown in Table 8.12, it is assumed that Airline B's 14 frequencies and 280 seats are distributed to each day of the week evenly where at least each day is served by 2 frequencies with 20 seats per frequency, and Airline A offers 5 frequencies per week where each served day gets 36 seats. Therefore, for the two days that Airline A does not offer flights, the demand would shift to Airline B. As a result, for the 2 unserved days of the week, Airline B would gain the entire market, and in the remaining 5 days, Airline B would report 58.8% share (as the carrier owns 20 of the 34 available seats at the weekdays) and Airline A would have 41.2% capacity share. Therefore, the adjusted weekly capacity share, $\%_{a\_s}$, for Airline B is $\frac{(2\ x\ 100\%+5\ x\ 58.8\%)}{7} = 70.6\%$ where the remaining 29.4% share would belong to Airline A. The table then becomes as follows:

Table 8.13: Available Seats, Seat Share and Adjusted Weekly Seat Shares of Airlines A and B.

Airline	Available Seats	Seat Share ($\%_s$)	Adjusted Weekly Seat Share ($\%_{a\_s}$)
A	180	39.1%	29.4%
B	280	60.9%	70.6%

As the distribution of demand throughout the week is out of the scope of this research, an even and uniform demand distribution was assumed throughout the study. The procedure for calculating the adjusted weekly seat share by using daily shares is straightforward. After calculating the daily seat s_i for each airline *i* in a market, the airline or airlines which do not offer daily services are identified. For the non-served days, those airlines would get a zero per cent seat share, whereas the available carriers share the hundred per cent in reference to their seat supply. The mathematical average of each airlines seat share from Monday to Sunday would finally result in the $\%_{a\_s}$. An example follows:

Table 8.14: Daily Seats of Airline C, D and E and Weekly Seat Shares (%s).

Airline	Mon	Tue	Wed	Thu	Fri	Sat	Sun	$\%_s$
C	25	25	25	25	25	25	25	54.7%
D	10	10	10	10	10	10	10	21.9%
E	15	15	15	15	0	0	15	23.4%

Airline C and D operate daily on the route while Airline E lacks flights on Fridays and Saturdays. The total seat supply in the market is 320, where Airline C offers 175/320 = 54.7% of those seats, 70/320 = 21.9% is by Airline D and 75/320 = 23.4% by Airline E. To calculate the adjusted capacity shares, the seat shares are required to be calculated at the daily level as shown in the table below:

Table 8.15: Daily Seat Shares of the Airlines and Adjusted Seat Shares ($\%_{a\_s}$).

Airline	Mon	Tue	Wed	Thu	Fri	Sat	Sun	$\%_{a\_s}$
C	50%	50%	50%	50%	71.4%	71.4%	50%	56.1%
D	20%	20%	20%	20%	28.6%	28.6%	20%	22.5%
E	30%	30%	30%	30%	0%	0%	30%	21.4%

The adjusted seat shares are computed by taking the mathematical average of the daily seat shares for each Airline. It is deduced that Airline E previously had a weekly seat share of $\%_s$ = 23.4, but its share was reduced to 21.4% after the adjustment process. The two per cent that is taken away from Airline E is transferred to Airline C and D, in proportion to their weekly seats. Therefore, Airline C's adjusted share increased by 1.4 points to 56.1%, while Airline D's share raised by 0.6 points to 22.5%.

There exist certain drawbacks with the seat capacity adjustment model. As the model takes the simple averages of the daily per cent capacity shares, it does not take the divergences with the daily sum of seat supplies into account. Simple averaging undermines the impact of daily fluctuations in the total seat availabilities for the analysed O&D. On the other hand, because daily variations in seat capacities are not reflected into the adjustment methodology, it would not be plausible to argue that demand is distributed evenly among each day of the week. For instance, the calculations shown in Table 8.15 infers that the demand for Friday and Saturday is lower compared to other days of the week. Therefore, the second method for the adjustment called "waste capacity discount model" is introduced below.

8.3.2.5.2. Waste Capacity Discount Adjustment Model

The waste capacity discount adjustment model is based on two assumptions: First, the demand is split evenly among each day of the week. Second, if all parameters influencing market share expectations are identical among carriers but the capacities, airlines expect to obtain a market share equal to their weekly capacity shares. These two assumptions together dictate that airlines which do not offer a flight on each day of the week would be wasting some of their capacities for the days that they offer flights. For instance, if an airline X flies to a destination only on Mondays and offers 70 seats on that day, where the other airline Y flies to the same destination with 10 seats each day, although both airlines report the same weekly seat supply, airline X would get a low share. Since airline X operates once per week, only 1/7 of the carrier's seats are to be met by the demand and 10 seats are utilised, where the remaining 60 seats on Mondays are "wasted". Although Airline X may expect all 70 seats of the Monday flights to contribute to its overall market share estimation by assuming that the demand would shift to Mondays, that would not happen as Airline Y offers daily services. For this reason, 6/7 of Airline X's Monday capacity is wasted. Therefore, the total weekly supply in the market is 80 where 10 of them belongs to Airline X and 70 to Airline Y. This implies that the adjusted share $\%_{a\_s}$ of airline X is calculated to be 10/80 = 12.5% and the remaining 87.5% is the adjusted share of airline Y under the waste capacity discount adjustment model.

The adjustment procedure with the waste capacity discount model is as follows: In case at least one airline offers a daily service in the analysed market, the non-daily serving airline *i*'s total weekly seat capacity, s_i, is discounted by z/7 where *z* refers to the number of unserved days of the week. The total discounted amount is then subtracted from the total seat supply of all airlines competing in the market, and the new distribution is calculated based on the subtracted total seat supply, forming the $\%_{a\_s}$. In other words, while keeping the seat supply of daily performing airlines intact, the seat supply of the non-daily performing airlines is discounted which subsequently reduces the overall weekly seat count in the market. The adjusted seat capacity of the above case given in Table 8.14 is as follows with the waste capacity discount model:

Table 8.16: Case for the waste capacity model for Airline C, D and E.

Airline	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Physical	Discounted
C	25	25	25	25	25	25	25	175	175
D	10	10	10	10	10	10	10	70	70
E	15	15	15	15			15	75	53

As per the table above, the total weekly physical seat supply in the market is 320 where Airline C holds 175 of the seats and D and E offer 70 and 75 seats respectively. Since Airline E does not offer services on Fridays and Saturdays, its seat capacity is discounted by 2/7 and thus becomes 75x(1–2/7) = 53 (rounded down from 53.5). The wasted capacity of 75 – 53 = 22 seats is subtracted from the 320 weekly seats, and the new seat supply in the market becomes 320 - 22 = 298. The new capacity table and the adjusted shares are calculated in the table below:

Table 8.17: Weekly Adjusted Seats and Adjusted Share for Airline C, D and E.

Airline	Original Seat (s_i)	Adjusted Seats	Adjusted Cap. Share ($\%_{a\_s}$)
C	175	175	175/298 = 58.7%
D	70	70	70/298 = 23.5%
E	75	53	53/298 = 17.8%
Total	320	298	100%

Although the previous daily share adjustment model took 2 points off from airline E and distributed this share to Airline C and D, the waste seat discount model took 5.5 points off from Airline E, which is then re-distributed to Airline C and D.

The S-curve model discussed in the literature survey suggested that increases (or reductions) in marginal flights results in a greater-than-proportional gain (or loss) of the market share (O'Connor, 2001). Since the waste capacity discount model results in a more than proportional change in the capacity share by punishing the non-daily services, it complies better with the theoretical background of the S-curve in comparison to daily seat share adjustment model. For this reason, the waste capacity discount model was adopted throughout the research.

This Chapter iterated through the steps of $\%_{a\_s}$ which effectively benchmarks the relative capacity of airlines competing in a given market. It is a consumer-centric parameter calculated upon the research specific parameters that are verified with the passenger survey and factors explored in the literature review. Therefore, $\%_{a\_s}$ refers to the Objective 1 of this study. The next chapter addresses the schedule related quality score calculation methodology for each competing airline in a market for direct and connects services. $\%_{a\_s}$, together with quality-related scores, is used to compute the competing airlines realistic market share estimation.

Chapter 9: Network Performance Model Development – Quality Scores and the REMSET

9.1. Introduction

The previous Chapter introduced a consumer-centric capacity share determination method for all airlines competing in a market. As previously addressed, this research's proposed realistic market share estimation model relies on two major input streams. The first input stream is the adjusted capacity shares, abbreviated $\%_{a\_s}$, that was explained in Chapter 8. This Chapter focuses on schedule related quality score determination of each capacity available in the market, referring to the second major input stream of the REMSET model and the Objective 2 of the research. It was aimed that each carrier's schedule quality is translated into a quantitative metric, abbreviated as $q_{a\_index\_normalised}$. The information retrieved from the passenger survey was effectively used to design $q_{a\_index\_normalised}$ scores, which ensured the consumer-centric nature of this research. This Chapter also contains the introduction of the REMSET model, which incorporates $\%_{a\_s}$ and $q_{a\_index\_normalised}$ scores. The final section of this Chapter presents a case study by walking through the steps of the $\%_{a\_s}$ and $q_{a\_index\_normalised}$ calculation and then computes the final realistic market share estimation of the rival carriers by using the REMSET tool.

As discussed in the previous Chapters, the quality definition of the air transport product is highly subjective and therefore does not infer a straightforward characterisation. However, it is certain that the schedule-convenience of a product is determined through the combination of various factors. Although current literature did not emphasise a singular definition of the itinerary quality, the parameters that construct the overall consumer satisfaction were substantiated and quantified analytically through the passenger survey. Nevertheless, each passenger possesses varying attitudes towards these parameters, mapping those factors in their thought process to eventually decide the perceived quality value of the prospective itinerary. It is essential to reiterate that only schedule-convenience related parameters were included in terms of product quality throughout the scope of this research and this Chapter. Fare and airlines' brand related attractiveness that are influential in consumer preference were beyond the scope of this research and their impacts were ignored as part of the REMSET model.

The parameters that determine the consumers' overall schedule convenience are in abundance. Passengers do care when they depart from the origin (q_{dep}) and arrive at the destination (q_{arr}) in addition to time-related parameters, including t_{total} as well as t_{conn}, t_{stress}, t_{waste} and t_{flight} for the connecting itineraries. Furthermore, the routing of their journey (whether direct or connecting) is an essential concern for consumers. The operation type of the journey (whether online or codeshare) is another crucial factor that passengers evaluate during their itinerary selection process. Moreover, the passenger survey has found that passengers do not prefer an evenly split journey for connecting itineraries.

It is not just the airline schedule that have an impact on passengers' perceived schedule convenience, but the airport facilities. Airports not only determine the MCT and subsequent time related parameters including t_{flight}, t_{conn} and t_{total}, they also indicate the time of the day that the flights can be operated. Factors like slot restrictions and curfew implementation prove that airports compose a restriction on the airlines scheduling process and therefore directly affect a flight's product quality. The below sections address the components of schedule-related quality and walk through the steps of the $q_{a\_index\_normalised}$ calculation. Similar to the procedure in the capacity share calculation procedure, the quality assessments are made on a weekly basis as the airline schedules are planned and repeated weekly.

9.2. Calculation of Time Related Parameters

Time-related parameters are critical components of schedule quality. As the passenger survey unveiled, the perceived value of a flight that offers a relatively better timing in terms of flight duration, departure and arrival time is valued higher compared to its peers. Therefore, it was essential to develop a methodology to calculate time-related parameters of the airlines competing in a market. On the other hand, if multiple flights were performed in a given O&D, it is vital to calculate the average values of the time-related parameters for each service in order to form a meaningful basis of comparison and benchmark with the other carriers. The following subsections introduce the quantitative metrics of time-related parameters and discuss their calculation procedures for direct and connecting flights separately.

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9.2.1. Calculating Time-Related Parameters for Direct Flights

The computation of time-related parameters for direct flights is straightforward. It is expected that direct flights in a given market have no or minor variances in t_{total} which is equal to t_{flight} as $t_{conn} = 0$. Since the path for all direct itineraries available in a market is almost identical, t_{flight} is not expected to change on different days of the week. The example below shows the departure and arrival time of a South African Airlines (SA) flight from Johannesburg to Nairobi numbered SA184.

Figure 9.1: Timetable Information of SA184 Flight from JNB to NBO

Flight Details (South African SA 184 JNB NBO) Back to Results

Departure Johannesburg - O.R. Tambo International Airport

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	10:10	10:10	10:10	10:10	10:10	10:10	10:10

Arrival Nairobi - Jomo Kenyatta Intl

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	15:05	15:05	15:05	15:05	15:05	15:05	15:05

For SA184, the departure time from the origin and arrival time to destination is identical for each day of the week. The departure and arrival times are displayed in local times at Figure 9.1. Taking the local time difference between South Africa and Kenya into consideration, the t_{total} for SA184 was found to be 235 minutes.

In some cases, minor variances of t_{total} for different days of the week for the same flight number or route could be observed, as shown in the example below for the SV1102 flight from JED to DMM:

Figure 9.2: Timetable Information of Saudi Arabian Airlines from JED to DMM

Flight Details (Saudi Arabian Airlines SV 1102 JED DMM) Back to Results

Departure Jeddah - King Abdulaziz Intl

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	-	-	04:55	-	04:50	-	02:30

Arrival Dammam - King Fahad International Airport

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	-	-	07:00	-	06:55	-	04:40

As illustrated in the image above, there are three weekly flights of Saudi Arabian Airlines from Jeddah to Dammam under SV1102 flight number. Each day, the flight departs at different times. On Wednesdays and Thursdays, the flight depart at 04:55 and 04:50 respectively, with a t_{total} of 125 minutes. On the other hand, SV1102 departs Jeddah airport at 02:30 on Sundays and arrives at Dammam at 04:40, inferring a t_{total} of 130 minutes. As this example proves, throughout the different days of the week, there may be slight divergences in the duration of direct flights having the same flight number. These variances can be sourced from various technical or commercial reasons. Therefore, in order to compute the weekly average of t_{total} for such flights, a particular methodology had to be adopted.

To compute the weekly average t_{total} for direct flights with varying flight durations depending on the day of the week, certain approaches could be implemented. One method could be taking the simple average of t_{totals} for each service day of the week. As each flight corresponds to one frequency, taking the simple average would yield to determine t_{total} per frequency. However, this approach would undermine seat per frequency, s_f. Although the number of frequencies is an indicator of capacity supply, the total number of seats on these frequencies dictates how many passengers could be transported via this product. Therefore, to compute the weekly t_{total} for such irregular direct flights, the weighted average based on seat per frequency would be a more realistic approach and therefore adopted as part of the research methodology. For the case shown in Figure 9.2, the t_{total} computation for SV1102 is shown in the table below:

Table 9.1: Weekly t_{total} Computation for Flight SV1102

Day	t_{total} of the day	Seat Supply
Wednesday	125 minutes	232
Friday	125 minutes	298
Sunday	130 minutes	132

It is observed in the table that on Sundays, Saudi Arabian Airlines assign a smaller capacity aircraft for SV1102. Using the information in Table 9.1 the t_{total} for SV1102 is $\frac{(125\ x\ 232) + (125\ x\ 298) + (130\ x\ 132)}{(232 + 298 + 132\ )}$ = 126 minutes by weight-averaging each day's t_{total} with the seat supply.

The above-mentioned calculation methodology of time-related parameters covers the computation for each flight number. However, an airline may offer more than one direct flight number in a market. Under such circumstances, in order to obtain the global average $t_{total\_i\_O\&D}$ for carrier *i* covering all of its services to an O&D, the following formula is applied;

$$\frac{\sum_{x=1}^{x=n}(t_{total\_x}\ *\ s_{f\_x})}{\sum_{x=1}^{n} s_{f\_x}}$$

where *n* is the number of distinct flight numbers operated and t_{total_x} refers to the total average flight time for flight number *x*, and s_{f_x} is the total weekly seats available on flight *x*. Therefore the weighted average travel time for airline *i* including each of its distinct flight numbers is calculated in proportion to the total weekly seats associated with the corresponding flight number. The example below depicts the calculation of weekly t_{total} for airline *i* between city *A* to city *B*.

Table 9.2: Average Weekly t_{total} for an Airline with Multiple Flight Numbers

Flight Number	Weekly t_{total}	Weekly Seat Count (s)
I101	200 minutes	1000 seats
I102	190 minutes	500 seats

Airline *i* offers two direct flight numbers between A and B, flight I101 and I102, with different weekly t_{total} and seat count. The global average of the t_{total} for airline i between City A and City B is then calculated as $t_{total\_i\_O\&D} = \frac{(200\ x\ 1000) + (190\ x\ 500)}{(1000 + 500\ )}$ = 196.66 minutes.

As a result, in order to compute the airline's total flight time in a market, two steps are required. In the first step, the average t_{total} of each flight number is calculated by weight-averaging each day's t_{total} value with the daily seat count of the flight number. The second step includes taking the weighted average of all flight numbers' average weekly t_{total} based on the number of weekly seats for the corresponding flight number.

9.2.2. Calculating Time-Related Parameters for Connecting Flights

The method for computing the connecting flights' time-related parameters is very similar to that of direct flights in principle. The slight difference is, unlike direct flights, t_{total} is the sum of t_{conn} and t_{flight} which are both non-zero values. On the other hand, while the calculations for direct flights are handled at the flight number level, for connecting itineraries, the computation process is based on the combinations that meet the t_{conn} >= MCT and t_{conn} <= MaxCT criteria. The procedure for calculating time-related parameters for the connecting journeys is again a two-step procedure in which at the initial phase, successful combinations' time related parameters including t_{conn} and t_{flight} for each day of the week are identified along with their seat capacities, as shown in Table 9.3.

Table 9.3: Combination Hits for Airline X From City1 to City2 via a Hub. (Step 1)

Combinations	Day	Time Related Parameters	$s_{O\&D}$
A101/A301	Monday	t_{conn} = 60 minutes, t_{flight} = 120 minutes t_{total} = 180 minutes	20 seats
A101/A301	Tuesday	t_{conn} = 60 minutes, t_{flight} = 120 minutes t_{total} = 180 minutes	15 seats
A101/A301	Friday	t_{conn} = 50 minutes, t_{flight} = 115 minutes t_{total} = 165 minutes	30 seats

For A101/A301 combination, the weekly average connecting time is, t_{conn} = $\frac{(60\ x\ 20) + (60\ x\ 15) + (50\ x\ 30)}{(20 + 15 + 30)}$ = 55.38 minutes, where the weekly average flight time is t_{flight} = $\frac{(120\ x\ 20) + (120\ x\ 15) + (115\ x\ 30)}{(20 + 15 + 30)}$ = 117.69 minutes. Since $t_{total} = t_{conn} + t_{flight}$, the weekly average total journey time, t_{total} , is then calculated as 55.38 + 117.69 = 173.07 minutes. Should the carrier have other combinations offering an itinerary on the same O&D, the above procedure is repeated for each hit and the time-related parameters are calculated individually for each combination. In the table below, the other combination of airline x offering a connection on the same route from City 1 to City 2 is displayed.

Table 9.4: Other Combination for Airline *x* From City1 to City2. (Step 1 repeated for the Other combination A102/A301)

Combinations	Day	Time-Related Parameters	$s_{O\&D}$
A102–A301	Monday	t_{conn} = 100 minutes, t_{flight} = 120 minutes t_{total} = 220 minutes	20 seats
A102–A301	Saturday	t_{conn} = 120 minutes, t_{flight} = 120 minutes t_{total} = 240 minutes	10 seats

Repeating the same calculations for the above-mentioned A102/A301 hit, t_{conn} is calculated as 106.66 minutes, where t_{flight} is equal to 120 minutes and therefore t_{total} = 226.6 minutes for the A102–A301 hit. In the second-step for calculating the global average time-related parameters of the airline, weekly combinations are listed, and the computed time-related factors of each hit are similarly weight averaged based on the weekly available seats. Assuming no other viable connections exist from City1 to City2 for airline x, we obtain the following table:

Table 9.5: Consolidated Hits and Time-Related Parameters for Airline x from City1 to City2. (Step 2)

Combination Groups	Time-Related Parameters	Weekly $s_{O\&D}$
A101/A301	t_{conn} = 55.38 minutes, t_{flight} = 117.69 minutes t_{total} = 173.07 minutes	65 seats
A102/A301	t_{conn} = 106.66 minutes, t_{flight} = 120 minutes t_{total} = 226.6 minutes	30 seats

In order to calculate global average time-related parameters for airline x from City1 to City2, the same weighting methodology is applied based on the weekly seat supply for each combination group resulting with $t_{conn\_x\_City1\&City2}$ = 71.57 minutes, $t_{flight\_x\_City1\&City2}$ = 118.41 minutes and $t_{flight\_x\_City1\&City2}$ = 189.98 minutes.

It should be noted that for this example, total seat availability from City1 to City2 using the A101/A301 and A102/A301 combinations do not merely add up to 95, as flight A301 is the capacity constrained flight on Mondays. Therefore, subtracting the duplicate seats for Monday flights, the total weekly seat available for airline x from City 1 to City 2 is calculated as 75. However, the final capacity determination procedure is irrelevant to the calculation of time-related parameters. Since the capacity constrained flight A301 can be fed by both A101 and A102, it is essential to incorporate all possible combinations time values into the calculation without dismissing any combination due to the bottleneck. Although both hits share the same capacity belonging to A301, it is sold via two distinct itineraries on Mondays. Therefore, in order to come up with a realistic average time-related score, each hit's parameters need to be weighted by its corresponding seat count without any capacity constraints.

Thus for a given airline, it is possible to formulate the average $t_{conn\_O\&D}$ for connecting journeys as the weighted average of each combination's connecting time values, based on total seats allotted for each combination, denoted by $\frac{\sum_{x=1}^{x=n}(t_{conn\_x} * s_{O\&D\_x})}{\sum_{x=1}^{n} s_{O\&D\_x}}$ where *n* is the number of relevant combinations meeting t_{conn} >= MCT and t_{conn} <= MaxCT criteria. On the other hand, it is also possible to formulate the average $t_{flight\_O\&D}$ for connecting journeys as the weighted average of each combination's flight time values based on the total seats allotted for each combination, denoted by $\frac{\sum_{x=1}^{x=n}(t_{flight\_x} * s_{O\&D\_x})}{\sum_{x=1}^{n} s_{O\&D\_x}}$ where *n* refers to the same notion. Consequently, the average weekly total time for connecting journeys is simply the sum of $t_{conn\_O\&D}$ and $t_{conn\_O\&D}$.

9.2.3. Calculation of MCT Surplus, Stress Time (t_{stress}), Waste Time (t_{waste}) and Inconvenient Time ($t_{inconvenient}$) Factor

In Chapter 2, the phenomenon of MCT Surplus, Stress Time, Waste Time and Inconvenient Time were introduced. These terms emerged from the fact that the t_{conn} has a direct influence on consumers' perceived schedule convenience for connecting itineraries. The passenger survey found that passengers demand an average t_{buffer} of 29.2 minutes extra, on top of the airports' official MCT values, to deem their journey less stressful. The ideal t_{conn} for a journey is therefore equal to MCT + t_{buffer}. Any t_{conn} which is less than (MCT + t_{buffer}) is stressful for consumers, whereas connecting times which are higher than (MCT + t_{buffer}) would lead passengers to wasting time at a hub airport. As the survey found ideal t_{buffer} to be 29.2 minutes, barely half an hour, 30 minutes was used as the global t_{buffer} value in the proceeding sections. It is noteworthy to mention that t_{stress}, t_{waste} and $t_{inconvenient}$ do not apply to direct flights and are zero for non-stop itineraries.

Table 9.6: t_{stress}, t_{waste} and $t_{inconvenient}$ Values for Different t_{conn} Cases Under t_{buffer} = 30 Minutes Assumption

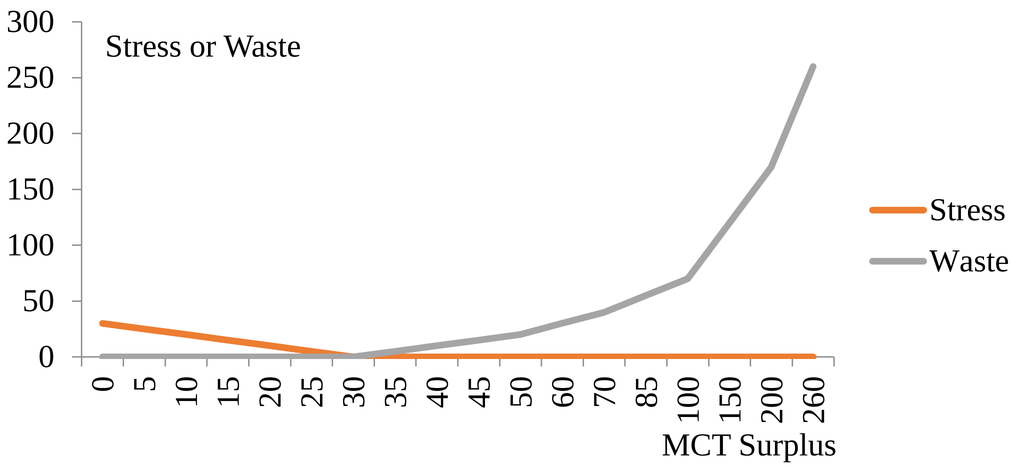
Conecting Time	Case	t_{stress}	t_{waste}	$t_{inconvenient}$
t_{conn} < MCT + 30 min	Stress	MCT + 30 - t_{conn}	0	MCT + 30 - t_{conn}
t_{conn} > MCT + 30 min	Waste	0	t_{conn} - MCT - 30	t_{conn} - MCT - 30
t_{conn} = MCT + 30 min	Perfect	0	0	0

Table 9.6 shows the calculation method for t_{stress}, t_{waste} and $t_{inconvenient}$. In the 'stress' case, the connection time is greater than the MCT but less than (MCT + 30) minutes. Therefore the MCT surplus is (t_{conn} - MCT), which is less than the t_{buffer}, deeming the journey stressful. t_{stress} is the difference between t_{buffer} and MCT Surplus which is equal to (30 - (t_{conn} - MCT)) = (MCT + 30 - t_{conn}). In the second case, the connection time is greater than (MCT + 30) minutes.

Therefore, a passenger has plenty of time at the hub airport where the MCT Surplus is calculated to be above 30 minutes. This excess waiting time would result in wasted time, which could be formulated as (MCT surplus - t_{buffer}) or (t_{conn} - MCT - 30). Finally, if the t_{conn} is equal to (MCT + 30), then there exists neither stress nor waste time at the intermediary hub airport. This would be a perfect case where the MCT surplus is equal to the t_{buffer}. In the perfect case, the MCT Surplus value of 30 minutes both eliminates the stress and leaves no minutes for wasted time.

Figure demonstrates stress and waste time curves for different MCT Surplus values. As shown in Figure 9.3, passengers do not experience any further stress if their MCT surplus exceeds the t_{buffer}, which is 30 minutes. The stress is highest when the MCT Surplus is equal to zero, meaning there exists no buffer time. On the other hand, passengers do not waste any time if the MCT Surplus is more than 30 minutes. In case the MCT Surplus exceeds 30 minutes, each additional minute would be wasted. The passenger survey also found MaxCT to be 290 minutes. Therefore the maximum value of MCT Surplus can be equal to (290 - MCT) minutes.

Figure 9.3: Stress and Waste Time Factors in minutes with respect to MCT Surplus.



The inconvenient time, $t_{inconvenient}$, for a connecting journey is simply the sum of t_{stress} and t_{waste}. For non-perfect connecting journeys, the itinerary involves an inconvenient time component sourced either through a non-zero t_{stress} or t_{waste} value. On the other hand, the inconvenient time ratio, $\%_{inconvenient}$, of an itinerary is the share of inconvenient time within the total journey time. The example in Table 9.7 illustrates the calculation of t_{stress}, t_{waste}, $t_{inconvenient}$ and $\%_{inconvenience}$ of Qatar Airways (QR) hits from Athens (ATH) to Bangkok (BKK) via Doha

(DOH) on Fridays. There are four different flight combinations on the O&D operated by the carrier. The official MCT of DOH airport is 45 minutes.

Table 9.7: t_{stress} and t_{waste} Calculation for QR for from ATH to BKK on Fridays as of Summer 2016 Schedule.

Combination	t_{conn}	Official MCT	MCT Surplus	t_{stress}	t_{waste}
QR208/QR832	150 min.	45 min.	105 min.	0 min.	75 min.
QR210/QR830	145 min.	45 min.	100 min.	0 min.	70 min.
QR212/QR834	85 min.	45 min.	40 min.	0 min.	10 min.
QR212/QR836	60 min.	45 min.	15 min.	15 min.	0 min.

Using the information shown in the above table onwards, the inconvenient time and inconvenient time ratio computations are illustrated as follows:

Table 9.8: $t_{inconvenient}$ and $\%_{inconvenience}$ for the Case Shown in Table 9.7.

Combination	$t_{inconvenient}$	t_{total}	$\%_{inconvenience}$
QR208/QR832	75 min.	830 min.	9%
QR210/QR830	70 min.	820 min.	8.5%
QR212/QR834	10 min.	760 min.	1.3%
QR212/QR836	15 min.	740 min.	2%

Although among connection alternatives the QR212/QR836 combination has the shortest flight time, it is not the most convenient in terms of $\%_{inconvenient}$ as passengers are exposed to more inconvenient time in comparison to QR212/QR834, which reports a 1.3% inconvenient time ratio. In order to come up with a single $\%_{inconvenient}$ factor for connecting QR services from ATH to BKK on Fridays, the procedure to follow is similar to other performance indicators and time-related parameters, which are weight-averaging the figures with respect to available seats for each hit.

9.2.4. Calculation of Departure (q_{dep}) and Arrival Time Quality (q_{arr}) Parameters

The passenger survey uncovered that consumers report varying degrees of appreciation for different departure and arrival time bands throughout the day. Respondents marked their appreciation level for each time interval of the day from 1 to 4, where the lower score implied the lower convenience. Therefore, it is possible to use these scores numerically to quantify both the average departure and arrival time score. For direct flights, the relative quality score of the local departure time indicates the q_{dep} while the local arrival time indicates the q_{arr}. For connecting flights, the departure time of the first flight determines q_{dep} while the arrival time of the final leg dictates the q_{arr}. For example, the q_{dep} value of a flight departing 19:00 from the origin is equal to 4, the best score, as this time zone was identified to be one of the most preferred times of day to fly. On the other hand, if the itinerary arrives at the destination at 02:00, q_{arr} is equal to 1, the worst score, as this time interval is one of the least preferable arrival times marked by the survey respondents.

If an airline offers multiple products on a route, the calculation of average q_{dep} and q_{arr} scores of the carrier is required to form a suitable base to benchmark the values with those of the competitors. In order to calculate the average $q_{dep\_x\_O\&D}$ and $q_{arr\_x\_O\&D}$, for airline x on a given O&D, a two-step procedure is again followed, similar to the calculation process of the time-related parameters. When translating multiple flights departure and arrival time quality scores into one final index, the total number of available seats is used as the key of weight averaging. The initial step involves the calculation of each flight hits' weekly weighted average q_{dep} and q_{arr} score in reference to each day's seat supply. At the second step, it is required to take the weighted average of each flight number or combinations' weekly q_{dep} and q_{arr} values again based on the available seats offered for that particular flight number or combination. Therefore, the final weekly quality value of $q_{dep\_O\&D}$ and $q_{arr\_O\&D}$ for a given airline is illustrated as

$$\frac{\sum_{x=1}^{x=n}(q_{dep\_x} * s_{O\&D\_x})}{\sum_{x=1}^{n} s_{O\&D\_x}} \text{ and } \frac{\sum_{x=1}^{x=n}(q_{arr\_x} * s_{O\&D\_x})}{\sum_{x=1}^{n} s_{O\&D\_x}}$$

respectively where *n* refers to the total number of available flight numbers or hits on the O&D. It should be noted that there is no difference in the formulations of both connecting and direct flights. Referring to flight SV1102 shown in Figure 9.2 from Jeddah to Dammam, the consolidated table containing the q_{dep}, q_{arr} and seat count (s) is disclosed below:

Table 9.9: Daily departure and arrival time qualities of SV from JED to DMM.

Day	Time Quality Related Parameters	Number of Seats
Wednesday	Departure Time : 04:55 ($q_{dep\_wed} = 1$) Arrival Time : 07:00 ($q_{arr\_wed} = 2$)	232
Friday	Departure Time : 04:50 ($q_{dep\_fri} =1$) Arrival Time : 06:55 ($q_{arr\_fri} = 2$)	298
Sunday	Departure Time : 02:30 ($q_{dep\_sun} =1$) Arrival Time : 04:40 ($q_{arr\_sun} = 1$)	132

The weekly average of q_{dep_SV1102} and q_{arr_SV1102} scores are calculated similarly – by weight averaging in reference to seat count formulated as $\frac{(q_{dep\_wed}\ x\ s_{wed} + q_{dep\_fri}\ x\ s_{fri} + q_{dep\_sun}\ x\ s_{sun})}{(s_{wed} + s_{fri} + s_{sun})}$ for the weekly average q_{dep} and $\frac{(q_{arr\_wed}\ x\ s_{wed} + q_{arr\_fri}\ x\ s_{fri} + q_{arr\_sun}\ x\ s_{sun})}{(s_{wed} + s_{fri} + s_{sun})}$ for the weekly average q_{arr}. Substituting the abbreviations shown in the formula with the actual values as shown in Table 9.9, q_{dep_SV1102} is calculated to be 1 and $q_{arr\_SV1102} = 1.8$

Supposing there is another imaginary Saudi Arabian Airlines flight from Jeddah to Dammam numbered SV_XXX departing from JED each day at 17:15 and arriving in DMM at 19:25, operated with 250-seated aircraft daily, the carrier's quality scores on the JED–DMM market, abbreviated as $q_{dep\_SV\_JED\text{-}DMM}$ and $q_{arr\_SV\_JED\text{-}DMM}$, would change as shown in Table 9.10.

Table 9.10: Direct Services of SV from JED to DMM.

Flight Number	Time Quality Related Parameters	Weekly Seats
SV1102	$q_{dep\_SV1102} = 1$ $q_{arr\_SV1102} = 1.8$	662
SV_XXX	$q_{dep\_SV1102} = 3$, $q_{arr\_SV1102} = 3$ As per the survey results, 17:15 departure and 19:25 arrival both correspond to 3.	250 x 7 = 1.750

Based on the information shown in Table 9.10, the general departure and arrival time quality of all SV services from JED to DMM is calculated in reference to the weekly seat count for each flight number and thus the following calculations are performed: $q_{dep\_SV\_JED\text{-}DMM} = \frac{(1x662 + 3\ x\ 1750)}{(662 + 1750)} = 2.45$ and $q_{arr\_SV\_JED\text{-}DMM} = \frac{(1.8x662 + 3\ x\ 1750)}{(662 + 1750)} = 2.67$. Therefore, it can be concluded that the q_{dep} score of the SV flights from JED to DMM increased from 1 to 2.45 while the q_{dep} raised from 1.8 to 2.67, soon after the addition of SV_XXX flight into the carrier's timetable.

9.2.5. Additional Time-Related Parameters and Their Impact on Quality

The passenger survey and literature review uncovered other time-related parameters that directly influence consumer convenience. Incorporating these findings into the quality score determination model enhanced this research's methodology, providing a further realistic quantification of an airline's schedule attractiveness. The below sections discuss these factors and elaborate on whether and how they were integrated into the model.

i. *The number of stops:* Some direct flights to a destination are operated with stops. Rather than planning the flight directly to the final destination, network planners may introduce one or more stops in between to enhance the efficiency and profitability of the flight, or to refuel the aircraft or due to any other technical and commercial reason. Undoubtedly, increasing the number of stops reduces passengers' schedule convenience, as longer journey time has a definite adverse effect on consumer convenience. The variation in air journey time depends on whether the flight was non-stop or involved an intermediate stop. Therefore, journey time is closely correlated to the existence or non-existence of an intermediate stop (Air Transport Research Group, 1997). As a result, since time-related parameters including t_{flight} and t_{total} were employed as an integral aspect of the supply quality determination methodology, in order to avoid repetitiveness, the number of stops in the itinerary was not used as a discrete and separate parameter within the schedule quality determination model.

ii. *Flight Time Ratio:* Under similar or equal t_{total} figures for the two competing connecting itineraries, the share of flight time was argued to be a potential parameter influencing passenger convenience. For some travellers, especially for smokers, spending more time at a hub airport could be preferred in contrast to flying as smoking is strictly prohibited onboard. On the other hand, some others may appreciate a higher flight time ratio in case they enjoy the flight and onboard services like the catering, in-flight entertainment or any other service in the aircraft. The passenger survey did not report a clear perspective on whether the respondents preferred waiting at the airport rather than flying. Therefore the flight time ratio was not used as a parameter of schedule convenience assessment model.

iii. *Connecting Journey Flight Time Split:* For connecting itineraries, the location of the hub airport is critical in as it determines when and where the journey would be interrupted by the connection. The passenger survey found that respondents did not prefer an equal split or equivalently similar flight time among the legs forming the journey. The results suggested that for longer connecting flights, passengers prefer itineraries that are interrupted by a connection either at the very beginning or towards the very end of their journey. Therefore, the concept of q_{split} was introduced to denote the additional score that an itinerary would gain if the journey is split with a connection either at the very early or very late stage of travel. To determine whether a journey is split with a connection at the very early of late phase, a term denoted by $\%_{q\_split}$ was also introduced. If one of the legs' flight time share among the total flight time exceeds $\%_{q\_split}$, then the itineraries qualify for the q_{split}. Therefore, the value of q_{split} is either zero, referring to no extra score, or a pre-determined non-zero positive number for those qualifying for the additional score. By definition, q_{split} is zero for all direct flights. Supposing $\%_{q\_split}$ to be 0.8 or 80%, if the duration of one of the flight legs within an itinerary is more than or equal to 80% of the total flight time, then the itinerary qualifies for a q_{split} score. Should the journey be split equally between legs, then the itinerary does not qualify for a q_{split} score since none of the legs shares of total flight time exceed $\%_{q\_split}$.

9.3. Products Quality Index Score (q_{index}) Determination

The passenger survey found that travellers are willing to pay more for direct flights than the connecting services. On the other hand, it was also discovered in the questionnaire that a consumer's willingness to take a codeshare flight is lower compared to an online-operating service. Furthermore, as argued in the literature review, airlines tend to charge more for flights with relatively better arrival and departure times, as consumers better appreciate such flights. The mathematical relationship between the values of direct vs connecting, operating vs codeshare and time-convenient vs inconvenient combinations were calculated in Chapter 7. These parameters were abbreviated as u_{do}, u_{co}, u_{dc}, u_{cc} re-shown in Table 9.11 below. These scores were used as the basis of the itinerary's quality index score which is denoted as q_{index}.

Table 9.11: u_{do}, u_{co}, u_{dc}, u_{cc} Determination for Convenient and Inconvenient q_{dep} and q_{arr}

	Connecting Flight		Direct Flight	
	Operating (u_{co})	Codeshare (u_{cc})	Operating (u_{do})	Codeshare (u_{dc})
Convenient Time	1.131	0.854	1.333	0.990
Inconvenient Time	1.000	0.796	1.230	0.864

As the above table implies, the q_{index} value of an O&D is determined by mapping the three attributes of the product. They are 1) routing type (whether direct or connecting), 2) operation type (whether operating or codeshare) and 3) time convenience of the itinerary. Although the distinction between connecting vs direct flight, as well as operating vs codeshare, is clear-cut, the difference between convenient and inconvenient timing is conceptual, requiring further justification and quantification. For this reason, departure and arrival time quality of the flights were used which were formed with the q_{dep} and q_{arr}. On the other hand, q_{split} was discussed to be another parameter which contributes to the time quality of the connecting journeys. Therefore, time convenience quality can be defined as:

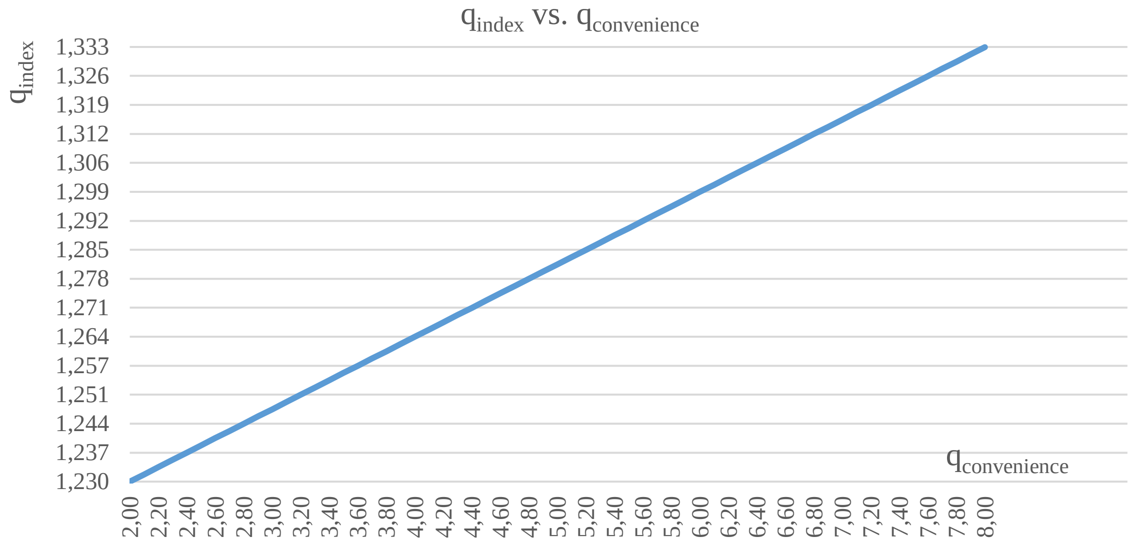
$$q_{convenience} = q_{dep} + q_{arr} + q_{split}$$

The $q_{convenience}$ score determines the mapping of a proposed itinerary in Table 9.11 to calculate the q_{index} value. The minimum possible value of $q_{convenience}$ defines the worst possible time convenience, whereas at the other extreme, the highest value refers to the best timing. For q_{dep} and q_{arr}, the values were defined to be betwen 1 and 4, where 1 implied the least preferred option. Besides q_{split} was introduced to be a non-negative factor, deeming its minimum value to be zero. Therefore, the minimum of $q_{convenience}$ can be 2 (1 for $q_{dep,}$ 1 for q_{arr} and 0 for q_{split}), while the maximum can be 8 + q_{split} (4 for $q_{dep,}$ 4 for q_{arr}). By definition, $q_{convenience}$ can range from 2 to 8 for direct flights, as the q_{split} is equal to zero for non-connecting services.

After identifying the routing and the type of an itinerary, the index score range is obtained from Table 9.11. As an example, for a direct and operating flight, the quality is an index value ranging from 1.230 to 1.333 depending on the time convenience factor, $q_{convenience}$. If the itinerary has the lowest $q_{convenience}$ score of 2, the quality value of the product would be 1.230. On the other hand, in the reverse case, if the $q_{convenience}$ is reported to be the highest, which is 8 for a direct service, then the quality value for the product would be 1.333. For itineraries with $q_{convenience}$ scores in between the lower and upper bound, the q_{index} value would result in a value more than 1.230 and less than 1.333.

To compute the exact q_{index} figures of itineraries, some assumptions were needed. First, the non-zero value of q_{split} was determined to be 1.00, as this approach would only slightly contribute to the time quality of the connecting itineraries in case a leg of the journey is longer than the $\%_{q\_split}$. The non-zero value of q_{split} was determined as 1.00 in order not to amplify the impact of split score on the q_{split}. Since the value of q_{dep} and q_{arr} ranges between 1 and 4, the additional split score of q_{split} = 1 would have a slight but reasonable contribution to the time convenience score which ranges between 12.5% and 50% of the connecting journeys. In this case, when the q_{dep} and q_{arr} scores are reported to be at the minimum value, the impact of a non-zero q_{split} would contribute to ½ = 50% while at the other extreme, when q_{dep} and q_{arr} scores are reported to be at the maximum value, its impact would be limited to 1/8 = 12.5% on $q_{convenience}$. If the q_{split} was set to be a higher score than 1, it would then undermine the impact of q_{dep} and q_{arr} within $q_{convenience}$. As per the second assumption, the impact of $q_{convenience}$ on q_{index} was assumed to be linear with a definite proportional scheme. For direct and operating journeys, as the q_{index} ranges between 1.233 and 1.333 (according to Table 9.11) and the $q_{convenience}$ scores varies between 2 and 8 for direct flights, the relational graph between these two parameters under linear/proportional assumption was plotted as follows:

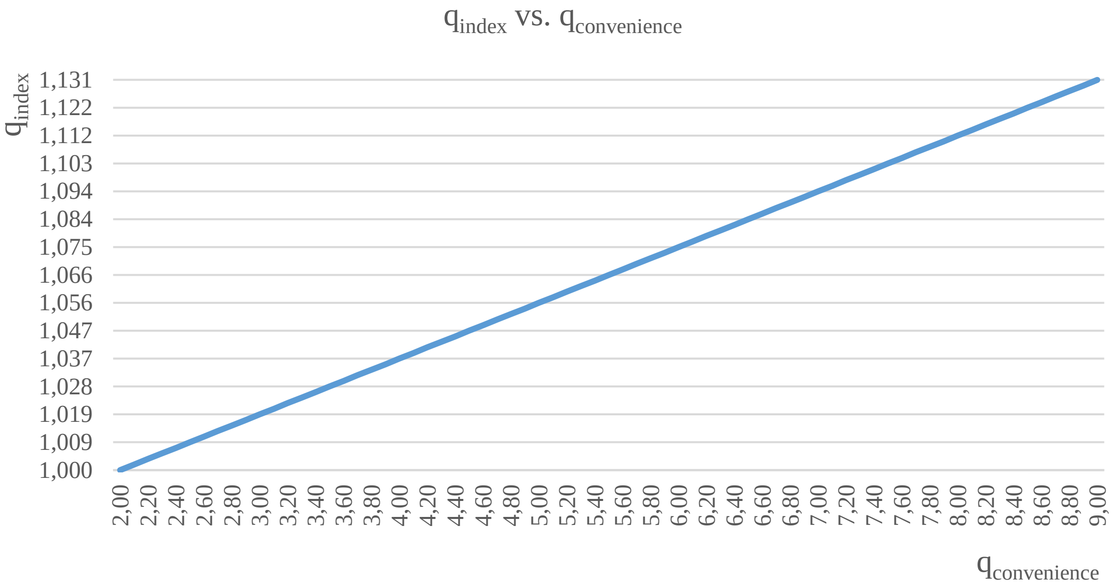
Figure 9.4: q_{index} vs $q_{convenience}$ Scores for an Operating – Direct Service.



As Figure 9.4 illustrates, for each additional point of $q_{convenience}$, the quality index score increases by $\frac{(1.333-1.230)}{(8-2)}$ = 0.0171 points. In decimals, each 0.1 increase in $q_{convenience}$ increases the q_{index} score by 0.00171 points for a direct and operating flight.

The calculation method differs for connecting itineraries slightly. For such journeys, while the minimum score of $q_{convenience}$ can be equal to 2.00, the maximum can go up to 9.00, under the assumption of q_{split} being equal to either 0 or 1. For instance, as per Table 9.11, a connecting-operating service's q_{index} ranges from 1.000 and 1.131 depending on the value of the $q_{convenience}$. Under linear distribution assumption, for such a connecting-operating itinerary, one additional point in $q_{convenience}$ would ascends the q_{index} by $\frac{1.131-1}{(9-2)}$ = 0.0187, and by 0.00187 in decimals as shown in the Figure below:

Figure 9.5: q_{index} vs $q_{convenience}$ Scores for an Operating – Connecting Service.



Therefore, the procedure to calculate the index score for an itinerary is 1) identifying the routing and the type of the itinerary, 2) fetching the lower and upper bounds of the index point, q_{index_upper} and q_{index_lower} respectively from Table 9.11 and 3) applying the formula:

$$\mathrm{q}_{\mathrm{index}_{\mathrm{lower}}} + \frac{\mathrm{q}_{\mathrm{convenience}} - \mathrm{q}_{\mathrm{convenience}_{\mathrm{min}}}}{(\mathrm{q}_{\mathrm{convenience}_{\mathrm{max}}} - \mathrm{q}_{\mathrm{convenience}_{\mathrm{min}}})} * (\mathrm{q}_{\mathrm{index}_{\mathrm{upper}}} - \mathrm{q}_{\mathrm{index}_{\mathrm{lower}}})$$

Substituting the corresponding upper and lower bounds of $q_{convenience}$, the below formula is obtained for direct flight as follows:

$$\mathrm{q}_{\mathrm{index}_{\mathrm{lower}}} + \frac{(\mathrm{q}_{\mathrm{convenience}} - 2)}{6} * (\mathrm{q}_{\mathrm{index}_{\mathrm{upper}}} - \mathrm{q}_{\mathrm{index}_{\mathrm{lower}}})$$

For connecting services, because of the change in the maximum $q_{convenience}$ score in case of a non-zero q_{split} score the formula is introduced as follows:

$$q_{index_{lower}} + \frac{(q_{convenience} - 2)}{7} * (q_{index_{upper}} - q_{index_{lower}})$$

9.4. Normalising the q_{index} Score ($q_{index\_normalised}$)

As discussed earlier, q_{index} is a function of an itinerary's routing, type and $q_{convenience}$ scores. However, the q_{index} score is not a leg-based metric assessing the standalone quality index of the individual segments within a journey. It rather refers to a factor that measures the quality value of the entire directional itinerary as a whole. This implies that for connecting journeys, q_{index} does not reflect the impact of an inconvenient time percentage within the total journey time. Since q_{index} is the quality index value of the entire itinerary and for the connecting journeys, there may be inconvenient time due to stress or waste time, q_{index} needs to be discounted by $\%_{inconvenient}$. As there is no inconvenient time for the direct flights, such itineraries' q_{index} scores are not discounted. The factor that is obtained after the discounting is called as $q_{index\_normalised}$ and are formulated as follows:

$$q_{index_{normalised}} = \begin{cases} q_{index} & \text{if } \%_{inconvenient} = 0 \text{ or journey is direct} \\ q_{index} * (1 - \%_{inconvenient}) & \text{if journey is connecting and } \%_{inconvenient} > 0 \end{cases}$$

If an airline offers more than one itinerary on a given O&D, the individual $q_{index\_normalised}$ scores are weighted based on the weekly seat availability for each hit which is performed separately for direct and connecting combinations. Therefore, $q_{index\_normalised\_i}$ for an airline *i* is formulated as follows,

$$\frac{\sum_{j=1}^{n} s_{j\_i} \text{ x } q_{index\_normalised\_j\_i}}{\sum_{j=1}^{n} s_{j\_i}}$$

where s_{j_i} refers to available seats of hit *j* and $q_{index\_normalised\_j\_i}$ is the quality score of combination *j* for airline *i*. In the below example, airline X operates on a market with both direct and connecting services whereas Airline Y, only offers connecting services in two distinct combinations. Table 9.12 shows the seat count and the $q_{index\_normalised}$ scores for each hits.

Table 9.12: Combination, Service Type, Weekly Seats and Normalised Quality Scores for Airline X and Y.

Combination	Service Type	Weekly Seats (s)	$q_{index\_normalised}$
X1	Direct	100	1.10
X2	Direct	200	1.15
X3/X4	Connect	50	0.90
X5/X6	Connect	30	0.75
Y1/Y2	Connect	20	1.00
Y3/Y4	Connect	40	0.80

As explained, an airline's weekly weighted average $q_{index\_normalised}$ score is prepared separately for direct and connecting services. The value of weekly $q_{index\_normalised\_direct\_airlineX}$ for the direct services of Airline X is equal to $\frac{(1.10\ x\ 100\ +\ 1.15\ x\ 200)}{(100+200)}$ = 1.133, whereas it is equal to $\frac{(0.90\ x\ 50+0.75\ x30)}{(50+30)}$ = 0.844 for the connecting services. The weekly $q_{index\_normalised\_connect\_airlineY}$ value for airline Y's connecting services is $\frac{(1.00\ x\ 20\ +\ 0.8\ x\ 40)}{(20+40)}$ = 0.866. Table 9.13 below summarises the airlines weekly normalised quality index scores as follows:

Table 9.13: Weekly Average Normalised Quality Indexes for Airline X and Y.

Airline	Service Type	Weekly $q_{index\_normalised}$
X	Direct	1.133
X	Connect	0.844
Y	Connect	0.866

9.5. The Impact of t_{total} on $q_{index\_normalised}$ and the Adjustment Based on t_{total}

In the previous section, the methodology to assess each airline's normalised quality score, the $q_{index\_normalised}$, was covered. Although $q_{index\_normalised}$ is a parameter measuring an itinerary's schedule related quality, it does not take the relative performance in total journey time into account. t_{total} is a definite factor of choice for the travellers, as tghey do not appreciate longer journey times. Therefore, the relative advantage or disadvantage of the itinerary's t_{total}

was needed to be incorporated into the final schedule convenience score calculation, which is performed by adjusting the $q_{index\_normalised}$. The adjusted normalised quality index score is abbreviated as $q_{a\_index\_normalised}$ and it refers to the final schedule quality (convenience) score, which was targeted to be the Objective 2 of this research.

In order to incorporate t_{total} into the final quality score calculation, each carrier *i*'s weekly average journey time t_{total_i} is calculated and benchmarked as the first step. If an airline offers more than one combination, total journey times of each combination are weighted in reference to the corresponding seat supply. As the second step, normalised quality indexes ($q_{index\_normalised}$) are discounted in reference to the shortest available product per service type to find the $q_{a\_index\_normalised}$. The weekly average $q_{a\_index\_normalised}$ scores are calculated separately for direct and connecting services. The procedure is shown in Table 9.14.

Table 9.14: Inputs for Calculating Weekly $q_{a\_index\_normalised}$, for Airline X and Y.

Combination	Service Type	Weekly Seats (s)	Total Journey Time (t_{total})
X1	Direct	100	60 minutes
X2	Direct	200	60 minutes
X3/X4	Connect	50	120 minutes
X5/X6	Connect	30	150 minutes
Y1/Y2	Connect	20	120 minutes
Y3/Y4	Connect	40	175 minutes

The average weekly value of total travel time for the direct services of Airline X, the $t_{total\_direct\_airlineX}$, is equal to $\frac{(60\ x\ 100\ +\ 60\ x\ 200)}{(100+200)}$ = 60 minutes, where the same carrier's average weekly total travel time for the connecting products, $t_{total\_connect\_airlineX}$, is $\frac{(120\ x\ 50+150\ x30)}{(50+30)}$ = 131.25 minutes. On the other hand, the $t_{total\_connect\_airlineY}$ value for airline Y's connecting services is $\frac{(120\ x\ 20\ +\ 175\ x\ 40)}{(20+40)}$ = 156.66 minutes. The final table summarising each airline's weighted weekly average journey times and the $q_{index\_normalised}$ scores are as follows:

Table 9.15: The Consolidated Table Showing Service Type, $q_{index\_normalised}$ and t_{total} for Airline X and Y.

Airline	Service Type	$q_{index\_normalised}$	t_{total_i} (minutes)
X	Direct	1.13	60
X	Connect	0.84	131.25
Y	Connect	0.86	156.66

For each service type, the best-performing airline gets $q_{a\_index\_normalised}$ equal to $q_{index\_normalised}$, where the remainings $q_{index\_normalised}$ are discounted in reference to t_{total_i}. Indexing the shortest t_{total_i} to 1.00, the above table is transformed as follows:

Table 9.16: Transformation of Table 9.15 by Indexing the Shortest t_{total} to 1

Airline	Service Type	$q_{index\_normalised}$	$t_{total\_indexed}$
X	Direct	1.13	1.00
X	Connect	0.84	2.18
Y	Connect	0.86	2.61

Since only one carrier, airline X, operates direct flights in the market, which reports the shortest t_{total}, its indexed total journey time, the $t_{total\_direct\_indexed\_airlineX}$, is fixed at 1.00. On the other hand, the indexed value for connecting services is computed by dividing its t_{total_i} values by the shortest flight time, which is 60 minutes. Therefore, the indexed total journey time for Airline X's connecting services ($t_{total\_connect\_indexed\_airlineX}$) is 131.25/60 = 2.18, whereas for Airline Y, it is calculated to be ($t_{total\_connect\_indexed\_airlineY}$) 156.66/60 = 2.61.

These numbers imply that the minimum total journey time index for the direct services is 1.00 while it is 2.18 for the connecting services. Since airline X's total travel time index is the minimum among direct services and there is no competing direct itinerary, its $q_{index\_normalised}$ is not discounted. Therefore, for airline X's direct flights, $q_{a\_index\_normalised}$ is equal to $q_{index\_normalised}$ = 1.13. If there were another airline offering direct services with an average t_{total} index of 1.01, then that airline's $q_{index\_normalised}$ would be discounted by 1% to calculate its $q_{a\_index\_normalised}$ score. For the connecting services, airline X scores the lowest indexed journey time with 2.18 compared to airline Y's score of 2.61. Therefore, for the connecting services of airline X $q_{a\_index\_normalised}$ is equal to $q_{index\_normalised}$ = 0.84. On the other hand, airline Y's normalised quality score has to be discounted by (2.61 – 2.18)/2.18 = 19.7% as its indexed journey time is 19.7 per cent worse than the minimum indexed journey time available in the connect market. Thus the adjusted normalised quality score of Airline Y's connecting services are $q_{a\_index\_normalised}$ = 0.86 x (1 – 19.7%) = 0.69.

Table 9.17: The Final Table Showing $q_{index\_normalised}$, Indexed t_{total_i} and $q_{a\_index\_normalised}$ for Airline X and Y.

Airline	Service Type	$q_{index\_normalised}$	t_{total_i} (Indexed)	$q_{a\_index\_normalised}$
X	Direct	1.13	1.00	1.13
X	Connect	0.84	2.18	0.84
Y	Connect	0.86	2.61	0.69

To sum up, an airline's adjusted normalised quality score, $q_{a\_index\_normalised}$, is calculated separately for direct and connect services. For direct itineraries, the minimal total travel time index among direct services is identified, and each airline's $q_{index\_normalised}$ is discounted by the per cent deviation from that minimum. The same procedure is repeated for the connecting services, in which the minimal total travel time among connecting services is recognised and the subsequent discounting procedure is applied. Through this discounting mechanism, shorter t_{total}s are rewarded. While the deviation from the minimum t_{total} increases, the adjusted normalised quality score decreases as the appreciation of the product descends in comparison to the competitors available in the market.

The $q_{a\_index\_normalised}$ effectively benchmarks the quality score of the airlines' itineraries competing in a market, referring to Objective 2 of this research. It also denotes the main output of the airline schedule quality determination model described in this Chapter. Furthermore, the $q_{a\_index\_normalised}$ is a focal input of the realistic market share estimation model, the REMSET, which is covered in the following section.

9.6. The REMSET Model

Chapter 8 addressed the calculation methodology of the adjusted capacity share ($\%_{a\_s}$) for direct and connecting services separately. $\%_{a\_s}$ is an indexed figure that successfully demonstrates relative supply strength or weakness of a carrier compared to its rivals on a given

O&D. In this Chapter, the quality score determination model for each carrier's direct and connecting services, the $q_{a\_index\_normalised}$, was introduced. As previously addressed, each capacity that is available for sale in the market has a quality value. Therefore, the $q_{a\_index\_normalised}$ score of a journey refers to the relative quality score of its supply, the $\%_{a\_s}$. In other words, $q_{a\_index\_normalised}$ quantitatively assesses the relative schedule performance of each $\%_{a\_s}$. As a result, the product of these parameters would result in the quality blended capacity scores of each carrier referring to the realistic market share expectation of the airline. In other words, the REMSET methodology covers the simple multiplication of $\%_{a\_s}$ and $q_{a\_index\_normalised}$ and its translation to percentages.

Continuing from the previous example, the weekly adjusted seat amounts for Airline X and Y are given in Table 9.18. Supposing both airlines operate daily for all service types and thus no waste capacity discounting is applied with $\%_s$, implying $\%_s = \%_{a\_s}$ for all rows, the following table is fetched:

Table 9.18: Service Type, Adjusted Weekly Seats, $\%_{a\_s}$ and $q_{a\_index\_normalised}$ of the Case

Airline	Service Type	Adjusted Weekly Seats	$\%_{a\_s}$	$q_{a\_index\_normalised}$
X	Direct	300	68.2%	1.13
X	Connect	80	18.2%	0.84
Y	Connect	60	13.6%	0.69

Multiplying $\%_{a\_s}$ with $q_{a\_index\_normalised}$, the following quality blended capacity scores are handled. Translating these scores into percentages, the realistic market share estimation (denoted as ms) is finally calculated.

Table 9.19: Final Realistic Market Share Estimation Calculation for the Case

Airline	Service Type	$\%_{a\_s}$ x $q_{a\_index\_normalised}$	R. Market Share Estimation (ms)
X	Direct	68.2% x 1.13 = 0.771	0.771 / 1.018 = 75.7%
X	Connect	18.2% x 0.84 = 0.153	0.153 / 1.018 = 15.1%
Y	Connect	13.6% x 0.69 = 0.094	0.094 / 1.018 = 9.2%
Total		1.018	100%

The above table implies that although the capacity share of Airline Y is 13.6%, its realistic market share, ms_{y_conn}, is estimated to be 9.2% as the product is relatively disadvantaged to Airline X's products. While the direct service of Airline X holds 68.2% of the entire capacity supply in the market, because of its strength in the relative quality score, it is expected to gain a market share of ms_{y_direct} = 75.7%, and the remaining 15.1% of the shares are estimated to be owned by the Airline X's connecting services. Using this information, the realistic market share estimation, abbreviated as *ms,* of an airline *i*'s direct flights is then formulated as:

$$ms_{i\_direct} = \frac{\%_{a\_s\_i\_direct} \text{ x } q_{a\_index\_normalised\_i\_direct}}{\sum_{j=1}^{k} \%_{a\_s\_j} \text{ x } q_{a\_index\_normalised\_j}}$$

and the ms of the same carrier for connecting flights is then formulated as:

$$ms_{i\_conn} = \frac{\%_{a\_s\_i\_connect} \text{ x } q_{a\_index\_normalised\_i\_connect}}{\sum_{j=1}^{k} \%_{a\_s\_j} \text{ x } q_{a\_index\_normalised\_j}}$$

Where *k* is the number of total airline and service type combination, and the denominators refer to the sum of each airline's adjusted seat share and quality score multiplication for all service types.

Since the REMSET model calculates the realistic market share estimation of the competing carriers' itineraries available in a market, the ability to calculate the ms refers to the Objection 3 of this research. A detailed case study demonstrating the step-by-step $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms calculation is presented in Appendix D.

This Chapter has iterated through the schedule quality determination procedure of each capacity supply in the market and introduced the REMSET model for obtaining the realistic market shares. The REMSET methodology employs $q_{a\_index\_normalised}$ whose calculation procedure was outlined in this Chapter and the $\%_{a\_s}$ which was mentioned in the previous Chapter. Using these methodologies, it is now possible to calculate the research outputs for each of the analysed routes. The following Chapter covers the results using all these methodologies covered in Chapter 8 and 9.

Chapter 10: Results (Part I) – Calculation of the Research Outputs for Selected the Markets

Chapter 8 has covered the methodology for calculating the consumer-centric capacity share while Chapter 9 introduced the schedule quality score determination and the REMSET models. It is possible to calculate the research outputs for the selected markets by running these introduced models with the schedule data of the listed carriers. As explained in Chapter 1, the research outputs are 1) the realistic capacity share ($\%_{a\_s}$), 2) the schedule quality score ($q_{a\_index\_normalised}$) and 3) the realistic market share estimation (ms) of the carriers competing in a route. The research outputs can be studied at various levels including airport to airport, country to country or region to region scale. For example, while it is possible to analyse the consumer-centric capacity share, schedule quality and realistic market share estimation of all listed carriers that operate from Manchester to Beirut, the same analysis can be performed to have a broader look to these factors at the country level from United Kingdom to Lebanon or at the regional scale from Europe to the Middle East. Since all schedule information was uploaded into the research's database and the methodologies were coded in the website software to enable a smooth, fast and transparent calculation process, the results were retrieved online directly from the website.

In this Chapter, it is intended to show the fulfilment of Objective 1, 2, 3 and 4 of the research using real schedule information of the listed carriers. In order to demonstrate the realisation of Objective 1 and 2 which refer to developing a consumer-centric capacity share and quantify the airline schedule quality, certain markets were identified and analysed in detail. The markets were identified at all levels, i.e. airport to airport, country-country and region to region. While selecting the O&Ds, the markets which are primarily served by the listed airlines within the focus regions of this research (Europe, Middle East and Africa) were selected. For instance, markets like New York – Sao Paolo were not included in the analyses as both cities are in the Americas which is not founded in the focus region of the study. In the New York – Sao Paolo market, American or Brazilian carriers might be competing intensively with each other. However, their schedule information was not uploaded into the research database as there exists no American or Brazilian carriers among the listed airlines. Nevertheless, there exists cases outside the research's focus region in order to assess non-operating performances of the listed carriers and benchmark their codeshare performance. It is noteworthy to state that, the proposed methodologies of the research enabled the successful measurement of the research outputs for all carriers' markets across the world as long as the schedule information of the airlines competing in that route and the MCT information of the hub airports were obtained. The methodologies proposed in this research allow any airline to get included in the listed airline set and enable their products to be benchmarked with the competitors.

As previously addressed, Objective 3 of the research aimed to determine a realistic market share estimation. In the cases introduced in Section 10.2, the ms figures of each rival carrier are assessed using the REMSET model for the selected O&Ds. Moreover, in some cases, the ms forecasts are benchmarked with the actual market shares whose information was retrieved using the MIDT data referred to in Chapter 5. The comparison of the estimated market shares with the actual figures enables evaluating whether the REMSET produces credible results. Furthermore, the credibility of the REMSET along with the consumer-centric capacity determination and quality assessment ensures the successful fulfilment of Objective 4 as a credible market share estimation tool to assist industry practitioners to assess schedule and network competitiveness effectively.

As discussed in Chapter 5, the schedule information of the following 36 airlines were uploaded into research database on www.phdsukru.com to perform the analysis and benchmark the relative performance: Aegean Airlines (A3), Aeroflot (SU), Air Berlin (AB), Air France (AB), Air Lingus (EI), Air Norwegian (DY), Alitalia (AZ), Austrian Airlines (OS), British Airways (BA), Brussels Airlines (SN), Easyjet (U2), El Al Airlines (LY), Egyptair (MS), Emirates (EK), Ethiopian Airlines (ET), Etihad (EY), Finnair (AY), Germanwings (4U), Iberia (IB), KLM (KL), Lufthansa (LH), Middle East Airlines (ME), Pegasus Airlines (PC), Qatar Airways (QR), Royal Air Maroc (AT), Royal Jordanian (RJ), Ryanair (FR), SAS Scandinavian (SK), Saudia Airlines (SV), South African Airways (SA), Swiss (LX), TAP Portugal (TP), Tuifly (X3), Tunisair (TU), Turkish Airlines (TK), Wizzair (W6). These airlines ensure a good mixture of regional and global carriers as well as service and low-cost airlines within the research's focus regions. Therefore, the following sections display the selected O&D's performances among the list of 36 carriers in case they serve a product in the market.

Before selecting the O&Ds and running the methodology over the schedule of the selected airlines, it was required to set the assumptions which were used as part of the $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms calculation procedure. For the cases in Section 10.2, the parametric assumptions used within the research methodologies were fixed to specific values which are covered in the following section. In Chapter 11, the cases presented in section 10.2 are repeated by revisiting the assumptions and also by changing the schedules, such as placing a new flight to assess its impact on performance parameters or introducing a codeshare agreement to measure the change in connectivity.

10.1. Assumptions

The survey results have provided an indispensable input for the development of the research's models. Although the survey results form the backbone of the capacity share, quality and the REMSET models, there exist other variables awaiting to be set to complement the methodologies. These variables were coded to be adaptable in the developed software allowing to re-run the model in case it was demanded to alter the variables and set them to a different value. The adaptable parameters and the assumed default figures of these parameters are introduced below.

i. *Connect Seat Factor (s_{conn}):* The connecting seat factor is estimated to be 20% by default. The maximum seats allotted to one connecting itinerary cannot be more than 20% of the physical capacity. (There might exist more than one connecting itinerary on a single physical flight.) As the REMSET model utilises a consumer centric capacity share parameter ($\%_{a\_s}$), capacity assignment overloads are avoided across different O&D calculations. Therefore, the model does not use the calculated capacities in absolute numbers, but the percentile shares.

ii. *Codeshare Seat Factor (s_{code})*: The codeshare seat factor is assumed to be 30% by default. Non-operating services can get at most 30% of the physical capacity in the operating seats. (There might exist more than one codeshare agreement on a single physical flight.)

iii. *Maximum Detour Factor:* Fixing the kilometre index of the shortest itinerary available in a market to the detour value of 1, any flights above 1.75 detour factor, which is more 75% of the shortest path, are eliminated from the available competing products. Although the maximum detour factor is not referred as a factor of the consumer-centric capacity calculation model, it was required to make a maximum detour factor assumption to avoid long connections. For instance, for a journey from London to Paris, any connections via Hong Kong are infeasible. The quality score determination process referred to in the methodology chapter already involves time-related parameters which are correlated with the detour factor and thus already available in the schedule quality determination model. However, for the reporting purposes, a maximum detour factor of 1.75 is used to eliminate listing the remote connections.

iv. *Default MCT:* The minimum connecting time of the airports were obtained from the OAG and SRS databases whose credibility was ensured through the mechanisms explained in Chapter 5. These databases cover almost all airports in the world and provide their MCT information. Although, some low-cost carriers may adopt their own (shorter) MCTs in comparison to the published MCT figures founded in the OAG/SRS database, the official MCT values in the OAG database are used without making any adjustment for specific carriers. Besides, there may exist a few airports whose MCT information is lacking in the OAG and SRS databases. These are usually tiny airports with limited flights; some of them are military bases where civilian flights are occasionally operated. Although the probability of ensuring a connection at such airports is improbable, a default MCT was required to be set. Therefore, the minimum connecting time for the airports whose MCT information are not found in the OAG and SRS database is set to 45 minutes.

v. q_{split}: As discussed in Chapter 9, this parameter refers to a bonus score offered to connecting itineraries in case the duration of one leg is more than or equal to $\%_{q\_split}$ of the total flight time. Setting q_{split} to 1 enables a slight but reasonable “quality” advantage to connecting itineraries in case one leg within the journey is long enough to enable extra convenience for consumers, as found to be important for the consumers in the passenger survey.

vi. $\%_{q\_split}$: In order for one leg of the connecting itinerary to be considered long enough within a journey, this parameter is set to 80%. For instance, if the flight time of a connecting journey is 10 hours, in case one leg is longer than or equal to 8 hours, the itinerary would be qualified for an additional q_{split} score, which is set to 1.

As discussed in Chapter 8, the waste capacity discount model is adopted while calculating the adjusted seat capacity. Besides, as founded in the survey results, t_{buffer} is set to 30 minutes and the MaxCT to 290 minutes.

10.2. Results for the Selected O&Ds

In this section, the competition on the selected routes is analysed in detail by running the methodologies introduced in Chapter 8 and 9 over the uploaded schedule data of the listed carriers using the assumptions mentioned above. Each of the selected O&Ds have different characteristics. For instance, while some markets were selected from a business environment where limited competition exists, some other routes were selected among the markets having intense competition. A good mixture of domestic and international services are presented and analysed. Furthermore, while some markets was investigated directional results the others included the bidirectional analyses. The first eight cases were selected from O&D pairs at the airport/city level where the competition between the listed carriers is analysed. The following five cases were determined at the country to country level in which all airport to airport O&D pairs of the selected countries were extracted and included into the analyses. Finally, the final case was determined at the regional level, where all O&D pairs at the city level of each country in the selected regions were included into the examination to benchmark the competing performance of the listed carriers.

Throughout the results Chapter, the directional markets are symbolised with a dash ("-") sign. For instance, a directional market from London to Paris is symbolised as London-Paris. As the reverse direction indicates a different market, Paris-London is not an identical route to the London-Paris market. The bidirectional markets, which refers to both directions are illustrated with a slash ("/"). In this case, the whole market between London to Paris and Paris to London are shown as London/Paris which is no different from Paris/London. On the other hand, in the reporting of the proceeding cases, in case the calculated figures results with a decimal, it is rounded to nearest integer for frequency (f) and seat supply (s). The percentages are displayed with 0.00 (one over hundred) sensitivity while the quality scores are reported in 0.0000 (one over ten-thousands). The selected O&D pairs are summarised in the table below:

Table 10.1: Selected O&Ds for Analysis

Case #	O&D	Region	Explanation
Case 1	GVA–ZRH	Intra - Europe	Short-Haul Directional Domestic Route
Case 2	DUB/SOF	Intra - Europe	Short-Haul Bidirectional International Route
Case 3	HAM/BEY	Europe / M. East	Short-Haul Bidirectional International Route
Case 4	SKG/TBS	Europe / CIS	Short-Haul Bidirectional International Route
Case 5	JED/AMM	Intra – M. East	Short-Haul Bidirectional International Route
Case 6	MAN/DOH	Europe / M. East	Mid-Haul Bidirectional International Route
Case 7	LGW/BKK	Europe / Far East	Long-Haul Bidirectional International Route
Case 8	LAS/MIA	N. America	Mid-Haul Bidirectional Domestic Route
Case 9	Portugal / Serbia	Intra - Europe	Country to Country Bidirectional Route
Case 10	UK / Israel	Europe / M. East	Country to Country Bidirectional Route
Case 11	Italy / Italy	Intra - Europe	Entire Italian Domestic Route
Case 12	Turkey / Turkey	Intra – Europe	Entire Turkish Domestic Route
Case 13	Canada / India Vs. Canada / Pakistan	North America / Asia	Country to Country Long Haul Bidirectional Route Comparison
Case 14	South America / Middle East	South America / Middle East	Entire Regional Market from/to S. America and the Middle East

10.2.1. Case 1: GVA-ZRH

The first case analyses a domestic directional route at the airport level. In this example, the flights from Geneva Cointrin Airport (GVA) to Zurich Kloten airport (ZRH) are assessed, not the other way around. Both cities are located in Europe, which is in the research's focus area. The objective to study this case is to comprehend the difference between the physical capacity and the capacity available for sale. As of 2016 schedule data, the only operating direct flight from GVA to ZRH was operated by Swiss (LX) under the following flight numbers. (No additional carriers other than the listed 36 airlines provide a direct service from GVA to ZRH) The table summarises routing, total weekly frequency (f), seat supply (s) per week as well as the average total journey time for each flight number.

Table 10.2: Direct Flights of LX from GVA to ZRH

Flight Number	Routing	Frequency	Seat per Week	t_{total}
LX 2801	Direct	7	679	00:45
LX 2805	Direct	7	1,299	00:55
LX 2807	Direct	7	2,380	00:55
LX 2809	Direct	7	1,177	00:55
LX 2811	Direct	7	1,050	00:50
LX 2813	Direct	7	679	00:55
LX 2815	Direct	7	1,050	00:55
LX 2817	Direct	7	679	00:50
LX 2819	Direct	7	966	00:50
Total		63	9,959	

The table implies that there existed 9,959 direct operating weekly seats from GVA to ZRH in total. However, some airlines have performed codeshare agreements with LX on some of the direct flights. For this reason, the partner airlines were enabled to sell domestic tickets from GVA to ZRH via the codeshare agreements and therefore could expect a market share. Marketing airlines and their direct non-operating seat supply per week are displayed in the table below. As discussed in Chapter 8, seat supply of codeshare flights is calculated by multiplying codeshare seat factor, the s_{conn}, with the total seats of the operating carrier.

Table 10.3: Non-operating Direct Flights from GVA to ZRH.

Airline	Routing & Type	Frequency	Seat per Week	t_{total}
AB	Direct – Non-Op	14	214	00:50
EY	Direct – Non-Op	14	214	00:50
LH	Direct – Non-Op	62	2,991	00:53
SA	Direct – Non-Op	7	290	00:45
SK	Direct – Non-Op	7	204	00:55
Total		104	3,913	

Table 10.3 shows that a total of 3,913 non-operating seats in 104 distinct frequencies were available for sale in the inventories of 5 distinct airlines as of 2016 schedules. 3,913 codeshare seats out of 9,595 physical supply refer to 39.3% which is higher than the s_{code} value of 30%. This is not an unexpected situation since more than one airline may have engaged into a contractual relationship with the LX which can also be verified by checking the operating vs non-operating frequency counts. As deduced from Table 10.2 and 10.3 the non-operating frequencies are higher than the physical operating frequencies in the GVA–ZRH market: 63 operating vs 104 non-operating. It is implied from these figures that, LX has signed off codeshare contracts with 104/63 = 1.65 airlines on average for each direct frequency. Since Lufthansa (LH) has 62 non-operating frequencies from GVA to ZRH, which is only 1 less than the entire physical frequencies, it can be argued that LH has signed codeshare agreements for almost all direct frequencies of LX. Air Berlin (AB), Etihad (EY), South African Airways (SA) and Scandinavian (SK) also signed off codeshares for some of the LX's direct flights from GVA to ZRH.

As of 2016 schedules, there also existed connecting services from GVA to ZRH. LX offerws connecting itineraries via LUG, Lugano. Since, the connections remained within the assumptions of the methodology to attain a successful hit, (i.e. t_{conn} >= MCT (of LUG airport) and t_{conn} <= MaxCT (290 minutes)), a market share could also be expected for the connecting itineraries too. The following table summarises, operating and codeshare connecting frequencies, available seats and average total time for the GVA–ZRH route.

Table 10.4: Connecting Operating and Codeshare Services from GVA to ZRH.

Airline	Routing & Type	Frequency (f)	Seat per Week (s)	t_{total}
LX	Connect – Op	14	213	255 minutes
TP	Connect – Non-Op	4	18	145 minutes
Total		18	231	246.4 minutes

Table 10.4 shows that LX offered operating connecting services from GVA to ZRH while TP offered only codeshare seats. While direct services of LX managed to transport passengers from GVA to ZRH approximately in 50 minutes, the t_{total} of LX's connecting journey time was reported to be 255 minutes. It is also observed in the table that TP's connecting products were shorter in time in comparison to LX. On the other hand, the number of available connecting seats were fewer compared to direct services. The following table demonstrates the consolidated view of routing (i.e. direct or connecting), total weekly frequency (f), frequency share, ($\%_f$), seat supply (s), seat share ($\%_s$) of all services in the GVA–ZRH market as of summer 2016 schedule.

Table 10.5: Consolidated Capacity Parameters for Carriers Serving From GVA to ZRH

Airline	Type	f	$\%_f$	s	$\%_s$
AB	Direct	14	7.57%	214	1.52%
EY	Direct	14	7.57%	214	1.52%
LH	Direct	62	33.51%	2991	21.21%
LX	Direct	63	34.05%	9959	70.62%
SA	Direct	7	3.78%	290	2.05%
SK	Direct	7	3.78%	204	1.44%
LX	Connect	14	7.57%	213	1.51%
TP	Connect	4	2.16%	18	0.13%
Total		185	100%	14,103	100%

Table 10.5 implies that the physical capacity offered by LX refered to the 34.05% of the total frequencies and 70.62% of the entire seats available for sale in the market. Furthermore, connecting seats added up to less than 2% of the whole seat availability. It is easily inferred from the table that the codeshare agreements demolished LX's monopoly position in the market and permitted other airlines to compete in the GVA–ZRH market. LX

might have signed off codeshare agreements with the marketing carriers to start selling tickets in the other markets where it was not physically present in exchange for the GVA–ZRH market. (Since LH owns LX, it was not beyond the expectations for the parent airline to receive a market share in GVA–ZRH route through codeshare contracts.) Such agreements might also have been an outcome of the regulatory requirements to ensure fair competition in the relevant jurisdictions. The following table shows the seat share ($\%_s$) and market share estimation (ms) of each airline & routing as fetched from the database and research software.

Table 10.6: Seat Share and Market Share Estimation of the GVA–ZRH Route.

Airline	Type	$\%_s$	Ms
AB	Direct	1.52%	1.28%
EY	Direct	1.52%	1.28%
LH	Direct	21.21%	16.86%
LX	Direct	70.62%	76.88%
SA	Direct	2.05%	1.92%
SK	Direct	1.44%	1.10%
LX	Connect	1.51%	0.59%
TP	Connect	0.13%	0.09%

As per the table, direct services of LX were expected to have a market share of 76.88%, despite 70.62% of $\%_s$. The higher market share of LX in comparison to its seat share was sourced due to the better quality score of its LX's direct flights in contrast to the rivals. (The following cases demonstrate how the computation of adjusted seat share and the quality scores shape the ms.) On the other hand, connecting services of LX was expected to gain only 0.59% market share where the physical seat capacity share of the service was reported to be 1.51%. Therefore, LX was expected to own 77.47% of the market of which 76.88% gained from the carriers' direct services and the remaining 0.59% via the connecting flights. LH followed LX with 16.86% market share expectation. While the carrier held 21.21% of the whole seats available for sale, it was expected to gain less market share since the "quality" of codeshare flights were relatively lower and therefore not equally preferred by the consumers. The other carriers were all expected to report less than 2% ms.

This case shows how codeshare agreements can alter the dynamics in the market and can change the structure of ms in favour of the marketing airline. It also proves that airlines that do not operate physical flights in a market can indeed expect a market share via codeshare mechanism. The following cases illustrate the impact of quality on the ms estimation and benchmark the calculated figures with the actual market shares to test the credibility of the results.

10.2.2. Case 2: DUB/SOF

The second case analyses the services between Dublin (DUB), Ireland and Sofia (SOF), Bulgaria. These cities are both located in Europe. It should be noted that this case studies a bidirectional market; therefore the results were calculated for each direction separately and later merged to form the calculations in the whole market. The calculated bi-directional market share estimations are also compared with the real market share values retrieved from the MIDT data to test the accuracy of the findings. The below table shows the routing type, total weekly frequency (f), frequency share, ($\%_f$), seat supply (s), seat share ($\%_s$), adjusted capacity share ($\%_{a\_s}$) from DUB to SOF (directional) for each airline serving in the route as of summer 2016 schedule.

Table 10.7: Consolidated capacity parameters for carriers serving from DUB to SOF

Airline	Type	f	$\%_f$	s	$\%_s$	$\%_{a\_s}$
AF	Connecting	7	13.46%	126	9.35%	9.47%
FR	Connecting	7	13.46%	265	19.63%	19.88%
KL	Connecting	9	17.31%	73	4.45%	5.52%
LH	Connecting	21	40.38%	638	47.35%	47.96%
LX	Connecting	1	1.92%	20	1.48%	0.21%
TK	Connecting	7	13.46%	226	16.75%	16.96%

As the table illustrates, there existed no direct flights from DUB to SOF. All services were offered through connections of AF, FR, KL, LH, LX and TK. The table also shows the difference between the physical supply and the adjusted seat supply ($\%_s$ vs $\%_{a\_s}$) which was sourced due to the unavailability of daily services for certain carriers. It is observed in the table that, except LX, each airline offered 7 or more frequencies and all days were served with at least one flight. Therefore the seat share of LX needed to be discounted by using the waste capacity discount model. As a result, although the physical seat share ($\%_s$) of LX contributed to 1.48% of the entire route, the consumer-centric adjusted seat share ($\%_{a\_s}$) was 0.21%. The carrier lost 6/7 of its capacity share as it offered only a single connection per week. The following table shows normalised quality index ($q_{index\_normalised}$), time index, adjusted normalised quality index ($q_{a\_index\_normalised}$), kilometre index and market share estimation (ms) for each carrier's services in the DUB–SOF market.

Table 10.8: Selected Parameters of the Carriers in the DUB–SOF Market as of 2016 Schedule Data.

Airline	$q_{index\_normalised}$	Time Index	$q_{a\_index\_normalised}$	KM Index	ms
AF	1.0586	1.447	0.7314	1.023	8.41%
FR	0.7921	1.417	0.5592	1.000	13.50%
KL	0.7390	1.164	0.6349	1.008	4.26%
LH	1.0331	1.000	1.0331	1.000	60.19%
LX	0.8172	1.293	0.6319	1.014	0.16%
TK	0.9561	1.463	0.6536	1.385	13.47%

Table 10.7 and 10.8 suggest that, although the adjusted capacity share of Lufthansa (LH) was 47.96%, the estimated realistic market share of the carrier was 60.19% as the airline scored the highest adjusted quality score of 1.0331 compared to its rivals. Nevertheless, LH offered the shortest journey time which positively affected the carries' schedule quality score. Ryanair (FR), scoring least in the $q_{a\_index\_normalised}$ value with 0.5592 score was estimated to be the second airline in the market and gain 13.5% share of the market, despite its 19.88% adjusted seat share. Turkish Airlines (TK) was estimated to own 13.47% of the market, lower than its $\%_{a\_s}$ due to the carriers relatively poor quality score. Therefore these results suggest that $q_{a\_index\_normalised}$ score has a direct influence on ms. Air France (AF), KLM (KL) and Swiss (LX) are expected to score relatively smaller market shares from DUB to SOF with 8.41%, 4.26% and 0.16% respectively.

The above analysis depicted the directional results from DUB to SOF. In order to have an idea concerning the bidirectional market, the same computations performed above were needed to be reported in the reverse direction, SOF–DUB. The following table summarises the routing type, $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms for each carrier operating from SOF to DUB.

Table 10.9: Selected Parameters in the SOF–DUB Market as of 2016 Schedule Information

Airline	Type	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AF	Connecting	5.83%	0.5030	3.63%
BA	Connecting	19.77%	0.6147	15.05%
KL	Connecting	6.03%	0.8058	6.02%
LH	Connecting	45.93%	0.9233	52.51%
TK	Connecting	22.45%	0.8202	22.80%

The table implies that there also exists no direct services from SOF to DUB. FR (Ryanair) cannot achieve a successful connection in the market, and therefore no market share was estimated for the carrier. This was because FR flight from SOF to STN (London Stansted Airport) arrived at STN at 23:10 and the next earliest flight from STN to DUB was at 08:15. Since the connecting time at the STN airport was higher than the MaxCT of 290 minutes, no connection was attained for FR. Similarly, LX could not achieve a successful connection in the SOF–DUB route and no market share forecast was allotted for the carrier. However, unlike DUB–SOF route, British Airways (BA) offered successful connections via LHR (London Heathrow Airport) in the reverse market.

The table below summarises the ms values produced by the REMSET model for each carrier in each direction. In case no market share was expected for the carrier, zero per cent was reported. The last column displays the average of DUB–SOF's and SOF–DUB's ms values. The flow of demand is assumed to be equal in both directions. Since demand is distributed to both directions equally, bidirectional ms values can be calculated by merely averaging ms of each direction.

Table 10.10: Directional Market Share Estimations of Carriers and Bidirectional ms in the DUB/SOF Market using the REMSET model.

Airline	DUB–SOF ms	SOF–DUB ms	DUB/SOF ms
AF	8.41%	3.63%	6.02%
BA	0%	15.05%	7.52%
FR	13.50%	0%	6.75%
KL	4.26%	6.02%	5.14%
LH	60.19%	52.51%	56.35%
LX	0.16%	0%	0.08%
TK	13.47%	22.80%	18.14%

Table 10.10 suggests that LH was expected to have the highest market share in the bidirectional SOF/DUB market with 56.35%, followed by TK with 18.14%. The rest of the carriers were expected to report less than ten per cent market share where the third largest carrier was forecasted to be BA with 7.52% ms. In order to check the accuracy of these estimations, the calculated bidirectional ms figures were compared and contrasted with the real market share information of 2016 retrieved from MIDT data and with the results of the traditional (naïve) model that simply utilises the capacity shares of the competing carriers illustrated in the table below:

Table 10.11: A Comparison of Calculated ms and Real ms in the Bidirectional SOF/DUB Route

Airline	Naïve model ms	REMSET ms	Real ms
LH	46.6%	56.3%	55.2%
TK	19.6%	18.2%	26.6%
BA	9.9%	7.5%	4.3%
AF	7.8%	6.0%	4.2%
KL	5.2%	5.1%	4.1%
Others	10.9%	6.9%	5.6%

According to the table, as per the MIDT figures, LH has been the largest carrier in the SOF/DUB market, reporting 55.2% market share. Comparing this value with the forecasted ms value of 56.3% of LH, it can be concluded that the model produced a credible estimation. On the other hand, the model also correctly identified the second and third carrier which are TK and BA respectively, further crediting the research's ms calculation methodology. However, while the REMSET model estimated the ms value of TK to be 18.2%, the real market share was 26.6%. On the other hand, while BA owned 4.3% of the market, the estimation was 7.5%. The difference between the calculated and actual market share values are not unexpected and can be justified due to various reasons. For instance, the variances between the fare structures of the carriers as well as their market penetration and brand perception can positively affect the actual market performance. Moreover, while calculating the ms in a bidirectional route, simply the average ms values of the carriers in each direction was taken. Since BA was not expected to have a market in the DUB–SOF market but reported a considerable share in the reverse direction, the carrier may have lost traffic especially from passengers booking roundtrip tickets. Moreover, an unlisted airline or airlines presenting at least one itinerary in the market may have existed whose ms calculations were not incorporated into the REMSET model. Therefore, despite the minor differences between calculated and actual market shares, the research model has produced a credible and accurate ms estimation in the SOF/DUB market.

In order to statistically test the efficiency of the competing naïve and REMSET models, a paired proportion test was implemented for naïve/real and REMSET/real market shares datasets using the market share values of the competing carriers shown in Table 10.11 including other airlines at the individual carrier level. As the values to be tested are in percentage values and they are dependent figures for the associated airlines, the paired proportion test was decided to be the appropriate method. This test would return the p value which is expected to be between 0 and 1. "p-values" simply provide a cut-off beyond which we assert that the findings are statistically significant; by convention, this is $p<0.05$. (Davies & Crombie, 2018) Therefore, any value of p less than 0.05 would imply significance with the results implying that there exists statistical difference between the measured percentages. Any p value closer to 1 would imply "extremely strong insignificance".

The p value for the naïve model vs. real market shares is 0.498 whereas the p value for REMSET vs. real market shares is 0.733. These findings imply that the results of both the traditional capacity-blended traditional naïve model and the REMSET model are insignificant to real market share data obtained from the MIDT. The naïve model's insignificance is not unexpected as the capacity is naturally the major driver of the competing carriers' market shares. However, as the p value of the REMSET model is higher than the naïve model, it can be concluded that, the REMSET model produced a stronger insignificance due to higher p value, in other words a stronger accuracy in the market share predictions in comparison to the naïve model.

Through this case, it was shown that research's Objective 1, 2 and 3 were fulfilled. First, the distinction between available seat supply share ($\%_a$) and consumer-centric adjusted capacity, in other words, the adjusted seat share ($\%_{a\_s}$) was shown (Objective 1). Second, the quality scores of each itinerary available in the market were calculated proving the achievement of Objective 2. On the other hand, the ms of each carrier was assessed in the market which refers to the attainment of Objective 3. The estimated ms values are similar to actual market shares, ensuring the credibility and accuracy of the REMSET model.

10.2.3. Case 3: HAM/BEY:

The third case examines the services between Hamburg (HAM), Germany and Beirut (BEY), Lebanon. Different from the previous cases which only evaluated inter European markets, this is an intercontinental route between Europe and the Middle East. The case intends to show the fulfilment of quality score determination for the competing carriers (Objective 2) and to demonstrate the accuracy of the REMSET model (Objective 3). The below table shows the routing type, adjusted capacity share ($\%_{a\_s}$), normalised quality index ($q_{index\_normalised}$), and realistic market share estimations (ms) in the HAM–BEY and BEY–HAM routes respectively for each airline competing in the market as of summer 2016 schedule.

Table 10.12: Figures for Airlines in the HAM–BEY Route as of Summer 2016 Schedule

Airline	Type	$\%_{a\_s}$	$q_{a\_index\_normalised}$	KM Detour	ms
A3	Connecting	0.24%	0.7158	1.068	0.30%
AF	Connecting	9.18%	0.7299	1.317	11.78%
BA	Connecting	6.96%	0.7685	1.422	9.41%
EK	Connecting	26.51%	0.6845	2.360	0.00%
LH	Connecting	22.73%	0.8994	1.092	35.94%
PC	Connecting	12.36%	0.5601	1.001	12.17%
SU	Connecting	1,70%	0.5551	1.423	1.66%
TK	Connecting	20.32%	0.8045	1.000	28.75%

Table 10.13: Figures for Airlines in the BEY–HAM Route as of Summer 2016 Schedule

Airline	Type	$\%_{a\_s}$	$q_{a\_index\_normalised}$	KM Detour	ms
AF	Connecting	9.10%	0.5534	1.317	7.67%
BA	Connecting	9.56%	0.6233	1.422	9.07%
EK	Connecting	16.60%	0.5615	2.360	0.00%
LH	Connecting	21.31%	0.7951	1.092	25.80%
PC	Connecting	11.59%	0.5931	1.001	10.46%
SU	Connecting	1.60%	0.5260	1.423	1.28%
TK	Connecting	30.25%	0.9932	1.000	45.73%

Table 10.12 and 10.13 suggest that there existed no direct flights in the BEY/HAM market. Furthermore, although Emirates (EK) managed successful connections in both routes; it was not expected to gain any market share since its KM detour was above 1.75, implying that passengers were required to travel a very long distance compared to rivals which would avert them to prefer the airline. Lufthansa (LH) was expected to obtain the highest market share from HAM to BEY whilst Turkish Airlines (TK) was expected to be the market leader on the route back. From the schedule quality perspective, in the HAM–BEY route, LH was reported to have the highest $q_{a\_index\_normalised}$ indicating the best quality among competitors, while in the BEY–HAM route TK's quality score was reported at the top. The below table summarises the bidirectional market share estimation of the carriers which is simply obtained by averaging the ms of each carrier in both directions.

Table 10.14: Realistic Market Share Estimations BEY/HAM Route as of 2016 Schedules.

Airline	Type	ms
A3	Connecting	0.15%
AF	Connecting	9.72%
BA	Connecting	9.23%
EK	Connecting	0.00%
LH	Connecting	30.87%
PC	Connecting	11.32%
SU	Connecting	1.47%
TK	Connecting	37.24%

According to the MIDT data, in 2016, TK ranked market leader with 37.8% of the entire market. Comparing the ms values shown in Table 10.14 with this information, it is inferred that the model generated a credible and accurate estimation concerning the market leader and its ms. (The model estimated ms to be 37.24% while the actual share was 37.8%) As per the MIDT, the second largest carrier in HAM/BEY market was Pegasus Airlines (PC) with 22.6% share while the third carrier was reported to be LH with 15.4%. However, the REMSET model estimated LH to rank second with 30.87% ms and PC to rank third with 11.32%. Although further analyses are required to fully and scientifically comprehend the difference between the estimated and actual market share, it could be considered that the fare structures of LH and PC can justify the difference. While LH is an FSC based in Germany, PC is a LCC in Turkey. It is certain that PC charges less for a ticket in the BEY/HAM market in comparison to LH. Although additional enquiries concerning the fare impact on ms are beyond the scope of this study, a separate analysis could be performed for the market share estimations for 2015. Since the schedule information of PC suggested that, the carrier has entered into BEY/HAM market as of 2016, running the ms estimation for 2015 schedules in the HAM/BEY route would eliminate the low-cost impact of the market that would assist justifying the fare impact on the estimated and actual market shares. The table below reviews the forecasted and actual market shares of the carriers in the same market as of 2015 schedules.

Table 10.15: Realistic Market Share Estimations and Actual Market Shares BEY/HAM Route as of 2015 Schedules.

Airline	Type	Estimated ms	Actual ms
AF	Connecting	10.18%	7.2%
BA	Connecting	13.28%	6.4%
LH	Connecting	24.83%	27.2%
LX	Connecting	2.32%	4.3%
SU	Connecting	1.27%	3.0%
TK	Connecting	48.13%	49.4%
Others	Connecting	N/A	2.5%

It is observed in the table that, PC and Aegean Airlines (A3) was not offering any service in the market as of June 2015. Both carriers entered the market in 2016 and PC had gained a substantial share within its first year. As per 2015 schedules, the model correctly estimated TK to be the most dominant carrier in the market with 48.13% ms. The MIDT results suggested a market share of 49.4% for TK, very similar to the forecast. On the other hand, the REMSET proposed LH to be the second carrier with 24.8% market share while the actual figure was reported to be 27.2%. These findings credit the argument raised while justifying the gap between the PC's calculated and actual ms values as of 2016 schedules in the sense that the LCCs' fare structure can significantly affect the actual market shares. As per 2015 results, the estimated and actual market shares for the remaining carriers were not far from each other, which validates the accuracy of the REMSET model.

This case showed the precision of the research's model in terms of accurately estimating the leading carriers in the market and their corresponding realistic market share values, fulfilling Objective 3 of the research. Being able to benchmark the quality scores at the directional level also proved the accomplishment of Objective 2. Additionally, the case also showed the impact of a newcomer LCC and its influence on the competitive dynamics in terms of shaping the market shares. Therefore, the model provided a useful tool for airline executives to assess their competitiveness given the changes in the market conditions, an instrument that can be considered as a partial fulfilment of Objective 4 which aimed to develop a tool for industry practitioners to assess schedule and network competitiveness.

10.2.4. Case 4: SKG/TBS:

In this case, the change in the competition from Thessaloniki, Greece (SKG) to Tbilisi, Georgia (TBS) is investigated. Different from the previous cases, this example studies the competition on the route beginning from 2010. Analysing the performance between 2010 and 2016 would enable industry experts to observe the historical market development and assist them to design their commercial strategies using these information, serving for the fulfilment of Objective 4.

As of 2010, the only product of the listed carriers in the SKG–TBS market was a connecting operating Lufthansa (LH) service via Munich (MUC). Therefore, the ms in the route was 100% in favour of LH. In the reverse direction, in addition to LH, Austrian Airlines (OS) used to offer connecting services via Vienna (VIE). The expected share in TBS–SKG was 52% and 48% for LH and OS respectively.

In the following year, in 2011, market conditions were slightly different. LH was again the sole carrier offering an itinerary in the SKG–TBS route, forecasted to gain the whole market share whereas on the way back TK replaced OS. LH was expected to own 53.90% while TK was expected to gain 46.10% share in the TBS–SKG market. It should be noted that since SKG/TBS has been a thin market where the available capacity was limited, and therefore the change in the schedules of the carriers significantly changed the competitive structure of the market. Since OS changed its schedule from TBS to VIE in 2011, no connection was attained to SKG, and the airline was therefore removed from the competition.

Rivalry in the market continued to further change in 2012. Aegean Airlines (A3) placed a flight from Athens (ATH) to TBS with two frequencies per week and therefore attained a connection from SKG to TBS via ATH. Moreover, OS managed a weak connection once per week and therefore destructed the monopole position of LH in the SKG–TBS route. The new entrants offered shorter journey times and thus eliminated LH's market share estimation due to the detour factor. The distance of the LH’s itinerary from SKG to TBS via MUC was 84.5% more than the shortest path in the market which belonged to A3’s connection. As of 2012, A3’s ms expectation was reported to be 94.19% while OS owned the remaining 5.81% estimated share in the SKG–TBS route. On the reverse direction, OS could not attain a hit and therefore could not compete in the market. Similar to SKG–TBS route LH was out of competition again due to detour elimination in the TBS–SKG market. Moreover, unlike 2011, TK completely lost its market in the TBS–SKG route due to a schedule change. The carrier changed its Istanbul (IST)–SKG departure time to 13:15 which used to be 10:00 in the previous year and therefore the connection was not attained due to high connecting time above the MaxCT. Thus, A3 remained the only carrier offering a product in TBS–SKG route and therefore reported to own 100% ms expectation.

In 2013, market dynamics shifted again. A3 inserted a domestic flight (flight number A3 127) from SKG to ATH which managed another successful connection hit to TBS. Moreover, LH’s services were again eliminated from the rivalry because of its longer routing, deeming A3 to be the only service provider in the SKG–TBS route. On the route back, a different carrier came onto the stage. Alitalia (AZ) did not have a flight from TBS to Rome (FCO) in 2012 summer but started flights in 2013 season and therefore managed a successful connection in the TBS – SKG route with a market share expectation of 66.24%, and the A3 was expected to take over the remaining shares.

In 2014, market conditions changed again significantly in the SKG–TBS route. A3 lost its market leader position and was replaced by TK with 96.86% ms estimation. Two actions of the carrier enabled TK to enter the market and dominate it. First, insertion of TK1894 flight from SKG to IST managed a successful connection to TBS. Second, the change in the departure time of TK1882 (flying from SKG to IST) from 15:40 to 09:40 accomplished another successful hit to TBS. Due to these network changes, TK's supply in the market massively increased with two distinct combinations and made the airline rank top with 96.86% ms estimation. Although the following carrier was LH in seat capacity, the methodology did not again qualify a market share for the carrier as the kilometre detour of the carrier is 2.14 times of the shortest path available in the market, which belongs to TK. In other words, LH's itinerary from SKG to TBS via Munich (MUC), is 2.14 times of the distance from SKG to TBS via IST, which is higher than the 1.75 cap. The remaining 3.14% market share of the SKG–TBS route was forecasted to be owned by A3. On the route back, TK was again estimated to be the market leader with 91.68% ms with a single hit linking TK387 (TBS–IST flight) with TK1881 (IST–SKG flight). A3 was expected to obtain the remaining shares.

The schedule changes in 2015 were detrimental in the shifting ms expectations. TK was completely removed from the competition as TK1882's departure time from SKG was moved back to 15:40, which used to be 09:40 in 2014 and thus lost connection to TBS. Moreover, TK1894 was cancelled. A3's connections remained intact, and no other airlines competed in the market. Therefore A3 was forecasted to capture the entire market from SGK to TBS. On the way back, AZ came back to the market since it changed its departure time of AZ734 from FCO to SKG to 09:20 which used to be 12:05 previous year and thus attained a connection with the AZ551 flight (TBS to FCO). The carrier also increased the weekly frequency of AZ734 from 4 to 7. These changes led AZ to expect 64.75% of the market while the remaining shares were forecasted to be owned by A3.

In 2016, TK came back to the stage in the SKG–TBS route. TK1894 was reintroduced and departed SKG at 21:25 and managed a successful connection to TBS via IST. This connection led TK to expect 69.86% market share in the route. The remaining shares were estimated to be owned by A3. On the TBS–SKG route, although KL, LH and OS offered a hit, the carriers did not qualify for a ms expectation due to the detour factor above 1.75, which routed passengers longer via their hubs Amsterdam (AMS), MUC and VIE respectively. TK was again estimated to be the market leader with 67.99% ms expectation while A3 held the remaining shares.

From 2010 to 2016, no carrier placed a direct flight in the O&D, and the carriers have always competed via their connecting products. The following three tables summarise the market share of the carriers in the market from 2010 to 2016. Table 10.16 shows the figures in SKG–TBS route while TBS–SKG route is displayed in Table 10.17. Table 10.18 demonstrates the bidirectional market shares by averaging the ms values in each direction.

Table 10.16: Market Share of Carriers in SKG–TBS Route from 2010 to 2016

	SKG–TBS						
	2010	2011	2012	2013	2014	2015	2016
A3	0.0%	0.0%	94.2%	100.0%	3.1%	100.0%	30.1%
AZ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
KL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LH	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OS	0.0%	0.0%	5.8%	0.0%	0.0%	0.0%	0.0%
TK	0.0%	0.0%	0.0%	0.0%	96.9%	0.0%	69.9%

Table 10.17: Market Share of Carriers in TBS–SKG Route from 2010 to 2016

	TBS–SKG						
	2010	2011	2012	2013	2014	2015	2016
A3	0.0%	0.0%	100.0%	33.8%	8.3%	35.2%	32.0%
AZ	0.0%	0.0%	0.0%	66.2%	0.0%	64.8%	0.0%
KL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LH	52.0%	53.9%	0.0%	0.0%	0.0%	0.0%	0.0%
OS	48.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TK	0.0%	46.1%	0.0%	0.0%	91.7%	0.0%	68.0%

Table 10.18: Market Share of Carriers in TBS/SKG Undirectional Route from 2010 to 2016

	TBS–SKG (undirectional)						
	2010	2011	2012	2013	2014	2015	2016
A3	0.0%	0.0%	97.1%	66.9%	5.7%	67.6%	31.1%
AZ	0.0%	0.0%	0.0%	33.1%	0.0%	32.4%	0.0%
KL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LH	76.0%	76.9%	0.0%	0.0%	0.0%	0.0%	0.0%
OS	24.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%
TK	0.0%	23.1%	0.0%	0.0%	94.3%	0.0%	68.9%

Tables 10.16, 10.17 and 10.18 imply that the market leaders have shifted over the years. Changes in the networks and schedules have significantly changed the competitive position of the airlines serving in the market. It is easily inferred from the tables that, the dominance of LH which was present in 2010 and 2011 had shifted to A3 and TK from 2012 onwards, except 2015 for TK when the carrier was not projected to receive any market share. AZ was reported to own a considerable market share above 30% in 2013 and 2015 only, not in the other years. As the demand in SKG/TBS market has been thin, it can be argued that carriers did not design a consistent and dedicated capacity, particularly for this market. Airlines actions at the leg basis to and from TBS or SKG determined their capacity in the bidirectional route. Therefore, this case showed how airlines could analyse the outcomes of their network and schedule related decisions for a specific market, accomplishing Objective 4 of the research.

10.2.5. Case 5: JED/ AMM:

For this case, the traffic between Jeddah, Saudi Arabia (JED) and Amman, Jordan (AMM) is selected. The case intended to demonstrate the credibility of the REMSET model by covering an international route within the Middle East where there existed both direct and connecting services. Tables 10.19 and 10.20 show the routing type, total weekly frequency (f), seat supply (s), adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) from JED to AMM and from AMM to JED respectively for each airline serving in the route as of summer 2016 schedule. Table 10.21 shows the average market share expectations of the competing carriers in the bidirectional market, obtained simply by averaging the ms expectations of the competing carriers in each direction.

Table 10.19: Results of the Selected Parameters from JED to AMM as of 2016.

Airline	Routing	f	S	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4.958	68.77%	1.2974	71.92%
SV	Direct	12	1.749	24.26%	1.2081	23.62%
AZ	Connecting	4	30	0.24%	0.7106	0.14%
MS	Connecting	14	309	4.29%	0.7277	2.52%
ME	Connecting	7	176	2.45%	0.9143	1.80%
Total		65	7.222	100%		100%

Table 10.20: Results of the Selected Parameters from AMM to JED as of 2016.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4.958	70.57%	1.2510	72.37%
SV	Direct	10	1.485	21.11%	1.2819	22.18%
MS	Connecting	14	398	5.65%	0.6987	3.24%
ME	Connecting	7	176	2.51%	1.0180	2.09%
SV	Connecting	2	40	0.16%	0.8329	0.12%
Total		61	7.057	100%		100%

Table 10.21: Market Share Expectations of Carriers in the Bidirectional JED/AMM Market as of 2016

Airline	ms
RJ (direct)	72.14%
SV (direct)	22.90%
ME (connect)	1.95%
MS (connect)	2.88%
AZ (connect)	0.07%
SV (connect)	0.06%

The tables show that Royal Jordanian (RJ) offered the most number of seats in both routes via its 4 direct flights per day (adding up to 28 weekly frequencies). Furthermore since the quality score of the RJ flights were also competitive against the rivals, the carrier was expected to have 72.14% market share. RJ was followed by another direct service operator, Saudi Airlines (SV) which is expected to obtain 22.90% share of the entire market. While SV sold 12 direct flights per week in JED–AMM market, the carrier offered 10 direct services on the reverse direction. Unlike RJ which made its aircraft to fly in JED–AMM route without any interruptions, (the frequency and seat supply of RJ is identical in both directions) SV flew from AMM to Madinah (MED) in two frequencies (on Mondays and Wednesdays) per week rather than flying to JED direct and offered connecting itineraries via MED. This connecting product of SV was expected to get 0.06% market share only as the quality of the product was profoundly disturbed by the connection.

Alitalia (AZ) offered non-operating connecting services in the market and was expected to receive a negligible share in the market while the operating connecting services of the Middle Eastern Airlines (ME) via Beirut (BEY) was estimated to receive 1.95% of the whole market. Egyptair (MS) offering service via Cairo (CAI) was estimated to catch 2.88% of the market. It is crucial to state that, since there existed multiple numbers of flight availabilities in the JED–AMM market, the model estimated direct flights to own approximately 95% of the shares which is in line with the market expectations. It is also apparent in the tables that, the quality scores of the direct flights were much higher than the connecting products that significantly impacted the ms expectations in favour of the direct flights.

For state-owned carriers like SV and RJ, operational convenience can be a more important factor than the marketing-related concerns. Such carriers may enjoy supply dominance in their home market which ultimately shapes their market share estimations. As inferred from the analyses, unlike the European routes, Middle Eastern markets are less open to competition and the routes were usually protected by the governmental regulations in favour of the national carriers. An analysis could be performed by checking the market share estimations in the same market for the past years to understand whether the competitive market dynamics were different in the previous years. The following table summarises the ms expectations of the competing carriers on the same route as of 2011 and 2006.

Table 10.22: ms Expectations of Carriers in the Bidirectional JED/AMM Market as of 2011 and 2006.

	RJ (direct)	SV (direct)	ME (connect)	MS (connect)	SV (connect)
2006 ms	65.73%	27.91%	0.39%	5.97%	N/A
2011 ms	73.25%	22.17%	1.11%	3.26%	0.21%
2016 ms	72.14%	22.90%	1.95%	2.88%	0.06%

According to the table, the market structure of the route was very similar in 2006 and 2011 when compared with the figures of 2016. RJ has always been the strongest carrier in the market followed by SV with minor market share estimation changes. The connecting products' ms expectations were again minimal in the past years. Therefore, the figures in Table 10.22 imply that the market structure in the JED/AMM has been protected and it did not radically change since 2006. Table 10.23 shows the total seat supply of the active carriers in the market.

Table 10.23: Total Seat Supply of the Carriers in JED–AMM and AMM–JED as of 2006, 2011 and 2016

	Year	RJ direct	SV direct	ME connect	MS connect	SV connect	AZ connect	Total
JED–AMM	2006	1.014	873	60	203			2.150
	2011	3.068	997	169	490			4.724
	2016	4.958	1.749	176	309		30	7.222
AMM–JED	2006	1.014	873		58			1.945
	2011	3.068	937	7	53	29		4.094
	2016	4.958	1.485	176	398	40		7.057

The table implies that total seat supply in the market has more than tripled in both directions from 2006 to 2016 and the market share expectations of the airlines were kept almost intact as shown in Table 10.22. It is inferred from these figures that, although AMM/JED market has been growing, it is somehow protected and dominated by the national carriers forming a substantial barrier for market entry and potential competition. Therefore, through the employment of the research's models and using the historical schedule information, such useful market intelligence material could be gathered, proving the fulfilment of Objective 4.

10.2.6. Case 6: MAN/DOH:

The previous case covered a market where there existed both direct and connecting services where direct flights were dominating almost the entire market. In this case, a market is selected where both direct and connecting services exist again but not wholly dominated by the direct flight operators. The market is identified to be between Manchester, United Kingdom (MAN) and Doha, Qatar (DOH) where both cities are located in the research's focus region. Through this case, it was targeted to assess the accuracy of the REMSET model (Objective 3) from another perspective: Direct and connecting products' market shares in total. From the MIDT data, it is possible to measure the actual market shares of the direct and connecting services separately. The sum of all direct product offering airlines market share refers to "direct share" whereas the sum of all connecting products market shares refers to the "connect share". The convergence between the estimated and actual direct and connect share would attest to the robustness of the REMSET model. Table 10.24 belows presents the market share estimations of the direct and connecting services in the bidirectional MAN/DOH route as of 2016 schedule information.

Table 10.24: Market Share Estimations of Carriers (Table Split in Direct vs Connecting Services View)

Direct services		Connecting Services	
QR	76.17%	EK	17.23%
		EY	4.26%
		TK	1.11%
		KL	1.23%
Total Direct	76.17%	Total Connect	23.83%

The table suggests that the REMSET model estimated the direct flights (which is only offered by Qatar Airways (QR)) to take 76.17% share of the market while the connecting services were estimated to obtain 23.83%. As per the MIDT data, total demand in the MAN/DOH route in 2016 was 24,410 passengers. Among this demand, 17,725 passengers preferred direct flights whereas 7,135 travellers chose connecting itineraries. In other words, while 70.77% of the consumers preferred the direct flights, the remaining 29.22% chose the connecting services for their itineraries.

Although the market share forecasts of the REMSET model and the actual shares of the direct and connecting services are close to the actual figures, the slight difference requires a justification. It can be argued that the difference between the estimated and real market shares of the direct/connecting services is not beyond expectations, especially considering the fare effect. As the survey results have suggested, the fare was found to be the leading parameter in consumers' itinerary choice. The relatively higher fare structure of the direct services could justify the difference in favour of the connecting flights. Being the sole direct service provider, QR could prioritise yields and maximise its revenue through higher fares. Checking the quality scores of the rivals, this could be a wise strategy as the QR's $q_{a\_index\_normalised}$ is calculated as 1.2965 in DOH–MAN route while the second best $q_{a\_index\_normalised}$ score is 0.9517 (belonging to EK). Therefore, QR's pricing strategy can be very influential in shaping the market dynamics. This case has also demonstrated that the airlines' competitive advantage in the schedule quality can indeed be a driver of the actual market shares. Despite the slight difference between the estimates and actual results, the accurate expected market share estimations presents a useful guidance for industry experts, referring to the fulfilment of Objective 3 and 4.

10.2.7. Case 7: LGW/BKK

In this case, while one route is chosen among the research's focus regions, London – Gatwick Airport, UK (LGW), the other city is chosen out of the scope region in the Far East identified to be Bangkok, Thailand (BKK). The analysis of this case does not cover the whole competition in the city-wise London/Bangkok market, but only includes the traffic between Gatwick Airport and Bangkok Suvarnabhumi airport. There exist multiple airports both in London and Bangkok. On the other hand, it should also be reminded that the analysis to be retrieved from the database would not fully disclose the degree of competition in the market as there might exist Asian carriers operating in the route whose schedule information was not included into the database. The case also aimed to observe non-listed carriers' performance by comparing the ms of the listed carriers with the actual performances of the non-listed Asian carriers whose data is obtained from MIDT. Running the analysis, as of 2016, only two carriers, Emirates (EK) and Turkish Airlines (TK) were identified to be serving in the route solely offering connecting products. Total weekly frequency (f), seat supply (s), adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) of the listed carriers are disclosed in the table below for both directions.

Table 10.25: Parameters for EK and TK in the LGW/BKK Market (Both Directions)

	Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
LGW–BKK	EK	Connect	21	2054	81.68%	0.6668	76.84%
	TK	Connect	14	461	18.32%	0.8958	23.14%
BKK–LGW	EK	Connect	21	2054	81.68%	0.8112	83.39%
	TK	Connect	14	461	18.32%	0.7206	16.61%

Table 10.25 shows that the frequency and seat supply of the carriers were identical in both directions where the $q_{a\_index\_normalised}$ scores of the carriers varied depending on the direction of the market due to different schedule structures. While in the LGW to BKK route, TK was offering a relatively "better" product, on the reverse direction EK's product outperformed the TK's. Additionally, a relatively poor quality score reduced the ms of EK to 76.84% in the LGW–BKK market down from 83.39%, which was the ms of the carrier in BKK–LGW route. This finding reaffirmed that if the carrier reports a disadvantaged quality score, its market share expectation is negatively affected.

Other carriers whose schedule was not included into the research's scope like Cathay Pacific (CX) and Ukraine International (PS) were other prominent carriers functioning in the market. However, as those carriers were not listed, and their schedules were not uploaded into the database for competitive analysis, the general market share expectations were performed over the current computation shown in Table 10.25 by averaging the TK's and EK's figures. Therefore, in the bidirectional LGW/BKK market, ms expectation of EK was reported to be 80.12% while the figure was 19.88% for TK. Cross-checking this information with the actual MIDT numbers, it is observed that EK's market share in the route has been 85% and 8% belonged to TK. On the other hand, PS was reported to own 5% while other non-listed carriers including CX were estimated to obtain the rest of the shares.

This case showed that in addition to city-based competitive analysis, through the devised methodology, airport specific assessments of the carriers can also be achieved and benchmarked. Besides, the case also reproved that quality score has a direct impact on the market share expectation. Concerning the accuracy of the estimated market shares, it can be easily deduced that the methodology produced a credible result proposing EK to be the leading carrier in the market in line with the MIDT results, accomplishing Objective 3. However, it could also be argued that the model's performance would be better comprehended in case the schedule information of all carriers offering a product in LGW/BKK market is included into the competition database. This is not a weakness of the REMSET model; contrarily it refered to the strength of the methodology in producing accurate estimates as long as the schedule information of all carriers competing in the market is included as an input into the methodology. Therefore, it could easily be argued that the model can be implemented globally as long as the schedule information and the MCT of the airports are included into the analysis.

10.2.8. Case 8: LAS/ MIA:

In this case, an O&D which is not in the research's focus continents, i.e. Europe, the Middle East or Africa was chosen. The market was selected to be within North America and a domestic route between Las Vegas (LAS) – Miami (MIA) in the USA. None of the listed carriers were American airlines; hence no operating flight was performed in the market by them. Therefore, this case intended to measure the non-operating flight performance of the listed carriers and benchmark their performance in an American domestic market. In other words, this case would allow analysing the effectiveness of the codeshare agreements that were signed between the operating (American) carriers and the marketing (listed) airlines by reporting the adjusted (non-operating) seat share figures (Objective 1) as well as their quality scores (Objective 2). The supply and quality scores of the non-operating services would offer an insight to airline executives concerning the effectiveness of their codeshare agreements, referring to the accomplishment of Objective 4. The table below shows the airline, routing, weekly frequency (f), weekly seat supply (s), adjusted seat share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) of competing carriers in the LAS–MIA market.

Table 10.26: Parameters for LAS–MIA Market as of 2016 Schedule

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$
AY	Direct	3	144	1.70%	0.8754
BA	Direct	28	1393	38.33%	0.9273
IB	Direct	14	721	19.84%	0.9060
AF	Connecting	26	246	6.77%	0.7269
AY	Connecting	5	48	0.94%	0.5783
AZ	Connecting	9	82	2.25%	0.6982
BA	Connecting	64	625	17.22%	0.7019
EI	Connecting	4	32	0.50%	0.7281
EY	Connecting	7	67	1.85%	0.7747
KL	Connecting	31	288	7.93%	0.7594
SK	Connecting	6	53	0.83%	0.6925
TP	Connecting	8	78	1.84%	0.6592

The table implies that there existed both non-operating direct and connecting services of the listed carriers from LAS to MIA. Three airlines offered direct itineraries which all together formed 59.87% of the adjusted seats in the market. British Airways (BA), was reported to own the most number of available (marketing) seats in the route. On the other hand, BA also offered connecting services contributing to 17.22% of the adjusted seats. Therefore, the dominance of BA in the LAS–MIA market was apparent signalling its strength in codeshare agreements with the American carriers against its rivals. BA's partner Iberia (IB) was also active in the market as the carrier offers non-operating direct services totalling 19.84% of the whole adjusted seat supply. Other European carriers KLM (KL) and Air France (AF) followed BA and IB. Therefore, European carriers outperformed the Middle Eastern and African carriers in terms of seat supply in the LAS–MIA market.

As expected, the quality scores of direct services were higher in comparison to the connecting flights in the LAS–MIA market. Although the quality score of the BA's direct services seemed to be the highest among the competing carriers, the carrier's connecting services were not similarly attractive from the schedule quality perspective. The best quality score in connecting services belonged to Etihad (EY), although the non-operating seat supply of the carrier was very limited, contributing only to 1.85% of the adjusted seat supply. The poorest quality score in the connecting products belonged to Finnair, (AY). AY's connecting products' quality score was approximately 37% less than the best quality score, and 25.5% less than the best connecting services' $q_{a\_index\_normalised}$. AY also offered direct services along the route. However, its direct product's quality score reported again the lowest among direct itineraries. Table 10.27 shows the same parameters for the reverse direction from MIA to LAS.

Table 10.27: Parameters in the MIA–LAS Market as of 2016 Schedule

Airline	Routing	F	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$
AB	Direct	7	393	8.58%	0.9361
BA	Direct	28	1393	30.42%	0.9581
IB	Direct	21	1057	23.08%	0.9535
AF	Connecting	23	230	5.03%	0.7435
AZ	Connecting	14	134	2.94%	0.6779
BA	Connecting	74	743	16.24%	0.7168
EI	Connecting	1	9	0.12%	0.5432
EY	Connecting	21	221	4.83%	0.6091
KL	Connecting	35	324	7.08%	0.7243
RJ	Connecting	4	38	0.48%	0.5331
SK	Connecting	9	82	0.77%	0.5924
TP	Connecting	4	37	0.46%	0.6131

Table 10.27 shows that similarly, three direct product offering airlines were present in the MIA–LAS market. BA was again the dominant carrier in the route owning 30.42% of the adjusted seats via direct services and 16.24% via connecting flights, adding up to 46.66% of the entire adjusted seats in the market. IB again followed BA holding 23.08% of the adjusted seats through direct services. Unlike LAS–MIA route, AY offers neither direct nor connecting services in the MIA–LAS market. Instead, Air Berlin (AB) offered direct products that contribute to 8.58% of the $\%_{a\_s}$. The dominance of European carriers was still apparent in the MIA–LAS market where the non-European carriers' adjusted seat share was less than one per cent. EK, which offered the best quality score in connecting products in the LAS–MIA route, did not offer any service in the reverse direction.

BA's direct products were ranked top quality in the MIA–LAS route while the IB's direct services' score was not far from the BA's. AB's quality score is only 2.3% less than the best $q_{a\_index\_normalised}$. Among connecting products, Air France (AF) rated the best in schedule quality, followed by KL and BA. The worst $q_{a\_index\_normalised}$ belonged to Royal Jordanian's (RJ) connecting non-operating services, the sole non-European carrier serving in the route.

Reviewing the results of this case, the impact of the alliances can also be easily observed. Since Oneworld is the dominant alliance in the USA, Oneworld member carriers like BA and IB have an advantage in code-sharing with the operating airlines in the region. Furthermore, ms, $\%_{a\_s}$ and $q_{a\_index\_normalised}$ scores in each direction presented an insight concerning the effectiveness and performance of the codeshare agreements signed between the listed marketing carriers and non-listed American operating carriers, referring to the accomplishment of Objective 4. Moreover, being able to assess the adjusted seats and quality scores for the codeshare itineraries serves as a fulfilment of Objective 1 and 2.

10.2.9. Case 9: Portugal/Serbia:

In this case, an O&D at the country-to-country level is selected for examination which would analyse the entire traffic between two selected countries including the traffic among all their airports. The intention of this case was to demonstrate the strength of the research's model in terms of assessing supply, quality and ms estimation at a broader level, on the scale of countries. The countries were selected within Europe, between Portugal and Serbia. While estimating the carriers' ms values, all possible flights in the market were identified and included in the computation. The following table summarises the entire number hits from Portugal to Serbia as of 2016 schedule data shown at the O&D, flight type and routing detail.

Table 10.28 Flights from Portugal to Serbia as of 2016 Data

	Origin & Destination	Non-Op	Op	Total
Direct	No direct flights present from Portugal to Serbia.			
Connecting Flights	From: Faro	3	3	6
	To: Belgrade	2	3	5
	To: Pristina	1		1
	From: Lisbon	24	8	32
	To: Belgrade	17	5	22
	To: Pristina	7	3	10
	From: Madeira	2		2
	To: Belgrade	1		1
	To: Pristina	1		1
	From: Porto	4	4	8
	To: Belgrade	3	2	5
	To: Pristina	1	2	3
Total		33	15	48

The table suggests that there existed 48 different flight combinations from Portugal to Serbia and all of these services were connecting itineraries. The number of weekly frequencies in the route did not necessarily equate to 48 as each combination can be offered more than once per week. For example, a connecting flight which was operated daily is seen as a single hit in the table above, but that flight's weekly frequency would add up to seven. On the other hand, among 48 combinations, 15 of them were operating services while the remaining majority was non-operating. The table also shows that 4 different cities of Portugal were mapped to 2 cities in Serbia through these flights. (Author's note: As per the reporting, Pristina is shown as a city of Serbia, although Kosovo is recognised as a sovereign state by many countries.) While 102 combinations originated from Lisbon, 43 of them started from Porto. The other origination cities were Faro and Madeira. The following table reports the same parameters in the reverse route: Serbia–Portugal.

Table 10.29: Flights from Serbia to Portugal as of 2016 Data

	Origin & Destination	Non-Op	Op	Total
Direct	No direct flights present from Portugal to Serbia.			
Connecting Flights	From: Belgrade	23	10	33
	To: Faro	3	2	5
	To: Lisbon	17	4	21
	To: Madeira	1	1	2
	To: Ponta Delgada	1		1
	To: Porto	1	3	4
	From: Pristina	15	3	18
	To: Faro	4		4
	To: Lisbon	9		9
	To: Porto	2	3	5
Total		38	13	51

The table suggests that there existed 51 combinations from Serbia to Portugal, 3 more than the reverse direction. This might have occured for various reasons. For instance, the number of available codeshare agreements might not be equal in both directions. Furthermore, some connections which were available from Serbia to Portugal might not be attained in the reverse direction due to several reasons such as connection time-related factors or the routing of the flights. 2 cities of Serbia were mapped to 5 destinations of Portugal in total. The majority of the combinations existed on the Belgrade-Lisbon route. Ponta Delgada which did not offer an outbound flight product to any Serbian city is served via codeshare flights from Belgrade. The following table summarises the routing, total weekly frequency (f), seat supply (s), seat share ($\%_s$), adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) from Portugal to Serbia as of 2016 schedule data.

Table 10.30: Parameters from Portugal to Serbia as of 2016 Schedule Data

Airline	Routing	f	s	$\%_s$	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AB	Connecting	2	15	1.05%	0.36%	0.5606	0.30%
AZ	Connecting	11	97	6.63%	4.55%	0.6380	4.35%
DY	Connecting	1	37	2.53%	0.43%	0.7557	0.00%
EY	Connecting	25	196	13.31%	15.97%	0.6144	14.73%
IB	Connecting	1	10	0.69%	0.12%	0.7591	0.13%
KL	Connecting	11	84	5.75%	6.90%	0.7497	7.76%
LH	Connecting	27	621	42.29%	50.73%	0.7156	54.48%
LX	Connecting	4	43	2.94%	1.51%	0.5359	1.22%
OS	Connecting	6	58	3.97%	3.97%	0.5760	3.53%
SK	Connecting	16	141	9.57%	9.57%	0.4876	8.40%
U2	Connecting	5	166	11.27%	11.27%	0.8782	5.09%
Total		109	1,468	100%	100%	--	100%

As per the table above, total weekly frequency from Portugal to Serbia was 109 while the total seat count was 1,468. It is also observed that there existed a notable difference between the airlines' $\%_s$ and $\%_{a\_s}$ values as many of the O&D based frequencies were not operated daily. While Lufthansa (LH) was reported to provide the highest share of seat supply in the market with 42.29%, its adjusted seat share increased to 50.73% as the supply for the other carriers' unserved days of the week would be transferred to LH via the waste capacity discount model. Regarding $q_{a\_index\_normalised}$ scores, Easyjet (U2) was observed to have the best quality service among all competing carriers, followed by Iberia (IB).

Although Norwegian Airlines (DY) offered one frequency and 37 seats in the route, it was not estimated to have a market share because of the high detour factor of the carrier above 1.75. The kilometre index of DY was calculated to be 1.895 in the route. Excluding DY, ten carriers competed in the market where the highest market share was estimated to be owned by Lufthansa (LH), followed by Etihad (EY). Although Etihad is a Middle Eastern carrier based in the United Arab Emirates, its products were included in the market share as the carriers offers solely non-operating products in the market using several European cities like London Heathrow (LHR), Amsterdam (AMS), Rome Fiumicino (FCO) and Barcelona (BCN) as the hub point. Scandinavian Airlines (SK), KLM Royal Dutch Airlines (KL) and U2 follow those carriers with 8.40%, 7.76%, 5.09% ms expectations respectively. The remaining carriers reported ms estimations below 5%. The proceeding table summarises the same parameters in the reverse direction, from Serbia to Portugal.

Table 10.31: Parameters for the Serbia-Portugal Route as of 2016 Schedule Data

Airline	Routing	f	s	$\%_s$	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AB	Connecting	3	23	1.26%	0.39%	0.5271	0.32%
AF	Connecting	7	65	3.57%	3.90%	0.5318	3.23%
AZ	Connecting	10	78	4.26%	2.66%	0.6595	2.73%
EY	Connecting	16	134	7.36%	8.05%	0.4401	5.51%
KL	Connecting	7	54	2.95%	3.22%	0.4615	2.32%
LH	Connecting	38	739	40.55%	44.33%	0.6784	46.80%
LX	Connecting	20	300	16.45%	17.99%	0.7590	21.25%
OS	Connecting	2	34	1.85%	0.29%	0.8193	0.37%
SK	Connecting	28	262	14.37%	15.71%	0.5291	12.94%
U2	Connecting	4	134	7.37%	3.45%	0.8419	4.53%
Total		135	1,823	100%	100%	--	100%

As per the table above, total weekly frequency from Portugal to Serbia was 135 while the total seat count added up to 1,823. These figures were higher than the number of frequency and seat supply compared to the reverse direction. For instance, while LH offered 739 seats in 38 frequencies from Serbia to Portugal, it only offered 621 seats in 27 frequencies in the other direction. The additional capacity of LH in Serbia–Portugal was reported to have longer t_{total} with higher t_{conn} which were still in the MCT and MaxCT boundary. However, longer t_{total} figures reduced the $q_{a\_index\_normalised}$ score of the carrier. While the $q_{a\_index\_normalised}$ score of LH was 0.7156 from Portugal to Serbia, on the route back, it was 0.6784. It is also observed in Table 10.31 that, similar to the scheme in Portugal–Serbia, there was a notable difference between $\%_s$ and $\%_{a\_s}$ as many of the O&D based frequencies were not operated daily from Serbia to Portugal. LH ranked top both with the number of both physical and adjusted seats followed by Swiss (LX) 300 seats available per week (the carrier only offered 43 on the reverse direction). Moreover, LX's quality score was significantly better in the Serbia–Portugal market in comparison to the other direction. The best quality score among listed carriers was owned again by U2 in the Serbia–Portugal market. In terms of the ms forecasts, LH was expected to lead the market with 46.80% ms, while LX was estimated to score 21.25% ms. SK ranked third with

12.94%. Taking the average of the ms values in each direction, the final market share estimation of all carriers competing in the market are summarised in the table below.

Table 10.32: Market Share of All Competing Carriers Operating in Portugal/Serbia Route (Bidirectional)

Airline	ms
AB	0.31%
AF	1.62%
AZ	3.54%
DY	0.00%
EY	10.12%
IB	0.07%
KL	5.04%
LH	50.64%
LX	11.23%
OS	1.95%
SK	10.67%
U2	4.81%

As covered in the table, LH was expected to have more than half of the market where the following carrier was estimated to be LX with 11.23% ms. As the LH group owns LX, LH affiliates had significant market dominance in the Portugal/Serbia market. The third largest carrier concerning market share estimation was reported to be SK, while the EY, Air Serbia’s partner, was expected to rank fourth. It is interesting to observe that, TAP Portugal (TP) which is a listed carrier of the research and the home carrier of Portugal was not expected to catch a market share as the carrier lacked service to Serbia.

This case showed that the research's models could be applied not only at the city/airport level but also in the country to country markets. Analysing the results, it is possible for airline planners to develop an understanding concerning their competitive advantages or disadvantages of their product in terms of supply, quality and market share estimations at the country to country scale affirming the fulfilment of Objective 1, 2, 3 and 4 of the research at a broader level.

10.2.10. Case 10: The United Kingdom / Israel:

Case 10 analyses an intercontinental route within research's focus regions at the country-to-country level. The traffic between all airports of the UK and Israel is analysed in this case. In this intercontinental route, there existed a higher level of competition in comparison to the previous case. As of 2016 schedule data, from the UK to Israel, there existed 10 distinct direct flight options offering 48 frequencies per week and 209 connecting hits totalling to 272 connecting frequencies. On the reverse direction, the number of direct flight options and frequencies were identical, 10 and 48 respectively while the number of connecting hits were 195 totalling to 294 frequencies. Total weekly seats from the UK to Israel was 18,520 of which 10,344 were offered through direct flights, and the remaining 8,176 were via connecting products. On the reverse direction, more seats (19,594 in total) were available in total. Although the amount of direct seats was identical in each direction, the connecting seat count was slightly higher adding up to 9,250 in Israel–UK market. Parameters of the competing carriers at the directional breakdown were displayed in the table below.

Table 10.33: ms Expectations at the Routing and Market Breakdown in the UK/Israel Market

		f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
UK–Israel	Direct Flights	*48*	*10.344*	*53.49%*		*64.84%*
	BA	14	3.507	21.33%	1.2876	26.17%
	LY	18	4.005	17.40%	1.2754	21.14%
	U2	16	2.832	14.76%	1.2463	17.53%
	Connecting Flights	*272*	*8.176*	*46.51%*		*34.17%*
	TK	49	1.632	9.93%	0.7742	7.32%
	LH	29	1.111	6.76%	0.8695	5.60%
	PC	20	751	4.57%	0.7923	3.45%
	LX	26	6.27	3.81%	0.9186	3.34%
	OS	14	521	3.17%	0.7114	2.15%
	Other 12 carriers	134	3.534	18.27%		12.31%
Israel–UK	Direct Flights	*48*	*10.344*	*50.06%*		*62.28%*
	BA	14	3.507	19.96%	1.2909	25.17%
	LY	18	4.005	16.28%	1.2650	20.12%
	U2	16	2.832	13.82%	1.2588	16.99%
	Connecting Flights	*294*	*9.250*	*49.94%*		*37.72%*
	TK	49	1.641	9.34%	0.7357	6.71%
	LH	29	1.084	6.17%	0.7487	4.52%
	PC	19	711	4.05%	0.7386	2.92%
	OS	14	521	2.96%	0.9977	2.89%
	BA	14	562	3.20%	0.7641	2.39%
	Other 13 carriers	169	4.731	24.22%		18.29%

As per the table, three airlines operated a direct flight in both directions: British Airways (BA), El-Al Israel Airlines (LY) and Easyjet (U2). The weekly frequency and seat count of those direct service providers were identical in both routes. Although the adjusted seat share of direct flights accounted to 53.49% from the UK to Israel and 50.06% in the other direction, the market share expectations for the direct services were summed to 65.83% and 62.28% respectively. In other words, since passengers favoured direct flights over connecting products, direct services were estimated to have a market share higher than their adjusted seat shares. However, not all destinations of the selected countries were connected via direct services. Connecting services served more than one-third of the market in each direction. While BA's direct services were expected to hold more than a quarter of the market, its connecting products were estimated to gain a market share too. LY's direct services were expected to rank second with slightly more than 20% ms expectation in both routes. The third carrier was reported to be an LCC; U2 was expected to catch approximately 17% of the market. The average seat per frequency (s_f) was highest in the BA itineraries averaging to 250.5 per flight (3.507 seats divided to 14 frequencies), followed by LY with 222.5 seats per flight and U2 ranked third with 177. This implies that the BA was utilising larger aircraft having more seats in comparison to LY and U2. In addition to its supply with the capacity, BA's direct flights were calculated to be the "best" in terms of schedule quality score which placed the carrier in the leading position in both directions.

Among connecting products, in each direction Turkish Airlines (TK) was estimated to rank top in ms estimation, 7.32% from the UK to Israel and 6.71% from Israel to the UK. TK was followed by LH, and the third carrier was reported to be Pegasus Airlines (PC). 18 connecting itinerary offering carriers were forecasted to compete for the UK–Israel market in total, and they collectively shared 34.17% ms. On the route back, 19 airlines contested to get a portion from the 37.72% ms of connecting market share.

As previously addressed, the above analysis was obtained using 2016 schedule information. Running the same analysis over historical data, it was possible to observe the development of the outputs. The following table summarises the total frequency, seat count and ms expectations for direct and connecting services in both directions from 2007 to 2016.

Table 10.34: Yearly Development of Direct and Connecting Frequencies, Seat Count and ms from the UK to Israel and From Israel to the UK.

	Year	Direct services			Connecting Services			Total	
		f	s	ms	f	s	ms	f	s
UK – Israel	2007	28	6,260	73.60%	121	3,393	26.40%	149	9,653
	2008	28	6,906	76.65%	125	3,111	23.35%	153	10,017
	2009	32	8,006	78.68%	125	3,123	21.32%	157	11,129
	2010	37	8,539	77.02%	134	3,739	22.98%	171	12,278
	2011	33	7,988	73.09%	153	4,254	26.91%	186	12,242
	2012	33	8,543	75.77%	154	4,057	24.23%	187	12,600
	2013	48	9,590	76.21%	183	4,975	23.79%	231	14,565
	2014	52	10,339	69.83%	249	7,022	30.17%	301	17,361
	2015	49	9,745	66.94%	258	7,466	33.06%	307	17,211
	2016	48	10,344	64.84%	272	8,176	35.16%	320	18,520
Israel – UK	2007	28	6,260	72.94%	127	3,574	27.06%	155	9,834
	2008	28	6,906	73.25%	142	3,628	26.75%	170	10,534
	2009	32	8,006	75.60%	141	3,716	24.40%	173	11,722
	2010	37	8,539	76.58%	140	3,834	23.42%	177	12,373
	2011	33	7,988	75.26%	154	4,175	24.74%	187	12,163
	2012	33	8,543	75.51%	155	4,241	24.49%	188	12,784
	2013	48	9,590	73.84%	210	5,806	26.16%	258	15,396
	2014	52	10339	67.69%	263	7,764	32.31%	315	18,103
	2015	49	9,745	64.38%	274	8,002	35.62%	323	17,747
	2016	48	10,344	62.28%	294	9,250	37.72%	342	19,594

It is observed in the above table that, the total seat count in both directions almost doubled from 2007 to 2016. However, the per cent rise in the connecting products exceeded the growth in direct capacity. Although direct seats increased from 6,260 in 2007 to 10,344 in 2016, contributing to 65.2% rise, the percentage growth in connecting seats was 141% from the UK to Israel (from 3,393 in 2007 to 8,176 in 2016) and 158.8% in the reverse direction. As the supply in the connecting itineraries has significantly increased, the market share expectations have shifted in favour of the connecting itineraries too. While direct services' market share was estimated to be highest in 2009 in the UK – Israel market with 78.68% market share, the figure dropped to 64.84% as of 2016. Similarly, the direct services' ms expectation in the Israel – UK route was highest in 2010 with 76.58%. However, it dropped to 62.28% by 2016. On the other hand, while the average seat per frequency for direct flights was 223.5 (calculated by dividing the total seats to frequency, 6,260 divided by 28) in 2007, it dropped to 215.5 in 2016. Using these numbers, it can be inferred that Israel/UK market expanded both in favour of directing and connecting services, however, the pace of growth was reported to be higher in connecting products. Entry of new rivals and the insertion of new spokes in the market affected the capacity supply in the market positively, as the new hits added up to the number of products offered between the two countries.

Analysing the historical data, it is also possible to observe the performance of individual carriers from 2007 to 2016. The table below depicts the ms expectations of the national carriers, BA and LY, in each direction of the market for direct services. The table also displays the general bidirectional ms which is obtained by averaging route based market share forecasts.

Table 10.35: Yearly Development of BA's and LY's ms Estimation for Direct Services from the UK to Israel & from Israel to the UK and in the Bidirectional Market.

Year	UK – Israel		Israel – UK		UK/Israel (bidirectional)	
	BA	LY	BA	LY	BA	LY
2007	38.22%	35.38%	37.76%	35.18%	37.99%	35.28%
2008	36.17%	40.48%	34.68%	38.57%	35.43%	39.53%
2009	34.72%	43.96%	33.11%	42.49%	33.92%	43.23%
2010	30.71%	37.61%	29.87%	37.97%	30.29%	37.79%
2011	34.51%	25.48%	35.31%	27.00%	34.91%	26.24%
2012	31.86%	33.85%	31.68%	33.51%	31.77%	33.68%
2013	27.28%	34.22%	26.35%	33.17%	26.82%	33.70%
2014	20.52%	31.08%	19.92%	29.84%	20.22%	30.46%
2015	30.51%	23.03%	29.30%	21.94%	29.91%	22.49%
2016	26.17%	21.14%	25.17%	20.12%	25.67%	20.63%

The table shows that both BA's and LY's direct services' ms estimations have dropped over the years. The sum of both carriers' ms estimations were more than 50% until 2016. The entrance of U2 into the market in 2011 heavily impacted the ms expectation of LY, reducing it from 37.79% in 2010 to 26.24% the following year. The LCC entry not only impacted the ms estimation for direct service providers but also connecting service providers. The following table summarises frequency, seat count and ms estimation for legacy carriers and low-cost carriers in 2007 and 2016 in the bidirectional UK/Israel market. The seat and frequency count is reported by averaging f and s in both directions. (The low-cost carriers operating in the market are: U2, PC and W6)

Table 10.36: Parameters for the LCCs and Legacy Carriers in 2007 and 2016

Year	Legacy Carriers			Low-Cost Carriers		
	f	s	ms	f	s	ms
2007	152	9.743,5	100%	0	0	0.00%
2016	266,5	14.644,5	77.74%	64.5	4412,5	22.26%

The table explicitly shows that, while there was no LCC frequency in the market as of 2007, they were active and managed to offer a substantial capacity in the route and estimated to catch 22.26% share in the market by 2016. Although the capacity of the FSCs has expanded, they lost share against their LCC rivals.

This case showed that the quantity and the quality of the supply of all carriers operating in the market could be assessed at the country level demonstrating the fulfilment of Objective 1 and 2 of the research. On the other hand, market share estimations of the competing airlines at the country level can be successfully calculated via the REMSET model (Objective 3), enabling to assess the competition with a strategic perspective in the market. Historical development of the parameters including supply, market share estimation, etc. enabled to perform useful analysis for industry experts suggesting the fulfilment of Objective 4 from another perspective.

10.2.11. Case 11: Italy / Italy:

In Case 11, the Italian domestic market is examined. Only direct flights from Italy to Italy are studied in detail. Connecting flights are excluded from the analysis to assess direct flights' performance better. Since Italy is a geographically small country, it is unlikely for passengers to travel abroad to make a domestic journey within Italy, justifying the removal of connecting itineraries from the analysis. As of 2016 schedules, there existed 1,474 different flight numbers providing direct services in the Italian domestic market, contributing to 9,178 frequencies and 866,775 seats available for sale per week. However, these numbers do not necessarily contribute to physical capacity as the figures include non-operating services too. The following table summarises the origin points ranked by frequency per operation type.

Table 10.37: Number of frequencies and seat count per operation type and origin as of 2016 schedules

	Non – Op. frequency	Operating frequency	Total frequency
Rome-Da Vinci	2,009	1,029	3,038
Milan-Linate	454	471	925
Catania	359	298	657
Palermo	271	276	547
Cagliari	147	203	350
Bari	170	178	348
Naples	179	166	345
Lamezia Terme	169	129	298
Brindisi	133	129	262
Milan-Malpensa	39	207	246
Venice	139	73	212
Milan-Orio Serio		186	186
Other 22 Points	847	917	1,764
Total	4,916	4,262	9,178

As per the table, the number of physical frequency is 4,262 originating from 34 Italian airports. The remaining 4,916 frequencies are available for sale via codeshare agreements. It is inferred from these numbers that, an extensive degree of codeshare contracts have been signed in the Italian domestic market which led multiple airlines to compete in the market. The table below shows the frequency and seat count figures at the airline and operational type breakdown. The market share expectations of the carriers are also displayed. (It should be noted that Italy based Meridiana Airlines is not listed carrier of the research. Therefore the results do not reflect this carrier's market share estimations.)

Table 10.38: Number of Frequencies and Seat Count per Operation Type and Airline as of 2016 in Italian Domestic Market. The Final Column Shows the ms Estimation for the Carrier.

Airline	Non-Operating		Operating		Total		ms
	f	s	f	s	f	s	
AZ			2,610	347,203	2,610	347,203	42.96%
FR			1,264	238,896	1,264	238,896	29.59%
KL	1,293	58,489			1,293		5.28%
TP	929	42,472			929		3.83%
AF	823	38,318			823		3.46%
EY	703	28,972			703		2.63%
U2			388	62,448	388	62,448	7.75%
SU	541	22,581			541		2.04%
AB	443	18,450			443		1.66%
IB	150	7,535			150		0.68%
SV	28	1,136			28		0.10%
ME	5	245			5		0.02%
OS	1	30			1		0.00%
Total	4,916	218,228	4,262	648,547	9,178	866,775	100.00%

The table shows that among 866,775 seats available for sale, only 648,547 of them contribute to the physical capacity where the remaining 218,228 seats are non-operating services. Three airlines are reported to perform operating flights: Alitalia (AZ), Ryanair (FR) and Easyjet (U2). The operating services' market share estimations add up to 80.30% where the remaining 19.70% is projected to be owned by the non-operating rivals led by KL and followed by TP. The non-operating services' ms expectations are significantly less than their seat share since codeshare flights are less appreciated by consumers, as uncovered in the passenger survey. It is also inferred from the table that, the total ms estimation of the LCCs (composed of FR and U2) adds up to 37.34% while the legacy carriers' ms forecasts are 62.66%. On the other hand, the forecasted ms value of the home carrier (which is AZ only) is 42.96%, implying that non-Italian carriers are expected to own more than half of the market.

This case assisted in studying the market shares of direct operators in the Italian domestic market and building up strategic analysis over the estimations which serves a concrete fulfilment of Objective 3 and 4 of the research. The case also shows how non-operating carriers can reduce the market share expectations of the home carriers in a domestic market, signalling insightful information concerning the market's openness to competition.

10.2.12. Case 12: Turkey – Turkey:

Similar to Case 10, this section investigates a domestic route again, but in a different market. The Turkish direct domestic market is analysed in this case as the volume of the non-operating services in the home market is less than many European countries. The following table summarises the origin points ranked by frequency per operation type.

Table 10.39: Number of Frequencies and Seat Count per Operation Type and Origin as of 2016 Schedules

Origin Airport	Non- Operating frequency	Operating frequency	Total frequency
Istanbul - SAW	136	1,349	1,485
Istanbul - IST	194	1,084	1,278
Ankara	76	769	845
Izmir	83	442	525
Antalya	59	318	377
Adana	30	239	269
Trabzon	21	196	217
Bodrum	12	176	188
Dalaman	30	134	164
Kayseri	27	115	142
Gaziantep	7	113	120
Other 39 Points	0	1,159	1,159
Total	675	6,094	6,769

As per the table, the number of physical domestic frequency is 6,094 operated from 50 distinct Turkish airports while the total frequency available for sale is 6,769. Unlike the Italian domestic market studied in the previous case where there exists more codeshare frequency than the physical frequency, only 675 of the 6,769 total frequencies are observed to be non-operating frequencies, contributing roughly 10%. These numbers indicate that the actors in the Turkish market are less welcoming to codeshare flights in comparison to the Italian market referring to a lower degree of competition through codeshare services in the Turkish domestic market. The table below shows the frequency, seat count and market share figures at the airline breakdown.

Table 10.40: Number of Frequencies Seat Count Per Operation Type, Adjusted Normalised Quality Scores and ms Estimations of Each Airline in the Turkish Domestic Market as of 2016 Schedule Information.

Airline	Non-Operating		Operating		Total			ms
	f	s	f	s	f	s	$q_{a\_index\_normalised}$	
TK			4,171	721,283	4,171	721,283	1.2941	65.04%
PC			1,923	359,721	1,923	359,721	1.2988	32.56%
AB	255	14,234			255	14,234	0.9421	0.93%
SK	287	15,047			287	15,047	0.9351	0.98%
AT	70	3,742			70	3,742	0.9501	0.25%
TP	63	3,646			63	3,646	0.9299	0.24%
Total	675	36,669	6,094	1,081,004	6,769	1,117,673	--	100.00%

It is deduced from the table that, unlike the Italian case, Turkish carriers dominate the market in domestic services. It can be argued that comparing the supply in the Turkish and Italian markets; the Italian domestic market is more open and less protected to other carrier's competition. Turkish Airlines (TK) is the leading carrier in the market with 65.04% market share expectation followed by Pegasus Airlines (PC) with 32.56% ms forecast. Although TK's supply and market share estimation are higher compared to PC, the quality score of the carrier is slightly lower than its low-cost rival. TK might have focused on international flights' schedule convenience rather than the domestic flights' schedule convenience. Other 4 carriers offering codeshare domestic services are expected to report less than three per cent market share. Having the most number of non-operating seats among non-Turkish carriers, Scandinavian's (SK) market share estimation is less than one per cent in the market.

This case enabled to benchmark the openness of the Turkish domestic market by analysing its home carriers' supply and market share estimation. Indeed, the comparative analysis of the supply related parameters with the other domestic market provides invaluable market intelligence information concerning the level of protection in the market. Such an ability offers a handy guideline to airline executives when planning their network structure serving for the Objective 4 of the research. Being able to calculate the quality scores and the market share expectations of the available carriers in the market is another demonstration of Objective 2 and 3 fulfilment.

10.2.13. Case 13: Canada/Pakistan vs Canada/India:

In this case, the traffic between two distinct markets which are out of the research's focus continents are selected. They are Canada/Pakistan and Canada/India markets. The schedules of Canada's, Pakistan's and India's home carriers are not uploaded into the research database. Hence the rivalry of the research's selected airlines in an intercontinental market is assessed. Unlike Case 11 and 12 which analysed the competition at the domestic markets, this case is designed to assess the level of market protectionism by examining two distinct international markets. The following table summarises the total weekly frequency (f), seat count (s), adjusted seat share ($\%_{a\_s}$), adjusted normalised index quality score ($q_{a\_index\_normalised}$) and market share estimation (ms) from Canada (CA) to Pakistan (PK) and vice versa.

Table 10.41: Listed Parameters of Competing Carriers from CA to PK and PK to CA as of 2016

		f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	Ms
CA – PK	EK / Connecting	3	240	20.97%	0.9428	21.10%
	EY / Connecting	3	104	9.12%	0.9259	9.02%
	QR / Connecting	3	174	15.18%	0.8827	14.31%
	TK / Connecting	9	313	54.73%	0.9511	55.57%
	Total	15	831	100%	--	100.00%
PK – CA	EK / Connecting	3	240	13.16%	0.9414	13.36%
	EY / Connecting	3	228	12.50%	0.9525	12.84%
	QR / Connecting	3	164	8.98%	0.9193	8.90%
	SV / Connecting	1	68	1.25%	1.0339	1.39%
	TK / Connecting	16	501	64.11%	0.9187	63.50%
	Total	26	1.201	100.00%	--	100.00%

Table implies that there exist no direct services between Canada and Pakistan for the selected airlines. From Canada to Pakistan only 4 carriers compete and Turkish Airlines (TK) leads the competition with 55.57% ms expectation, followed by Emirates (EK) with 21.10%. On the route back, 5 airlines compete where TK leads the market again with 63.50% market share forecast. Although the seat share ($\%_s$) of TK in both directions is below 50%, (it is

313/831 = 37.6% in CA–PK and 501/1201 = 41.7% in PK–CA), the adjusted seat share figures are higher as the carrier offers daily connections where the competitors fail to offer itineraries for each day of the week. It is also inferred from the table that, none of the European carriers competes in the market and offers an itinerary to their consumers. (European carriers refer to home carriers of the EU market. As Turkey is partly located in Europe, it is not considered as a full European carrier.) The following table summarises the total weekly frequency, seat count, adjusted seat share, adjusted normalised index quality score and market share estimation from Canada (CA) to India (IN) and vice versa.

Table 10.42: Listed Parameters of Competing Carriers from CA to IN and IN to CA as of 2016

		f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
Canada – India	LH / Connecting	45	2.557	35.05%	0.8692	34.95%
	BA / Connecting	28	1.347	18.46%	0.9191	19.47%
	AF / Connecting	24	816	11.19%	0.9833	12.62%
	TK / Connecting	12	838	9.84%	0.8128	9.18%
	KL / Connecting	21	609	8.34%	0.7756	7.43%
	SK / Connecting	28	440	6.03%	0.7385	5.11%
	LX / Connecting	9	368	5.05%	0.8806	5.10%
	EK / Connecting	3	293	1.72%	0.9463	1.87%
	EY / Connecting	3	228	1.34%	0.9597	1.47%
	Other 3 Conn.	12	429	2.97%	--	2.80%
	Total	185	7.925	100.00%	--	100.00%
India – Canada	BA / Connecting	21	1.001	20.52%	0.9497	21.97%
	LH / Connecting	28	1.014	20.78%	0.8129	19.04%
	KL / Connecting	16	825	16.92%	0.8784	16.75%
	AF / Connecting	19	555	11.38%	0.9317	11.95%
	TK / Connecting	9	592	10.41%	0.9553	11.21%
	SK / Connecting	14	242	4.96%	0.7797	4.36%
	IB / Connecting	14	210	4.31%	0.7518	3.66%
	EK / Connecting	3	293	2.58%	0.9341	2.71%
	EY / Connecting	3	228	2.00%	1.0292	2.32%
	Other 3 Conn.	13	531	6.14%	--	6.03%
	Total	140	5.491	100.00%	--	100.00%

As the table depicts, there are no direct service operators among competing carriers in the Canada/India market, and in both directions, 12 airlines offer connecting itineraries only. This refers to a higher degree of competition in comparison to Canada/Pakistan market where a fewer number of airlines competed as of 2016 schedules. From Canada to India, Lufthansa (LH) is estimated to lead the market with 34.95% ms followed by BA with 19.47% while on the route back BA is estimated to rank first with 21.97% while LH follows with 19.04%. On the other hand, Air France (AF) is calculated to offer best schedule quality from Canada to India while Etihad's (EY) schedule quality is determined to be the best from India to Canada.

Analysing the table, it is deduced that unlike Canada/Pakistan market, the Canada/India market is heavily dominated by the European carriers. However using this information only, it is not possible to conclude that India is more open to competition than Pakistan due to the market's lack of European carrier presence. There might be several other reasons justifying European carriers' lack of service in the Canada/Pakistan market. For instance, many European carriers like BA, LH and AF suspended its flights to Pakistan due to security reasons in the previous years. It may also be possible that the yields in Pakistan might not be attractive enough to cover the costs of the European carriers. On the other hand, it is also probable for European carriers to miss connections in Canada/Pakistan routes whilst they attain itineraries in Canada/India market due to lack of demand, slot availability or any other reasons.

This case showed how the degree of competition in various markets could be analysed using the research's methodology. Although, comprehending the level of protectionism in the markets require further information that what the research methodologies offer, this analysis provides invaluable input to industry practitioners for their decision-making process, fulfilling Objective 4 of the research.

10.2.14. Case 14: South America – Middle East:

In this case, the O&D is selected at the regional level. The directional market from South America to the Middle East is presented in this case where the origin area is not within the research's focus region. The following table presents the total weekly frequency (f), seat count (s), adjusted seat share ($\%_{a\_s}$), adjusted normalised index quality score ($q_{a\_index\_normalised}$) and market share estimation (ms) from South America to Middle East which is prepared by incorporating all origins of the listed carriers South America and all destinations of those carriers in the Middle East.

Table 10.43: Selected Parameters from South America to the Middle East as of 2016 Schedules

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
EK	Direct	14	5600	25.51%	1.2337	30.32%
EY	Direct	7	2422	11.03%	1.2685	13.48%
QR	Direct	7	1813	8.26%	1.2472	9.92%
AF	Connecting	59	2298	10.47%	0.8683	8.76%
LH	Connecting	47	1793	8.17%	0.8788	6.92%
EY	Connecting	72	1475	6.72%	0.8270	5.36%
KL	Connecting	28	1283	5.84%	0.8707	4.90%
EK	Connecting	14	1120	5.10%	0.9279	4.56%
QR	Connecting	58	846	3.85%	0.9522	3.53%
AZ	Connecting	26	775	3.53%	0.8548	2.91%
BA	Connecting	19	759	3.46%	0.8190	2.73%
Other 8 airlines	Connecting	68	2009	8.06%	---	6.61%
Total		419	22.193	100%	---	100%

The table states that the listed airlines report 419 weekly direct and connecting frequencies from South America to the Middle East totalling 22.193 seats served by 16 carriers. The share of direct products in the market is estimated to be 53.72% where the remaining 46.28% is forecasted to be held by the connecting services. Emirates (EK) is estimated to lead the market with 34.88% ms estimation of which 30.32% comes from its direct services and 4.56% from the connecting itineraries. Etihad (EY) is estimated to follow EK with 14.48% (direct) + 5.36% (connecting) = 19.84% ms value. Another Middle Eastern carrier Qatar Airways (QR) ranks third in the market with 9.92% (direct) + 3.53% (connecting) = 13.45% ms estimation in total. It is deduced from this information that the Middle Eastern carriers, through their direct products, dominate the Latin America – Middle East route with more than 2/3rd of the entire ms estimation. European carriers report ms forecasts for connecting products led by Air France (AF) and Lufthansa (LH). However, it should be noted that among the connecting products, QR's service seems to have the best schedule quality score while for direct flights EY's product ranks top. This case proves the accomplishment of the research's Objectives 1, 2, 3 and 4 at a broader region-to-region level. Indeed through the implementation of the REMSET model, industry practitioners may conduct plenty of useful analysis at the regional scale similar to the example shown in this case.

10.3. Discussion

In this Chapter, 14 different cases are analysed at different levels including airport to airport, city-to-city, country-to-country and region-to-region. Through these cases, it is intended to show the fulfilment of research's objectives. While calculating the results for the cases, the listed 36 carriers' schedule information is used along with certain assumptions. The research's methodology already employs parameters which are obtained directly from the survey results as explained in Chapter 8 and 9. However, some pre-defined parameters like connect seat factor, codeshare seat factor, maximum detour, default MCT, q_{split} and $\%_{q\_split}$ are fixed to certain values as explained in Section 10.1. The results of the cases have proved that the research's objectives are successfully achieved in the sense that a consumer-centric capacity estimation model is developed (Objective 1), airline's schedule convenience is quantified (Objective 2), the REMSET tool is successfully formulated (Objective 3) and an instrument for industry practitioners to assess their schedule and network competitiveness is developed (Objective 4). However, it should be noted that the real market share figures are influenced by other factors like fare, brand loyalty and etc. The statistical tests that were implemented on certain cases have affirmed that the REMSET model provided credible outputs. It is also shown in some tests that, the REMSET model have produced more credible market share estimations in comparison to the traditional/naïve models. Therefore, using the survey results and the assumptions, the research objectives are successfully achieved. A separate analysis with changes to the input parameters enables an assessment of the impact of those parameters on the research outputs involving the supply, quality and market share estimations. The following chapter addresses the same case studies and examines the results using different input parameters.

Chapter 11: Results (Part II) – Scenario Analyses

11.1. Introduction to Results Chapter (Part II) – Scenario Analyses

Chapter 10 covered the outputs obtained by employing the research's consumer-centric capacity determination, quality assessment and REMSET methodologies in the selected origin and destination pairs at several layers including airport to airport, city to city, country to country and region to region levels. The chapter credited the methodologies and proved the fulfilment of the research's objectives by using airlines real schedule information. It is also discussed in the Chapter that the survey results are used as the input parameters of the research methodologies along with some pre-defined assumptions. These input parameters and the schedule of the carriers are usually regarded as "fixed" parameters – limiting to analyse the sensitivity of these factors on research outputs. This chapter is dedicated to overcome this limitation and demonstrate the adaptable nature of the research's models. It is intended to illustrate the impact of variations in inputs parameters on the calculated outputs which would be an indication of Objective 1, 2 and 3's accomplishment.

The flexible structure of the research's models enables industry practitioners to observe the marginal changes in market dynamics with respect to different inputs forming an indispensable market intelligence tool for industry practitioners, fulfilling Objective 4 of the research. For example, in case an airline executive would like to place a new frequency into a market, running the model with the proposed schedule information including the potential flight, the new consumer-centric supply share, quality score and realistic market share expectation of the carrier would be calculated which can later be benchmarked with the base case where the prospective frequency is not in effect. Such an analysis would assist the airline executive to plan the additional flight with a strategic perspective maximising the airline's commercial benefit by choosing the right aircraft type (seat supply) and timetable for the service. The research's methodology can also be used as a tool to measure the effectiveness of the codeshare agreements. As codeshare operations are displayed as a separate flight with unique flight numbers in the marketing airline schedules, running the model with the timetable including the prospective codeshare flight and benchmarking the outputs with the base case that the codeshare agreement is not in place would assist to demonstrate the marginal benefits of such agreements.

In addition to the capability of measuring schedule related variations impact on the research outputs, other inputs' effect on the market structure can be assessed including the fixed parameters obtained directly from the survey results and airports' MCT information. For example, although the MaxCT is found to be 290 minutes by the survey, this value can be changed to observe its effect on schedule convenience scores and market share estimations. On the other hand, whilst the MCTs are constant values determined by the airport the administrations, it is possible to observe the effect of a reduced or increased MCT on research outputs in terms of supply, quality and market share estimations for the specified origin and destination pairs. Other fixed parameter assumptions mentioned in Chapter 10 like connect seat factor (s_{conn}), codeshare seat factor (s_{code}), maximum detour factor, q_{split} and $\%_{q\_split}$ can also be changed to observe their impact on the outputs.

In this Chapter, the same O&D cases studied in the previous chapter are analysed in the same order with varying input parameters by introducing scenarios for each case. The results obtained in the previous results chapter are named as the "base status". In each case, the results of the scenarios are compared with the base status, and the deviations are discussed. In most scenarios of the cases, the base results are redisplayed in this Chapter too, for the sake of easing the comparison with the numbers. The inputs which are substituted with other values throughout to assess their impact on research outputs are as follows: s_{code}, s_{conn}, MCT, MaxCT, s_f, t_{buffer}, $\%_{q\_split}$ and $q_{a\_index\_normalised}$. Additionally, many cases involve changes in the schedule related factors including:

- New frequency insertion / deletion
- Total entrance/withdrawal of a carrier to/from a market
- Change of aircraft type – having more or fewer seats than the base status
- Codeshare flight (agreement) insertion / deletion
- Change in the departure time of the flight
- Switching airports in the same city
- Allowing / Banning stopover in a city en route from the origin to destination

In some of the scenarios of the following cases, certain statistical tests is undertaken to assess whether the research outputs differ significantly from the base case. For this reason, significance analyses are made employing the p values. For the testing of market share estimations, the paired proportion test is used as the figures are reported in percentages. However, if any other numeric parameters' significances are tested, Mann-Whitney test is used.

11.2. Results for the Selected O&Ds

11.2.1. Case 1: GVA–ZRH:

In this directional Swiss domestic route from Geneva to Zurich, two scenarios are introduced. The first instance evaluates the removal of one carriers' codeshare agreement with the operating airline where the second scenario reduces the codeshare seat factor from 30% to 20%. Similar to the base case, the analysis is performed over 2016 schedule data.

Scenario 1: For this scenario, the codeshare agreement between Swiss (LX) and Lufthansa (LH) is assumed to be cancelled, erasing LH's entire GVA–ZRH services from its timetable. The remaining marketing carriers' codeshare agreements with LX are kept intact. Since there exists 63 operating frequencies of LX in the market in which the carrier was partnering with LH for 62 of them in the base status, the codeshare supply in the market would fall extensively due to the annulment of the LX–LH codeshare partnership. The following table shows the frequency (f), frequency share ($\%_f$), seat supply (s) and seat share ($\%_s$) after the cancellation of the codeshare agreement between LX and LH in the GVA–ZRH route.

Table 11.1: Parameters in the GVA–ZRH Directional Route as of 2016 Schedules

Airline	Type	f	$\%_f$	s	$\%_s$
AB	Direct	14	11.38 %	214	1.93 %
EY	Direct	14	11.38 %	214	1.93 %
LH	Direct	0	0 %	0	0 %
LX	Direct	63	51.22 %	9,959	89.62 %
SA	Direct	7	5.69 %	290	2.61 %
SK	Direct	7	5.69 %	204	1.84 %
LX	Connect	14	11.38 %	213	1.91 %
TP	Connect	4	3.26 %	18	0.16 %
Total		123	100 %	11.112	100 %

As per the table, the removal of the codeshare agreement lessens the total frequency available for sale in the market from 185 to 12”3 while the seat supply is reduced to 11,112 from 14,103. However, the physical frequency and seat supply in the market is unchanged as the number of operating services remains intact. This reduction in the non-operating frequencies and seat supply works heavily in favour of the sole operating carrier, LX, ascending its seat share from 70.62% in the base status to 89.62% in the scenario. The following table summarises the seat share ($\%_s$) and realistic market share estimations (ms) and their comparison with the base status.

Table 11.2: Seat Share and ms for Carriers in the GVA–ZRH Route as of 2016 Schedules

Airline	Type	Scenario 1		Base Status	
		$\%_s$	$\%_s$	ms	ms
AB	Direct	1.93 %	1.52 %	1.28 %	1.44 %
EY	Direct	1.93 %	1.52 %	1.28 %	1.44 %
LH	Direct	0 %	21.21 %	16.86 %	0 %
LX	Direct	89.62 %	70.62 %	76.88 %	92.95 %
SA	Direct	2.61 %	2.05 %	1.92 %	2.10 %
SK	Direct	1.84 %	1.44 %	1.10 %	1.34 %
LX	Connect	1.91 %	1.51 %	0.59 %	0.61 %
TP	Connect	0.16 %	0.13 %	0.09 %	0.12 %

LX’s cancellation of codeshare agreements with LH escalates its market share expectation from 76.88% to 92.95%. On the other hand, although the sum of market share estimation for non-operating carriers’ fall due to the withdrawal of LH from the market, other non-operating carriers’ market share estimation is expected to increase in comparison to base status as their largest non-operating rival is not competing in the market anymore.

Scenario 2: In the second scenario, LX's codeshare agreement with LH is recovered back, but the codeshare seat factor (s_{code}) is reduced from 30% to 20%. This adjustment reduces the number of non-operating seats available for sale in the market, keeping the operating services unchanged. The table below summarises each carriers' seat supply under the new conditions in comparison to the base status.

Table 11.3: The New Frequency and Supply of the Carriers in the Market

Airline	Type	Scenario 2		Base Status	
		f	f	f	s
AB	Direct	14	214	14	143
EY	Direct	14	214	14	143
LH	Direct	62	2,991	62	1,994
LX	Direct	63	9,959	63	9,959
SA	Direct	7	290	7	193
SK	Direct	7	204	7	136
LX	Connect	14	213	14	213
TP	Connect	4	18	4	12
Total		185	12,793	185	14,103

s_{code}'s decline from 30% to 20% reduces the total weekly capacity available for sale from 14,103 to 12,793. Since direct service operators, Air Berlin (AB), Etihad (EY), Lufthansa (LH), South African Airways (SA) and Scandinavian (SK), offer codeshare services in the market, their capacity shrink substantially in comparison to the base status. Furthermore, as TAP Portugal (TP)'s connecting service is a codeshare product, its weekly seat supply falls from 18 to 12. The following table summarizes the seat share ($\%_s$) and realistic market share estimations (ms) of the carriers competing in the GVA–ZRH directional route compared with the base status which demonstrates that the reduction in the codeshare seat factor enables LX to upsurge its market share expectation to 83.13% while LH's, the largest non-operating carrier in the market, ms value declines from 16.86% to 12.15%.

Table 11.4: Seat Share and Market Share Expectations of the Scenario in Comparison to the Base Status

Airline	Type	Base Status		Scenario 2	
		$\%_s$	ms	$\%_s$	ms
AB	Direct	1.52 %	1.28 %	1.12 %	0.92 %
EY	Direct	1.52 %	1.28 %	1.12 %	0.92 %
LH	Direct	21.21 %	16.86 %	15.59 %	12.15 %
LX	Direct	70.62 %	76.88 %	77.85 %	83.13 %
SA	Direct	2.05 %	1.92 %	1.50 %	1.38 %
SK	Direct	1.44 %	1.10 %	1.06 %	0.80 %
LX	Connect	1.51 %	0.59 %	1.66 %	0.64 %
TP	Connect	0.13 %	0.09 %	0.10 %	0.07 %

The first scenario of this case exhibited the effect of a codeshare partnership cancellation between two carriers into market dynamics. Furthermore, the second case examined the influence of the codeshare seat factor on the capacity supply in the market and the ms expectations. Being able to measure the effect of these variable parameters on the research outputs refers to a clear fulfilment of Objective 1 and 3.

11.2.2. Case 2: DUB/SOF:

The previous Chapter has addressed that the directional DUB/SOF market lacked direct services. The scenarios of this case introduce two scenarios which are expected to change the market structure and add up to the rivalry among carriers. The first scenario involves the insertion of a direct flight by a carrier which did not offer any service in the market in the base case. Furthermore, the second scenario builds on the first scenario and assumes that the new carrier operating direct service in the market establishes a codeshare agreement with another airline. In each of these two scenarios, the maximum detour factor is fixed to 1.35 (which was 1.75 in the base status) implying that any itinerary travelling at least 35% more than the shortest path would be eliminated from the competition.

Scenario 1: Aer Lingus (EI) places a daily operating flight between SOF and DUB with a 150-seat aircraft. The flight departs from DUB at 10:00 am Irish local time, and after 3.5 hours of flight, it arrives in SOF at 15:30 pm Bulgarian local time. (The time difference between

Bulgaria and Ireland is 2 hours.) On the way back, the flight leaves SOF at 16:30 pm local time and arrives in DUB 18:00 pm local time. Running the REMSET model with this virtual flight, the bidirectional realistic market share estimations are computed as follows:

Table 11.5: Bidirectional Market Share Estimation for Scenario 1 Compared With the Base Status as of 2016 Schedules

Airline	ms – scenario 1 (operating flight of EI present)	ms – base status (no scenario EI flight)
EI (direct)	61.56 %	No flight present
AF (connecting)	3.48 %	6.02 %
BA (connecting)	3.67 %	7.52 %
FR (connecting)	4.04 %	6.75 %
KL (connecting)	2.27 %	5.14 %
LH (connecting)	24.93 %	56.35 %
LX (connecting)	0.05 %	0.08 %
TK (connecting)	0 % (detour elimination)	18.14 %

The table suggests that EI's brand new flight is expected to obtain 61.56% ms deeming the carrier to become the market leader. LH's share is expected to fall from 56.35% to 24.93% while TK completely lost its market presence. TK's ms is distributed to other competing airlines with regard to the new quality scores and the adjusted seat shares. TK's estimated removal from the market is due to the detour factor. The kilometres and the detour factor for all carriers operating in the market are summarised in the table below.

Table 11.6: Kilometre and Detour Factor of the Carriers Operating in the SOF/DUB Market

	EI	AF	BA	FR	KL	LH	LX	TK
KM	2487	2544	2495	2487	2508	2488	2522	3444
Detour	1.000	1.023	1.003	1.000	1.008	1.000	1.014	1.385

Table 11.6 displays each carriers' average distance in the SOF/DUB market that is computed by weight-averaging each hits' kilometre with respect to seat supply. As expected, the inserted direct flight of EI offers the shortest path of in the SOF/DUB routes fixing the airline's detour factor to 1. It is also observed in the table that, TK's products traverse 38.5% more distance on average than the shortest service provider. It is apparent that TK offers the

most extended routing and maximum detour cap of 1.35 eliminates the carrier from the competition. Therefore, this scenario suggests that the placement of a direct service entirely changes the market dynamics and competition scheme in favour of the direct product operator. On the other hand, the scenario also displayed the consequence of maximum detour cap on market share estimations.

Scenario 2: In this scenario, it is assumed that another carrier, supposing Etihad (EY), signs a codeshare agreement with EI in virtual the SOF/DUB direct flights described in the scenario above. The new ms figures under this circumstances become as follows. (Market share estimations are compared with the base status and scenario 1.)

Table 11.7: Bidirectional Market Share Estimation for Scenario 2 Compared with the Base Status and Scenario 1 as of 2016 Schedules

Airline	ms – scenario 2 (codeshare between EI and EY)	ms – scenario case 1 (operating flight of EI present)	ms – base case
EI	52.51%	61.56 %	No flight present
EY	12.30 %	No flight present	No flight present
AF	3.23 %	3.48 %	6.02 %
BA	3.20 %	3.67 %	7.52 %
FR	3.84 %	4.04 %	6.75 %
KL	2.06%	2.27 %	5.14 %
LH	22.82 %	24.93 %	56.35 %
LX	0.04 %	0.05 %	0.08 %
TK	0 % (detour elimination)	0 % (detour elimination)	18.14%

A codeshare agreement between EI and EY erodes EI's ms from 61.56% in Scenario 1 to 52.51% while EY gains 12.30% that is primarily taken away from the EI's share. EY's entrance into the market via the codeshare agreement made all competing carriers to lose some portion of their ms. Furthermore, TK is still expected to lack market presence as the carriers' detour is still more than the maximum detour cap of 1.35.

The scenario analysis of Case 2 showed that the research's model enabled to assess the ms impact of schedule-related variations accomplishing Objective 3 under changing market conditions including additional direct capacity, codeshare agreement and a lower detour index. Furthermore, the capability of estimating additional capacities' quantitative effect on ms fulfils Objective 4 in the sense that a useful tool is offered to industry practitioners to assess schedule and network competitiveness in their capacity planning.

11.2.3. Case 3: HAM/BEY:

It is referred to in the base status that, the bidirectional HAM/BEY market is fully served by the connecting services where multiple airlines compete through their products attaining a connection at their hub airports. The first scenario of this case assumes a decline in the maximum connection time tolerance of passengers which was found to be 290 minutes by the passenger survey. The change in the available capacity and competition scheme in the market would be recalculated after this adjustment with the MaxCT. In the second scenario, the MaxCT is recovered to its original level, but some hub airports' MCT values are increased in order to observe the impact on the research outputs.

Scenario 1: For this scenario, the MaxCT is reduced from 290 minutes to 150 minutes. In other words, it is now assumed that the connecting passengers can tolerate a maximum of two and a half hours, rather than 4 hours and 50 minutes, t_{conn} at the hub airport. The below table shows the routing type (i.e. direct or connecting), adjusted capacity share ($\%_{a\_s}$), normalised quality index ($q_{index\_normalised}$), and expected realistic market share (ms) in HAM–BEY and BEY–HAM routes respectively for each airline competing in the market as of summer 2016 schedule under the new MaxCT assumption.

Table 11.8: Figures for Airlines in the HAM–BEY as of 2016 Schedule (MaxCT = 150 minutes)

Airline	Type	$\%_{a\_s}$	$q_{a\_index\_normalised}$	KM Detour	ms
EK	Connecting	53.85 %	0.6182	2.160	0.00 %
LH	Connecting	46.15 %	0.9850	1.000	100.00 %

Table 11.9: Figures for the BEY–HAM as of 2016 Schedule (MaxCT = 150 minutes)

Airline	Type	$\%_{a\_s}$	$q_{a\_index\_normalised}$	KM Detour	ms
EK	Connecting	24.35 %	0.5615	2.360	0.00 %
LH	Connecting	31.27 %	0.9615	1.092	40.75 %
TK	Connecting	44.38 %	0.9932	1.000	59.25 %

The above tables illustrate that the competition in the market changes significantly with the MaxCT's reduction. As per the base status, in the HAM–BEY route, 8 airlines were competing through their connecting products. However, in this scenario, only Lufthansa (LH) and Emirates (EK) offer a product where the total market share is estimated to be owned by LH due to EK's elimination for the longer routing. Since the itineraries offering longer waiting times at the intermediary airport are eliminated, the adjusted normalised index quality score of LH rise too, from 0.8994 in the base status to 0.9850 in the scenario.

In the BEY–HAM route, while 7 airlines were competing, only 3 airlines offered a product with the MaxCT's decline to 150 minutes. Among those three carriers, only Turkish Airlines (TK) and LH managed to acquire a market share estimation, 59.25% and 40.75% respectively. EK is again eliminated from the competition due to the detour cap. Whilst LH's $q_{a\_index\_normalised}$ score has grown from 0.7951 to 0.9615 due to the elimination of some connections having t_{conn} greater than 150 minutes, TK's $q_{a\_index\_normalised}$ score is unchanged as all of its connecting products' t_{conn} was less than 150 minutes. The below table summarises the bidirectional market share estimation of the carriers which is simply obtained by averaging each carriers' ms in both routes as well as its comparison with the base status.

Table 11.10: Realistic market share estimations BEY/HAM route as of 2016 schedules.

Airline	Scenario 1	Base Status
	ms	ms
A3	0.00 %	0.15 %
AF	0.00 %	9.72 %
BA	0.00 %	9.23 %
EK	0.00 %	0.00 %
LH	70.38 %	30.87 %
PC	0.00 %	11.32 %
SU	0.00 %	1.47 %
TK	29.62 %	37.24 %

Implementing the paired proportion test on the airlines market share estimation for the base status and Scenario 1, a p value of smaller than 0.01 is calculated implying significant difference between the outputs. Therefore, the MaxCT has a significant role in market structure determination especially in an environment where solely connecting products compete. For the sake of this case, as the tolerance for passengers to wait at the hub airport decreases LH's market share expectation increases where the other carriers suffer from losing ms.

Scenario 2: In the second scenario, the MaxCT value is recovered back to 290 minutes, but the connecting seat factor (s_{conn}) is reduced from 20% to 10%. Such a decrease in s_{conn} indicates supply reduction for the connecting products. The table below summarises the total weekly seat capacity and market share estimation for each carrier in both directions under s_{conn} = 10% assumption as well as its comparison with the base status.

Table 11.11: Figures for Airlines in the HAM–BEY Route as of Summer 2016 Schedule

Airline	Type	Seat supply (s)		Market share estimation (ms)	
		Scenario 2	Base Status	Scenario 2	Base Status
A3	Connecting	17	35	0.30 %	0.30 %
AF	Connecting	97	194	11.78 %	11.78 %
BA	Connecting	86	172	9.41 %	9.41 %
EK	Connecting	280	560	0.00 %	0.00 %
LH	Connecting	240	480	35.94 %	35.94 %
PC	Connecting	131	261	12.17 %	12.17 %
SU	Connecting	42	84	1.66 %	1.66 %
TK	Connecting	215	429	28.75 %	28.75 %
Total		1108	2215	100 %	100 %

Table 11.12: Figures for Airlines in the BEY–HAM Route as of Summer 2016 Schedule

Airline	Type	Seat supply (s)		Market share estimation (ms)	
		Scenario 2	Base Status	Scenario 2	Base Status
AF	Connecting	102	205	7.67 %	7.67 %
BA	Connecting	108	215	9.07 %	9.07 %
EK	Connecting	187	374	0.00 %	0.00 %
LH	Connecting	240	480	25.80 %	25.80 %
PC	Connecting	131	261	10.46 %	10.46 %
SU	Connecting	42	84	1.28 %	1.28 %
TK	Connecting	341	681	45.73 %	45.73 %
Total		1151	2300	100 %	100 %

It is observed in the tables that the seat supply of each carrier competing in the market is halved after the reduction of s_{conn} from 20% to 10%. As the entire services in the market are connecting products, the total weekly seat supply declines by 50% in both directions. Since the capacity shrinks by 50% for all carriers in both directions, the ms figures are unchanged in comparison to the base status. In case a direct service existed in the route, the reduction in connecting capacity would work in favour of the direct service operator and would negatively affect ms for the connecting service providers. Such a scenario is to be introduced in the following cases.

The scenarios of Case 3 showed the influence of MaxCT and s_{conn} on the research outputs including supply, quality and market share estimations fulfilling Objective 1,2 and 3 of the research. On the other hand, the effect of these parameters on the research outputs provides an essential insight to industry practitioners while designing the airline schedule and network strategy referring to the fulfilment of Objective 4 of the research.

11.2.4. Case 4: SKG/TBS:

The base status has addressed the market's historical development from 2010 onwards. The competitive dynamics have often changed over the years for this thin market served solely by the connecting products due to the entrance/exit of certain carriers as well as the capacity and timetable changes. For this case, the MaxCT is increased substantially in the first scenario while the maximum detour factor is raised in the second scenario to observe those parameters' influence on the ms for such a thin market.

Scenario 1: In this scenario, the MaxCT is increased from 290 minutes to 600 minutes raising the probability of connections to become a successful hit as more t_{conn} is permitted for the connecting itineraries. Therefore, the number of products available for sale and competition is expected to be higher compared to the base case. The following sections summarise the market conditions as per the new MaxCT figure.

As of 2010, in the base case for SKG–TBS route, Lufthansa (LH) was the sole carrier operating in the market. The increase in the MaxCT enabled Austrian Airlines (OS) also to offer a product on the route. On the reverse (TBS–SKG) direction, the increase of the MaxCT did not change the competition and supply in the market in comparison to the base status. In the following year, in 2011, contrary to the base status, Turkish Airlines (TK) became the sole carrier expecting a market share in both directions. Since TK's product was relatively shorter in comparison to LH and OS, those carriers lost their ms as their detour factor was reported to be higher than 1.75 after TK's market entry.

As of 2012 and 2013, TK was not able to offer a product in the market in the base case as its t_{conn} was greater than 290 minutes. The increase of MaxCT in the scenario enabled the carrier also to offer a product in both directions and eliminate other European rivals expect Aegean Airlines (A3). A3 and TK were estimated to share the market in 2012 and 2013. Furthermore, from 2013 onwards, TK and A3 were again the sole carriers serving in the market with varying market share estimations. As TK composed the shortest path in each direction, unlike the base case, any European airlines competing with the airline other than A3 was removed from the rivalry due to the detour elimination. For example, while in the base status, Alitalia (AZ) was expected to gain a market share in the TBS–SKG route as of 2013, the carrier was estimated to gain no market under MaxCT = 600 assumption as the existence of TK in the route removed AZ from the market due to detour elimination. The following table summarises the bidirectional market share estimation for this scenario from 2010 to 2016.

Table 11.13: Market Share of Carriers in the TBS/SKG Route Bidirectional Route 2010 to 2016 under MaxCT = 600 Minutes Scenario

	TBS–SKG (undirectional) ms						
	2010	2011	2012	2013	2014	2015	2016
A3	0.0%	0.0%	13.08%	13.9%	3.7%	13.0%	23.2%
LH	58.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OS	41.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TK	0.0%	100%	86.92%	86.1%	96.3%	87.0%	76.8%

It is observed in the table that, the increase in the MaxCT has led the market to converge into a duopoly between TK and A3 as the other carriers were detached from competition due to detour elimination. Implementing a series of paired proportion tests for the market share estimations of the base case and scenario 1 for each year (from 2010 to 2016), for each test a p value smaller than 0.05 is computed implying significance. Although it was expected that, the increase with the MaxCT would enhance the degree of competition in the market, this was not attained due to the detour parameter constraints and as the test implies the results differed significantly. The following scenario assumes a higher maximum detour to analyse higher MaxCT's impact on market structure.

Scenario 2: In the second scenario, the MaxCT is still kept at 600 minutes, but the maximum detour factor is raised from 1.75 to 2.50. Therefore, itineraries traversing a distance up to 2.5 times the shortest available path in the market are also included in the competition.

The following table summarises the kilometre and detour values of the SKG/TBS market via hub airports of the airlines offering at least one connection hit in the market from 2010 to 2016.

Table 11.14: Kilometer and Detour Values of the Airlines' Path Offering At least One Connection in the TBS/SKG Market Between 2010 and 2016.

Airline	Connection Hub	Kilometre	Detour Index
A3	Athens (ATH)	2,124	1.160
AF (codeshare)	Rome (FCO)	3,597	1.965
AZ	Rome (FCO)	3,597	1.965
OS	Vienna (VIE)	3,306	1.806
KL	Amsterdam (AMS)	5,116	2.795
LH	Munich (MUC)	3,918	2.140
LH	Frankfurt (FRA)	4,416	2.413
TK	Istanbul (IST)	1,830	1.000

As per the table, since the shortest path is via IST, TK’s detour index is fixed to 1. All connections except AMS are below the maximum detour which is set to 2.5 for this case, and therefore OS, LH, AZ, A3 and TK are all able to expect a share in the SKG/TBS market. KLM Royal Dutch Airlines (KL) is eliminated due to more extended detour factor even above 2.5. On the other hand, Air France (AF) is expected to gain a market share due to its codeshare services via Rome (FCO), not via Paris. The following table summarises the market share estimation of carriers from 2010 to 2016 for scenario 2.

Table 11.15: Market Share of Carriers in the TBS/SKG Route Bidirectional Route 2010 to 2016 under MaxCT = 600 Minutes Scenario and Maximum Detour = 2.5

	TBS/SKG (bidirectional) ms						
	2010	2011	2012	2013	2014	2015	2016
A3	0.0 %	0.0 %	8.9 %	7.3 %	3.3 %	7.3 %	19.5 %
AF	0.0 %	0.0 %	0.0 %	1.1 %	0.2 %	1.0 %	0.0 %
AZ	0.0 %	0.0 %	0.0 %	19.2 %	1.4 %	17.0 %	0.0 %
LH	58.1 %	56.5 %	32.2 %	27.2 %	8.1 %	25.6 %	14.9 %
OS	41.9 %	0.0 %	0.1 %	0.0 %	0.2 %	0.0 %	0.3 %
TK	0.0 %	43.5 %	58.8 %	45.2%	86.8 %	49.1 %	65.3 %

It is observed in the table that, the increase in the maximum detour factor intensified the rivalry between the carriers and enabled more actors to expect a share in the market from

2010 to 2016. The duopoly structure between A3 and TK referred in the first scenario of this case is profoundly disturbed by the rise in the maximum detour factor. Therefore, as shown in the table, if passengers increase their tolerance to traverse a longer distance for their itineraries, it would contribute to the competition scheme of the market positively.

The scenario analysis of Case 4 showed the impact of MaxCT and maximum detour factor on the realistic market share estimation. Contrary to expectations, the sole MaxCT increase did not increase the competition as TK's path advantage abolished European rivals from the market share estimation due those carriers' longer routing. However, this was addressed by increasing the maximum detour factor such that the European airlines were able to join the competition. These findings confirm the accomplishment of Objective 3 and 4.

11.2.5. Case 5: AMM/JED:

The base case showed that there exists both direct and connecting services between JED and AMM besides the market is protected and dominated by national carriers providing direct services, forming a substantial barrier for new entrants. The first scenario of the case studies a further regulation which limits the maximum seats per frequency to a certain number. In the second scenario, the regulation on seat per frequency is lifted, and a new carrier that offers direct services is introduced to the market.

Scenario 1: In this scenario, the maximum seats per frequency (s_f) is fixed at 150. Such regulation is possible between countries to further protect their home carriers' competitiveness. The below tables show the routing type (i.e. direct or connecting), total weekly frequency (f), seat supply (s) with the new seat per frequency figures, adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) from JED to AMM and from AMM to JED respectively (directional) for each airline serving in the route as of summer 2016 schedule.

Table 11.16: Results of the Selected Parameters from JED to AMM as of 2016 Under $s_f = 150$ Assumption for Direct Services.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4,200	64.61%	1.2974	67.94%
SV	Direct	12	1,800	27.67%	1.2081	27.10%
AZ	Connecting	4	30	0.26%	0.7106	0.15%
MS	Connecting	14	309	4.75%	0.7277	2.80%
ME	Connecting	7	176	2.71%	0.9143	2.01%
Total		65	6,515	100%	--	100%

Table 11.17: Results of the Selected Parameters from JED to AMM as of 2016 under $s_f = 150$ Assumption for Direct Services.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4,200	66.82%	1.2510	68.73%
SV	Direct	10	1,500	23.89%	1.2819	25.18%
MS	Connecting	14	398	6.31%	0.6987	3.62%
ME	Connecting	7	176	2.80%	1.0180	2.34%
SV	Connecting	2	40	0.18%	0.8329	0.13%
Total		61	6,314	100%		100%

Table 11.18 shows the market share expectations of the competing carriers in the bidirectional market in comparison to base status, obtained merely by averaging the ms expectations of the competing carriers in each direction.

Table 11.18: Market Share Expectations of Carriers in the Bidirectional JED/AMM Market as of 2016 and Its Comparison with the Base Status

	Ms for Scenario 1	Base Case ms
RJ (direct)	68.33%	72.14%
SV (direct)	26.14%	22.90%
ME (connect)	2.18%	1.95%
MS (connect)	3.21%	2.88%
AZ (connect)	0.07%	0.07%
SV (connect)	0.07%	0.06%

It is observed in the above table that, the restriction of seat per frequency to 150, caused Royal Jordanian (RJ) to lose a portion of its market share expectation from 72.14% to 68.33%. Contrarily, Saudi Airlines (SV) flights were estimated to gain ms up from 22.90% in the base case to 26.14% in the scenario. These results are within expectations as in the base case s_f for RJ was 177 and 148.5 for SV. Therefore, $s_f = 150$ worked positively for SV but the other way around for RJ. Fixing s_f to 150 also led the total seat supply to drop in the market. As per 2016 schedules, while in the base case the seat supply in JED–AMM route was 7,222 and in AMM–JED route it was 7,057, the figures were reported as 6,515 and 6,314 respectively under the scenario. For connecting services, although the physical seat supply is unchanged, their market share estimations are reported to be slightly above the base case, as the total seat supply is dropped by fixing s_f for direct services. It is also observed in the tables that, the quality scores did not change with the s_f as the parameter is unrelated with the quality performance.

Scenario 2: As per the second scenario of the case, the restriction on seat per frequency is lifted and recovered back its original values, but a new entrant is introduced into the market operating daily flights. Although it is implausible for such a protected market, it is assumed that a virtual airline, airline XY (XY) enters the market with the following schedule information. The flight number of the virtual flight from JED to AMM is XY 9997 while it is XY 9998 for AMM–JED service.

Table 11.19: Schedule Information of XY 9997 Simulation Flight

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Depart JED	01:35	15:45	15:45	01:35	15:45	15:45	01:35
Arrive AMM	03:40	17:50	17:50	03:40	17:50	17:50	03:40

Table 11.20: Schedule Information of XY 9998 Simulation Flight

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Depart AMM	04:45	19:00	19:00	04:45	19:00	19:00	04:45
Arrive JED	06:50	21:05	21:05	06:50	21:05	21:05	06:50

The simulated XY flights have different departure and arrival times depending on the day of the week. The timetable is reported in local times which is identical for Saudi Arabia and Jordan. The flight duration is 125 minutes for each day of the week. On Mondays, Thursdays and Sundays, the virtual flight leaves JED at 01:35 am and arrives in AMM at 03:40 am. The 125-seat aircraft makes a 65-minute ground time in AMM and departs the city at 04:45 am and arrives back to JED at 06:50 am. In the remaining days of the week, the flight leaves JED at 15:45 pm and arrives in AMM at 17:50 pm. On Tuesdays, Wednesdays, Fridays and Saturdays, the aircraft is assumed to be a different (larger) type with 180 seats per frequency and scheduled to make a 5 minute longer ground time, totalling to 70 minutes. Therefore, the simulated XY flight leaves AMM at 19:00 pm and arrives back to JED at 21:05 on Tuesdays, Wednesdays, Fridays and Saturdays. The varying timing scheme of the XY flight leads to different quality scores for the carrier, depending on the day of the week. The following table summarises available seats (s) and $q_{index\_normalised}$ for the simulated XY flight for different days of the week.

Table 11.21: Available Seats and $q_{index\_normalised}$ Scores of the XY Simulation Flights

	s	XY 9997 $q_{index\_normalised}$	XY 9998 $q_{index\_normalised}$
Monday	125	1.2300	1.2644
Tuesday	180	1.2987	1.3159
Wednesday	180	1.2987	1.3159
Thursday	125	1.2300	1.2644
Friday	180	1.2987	1.3159
Saturday	180	1.2987	1.3159
Sunday	125	1.2300	1.2644
$q_{index\_normalised}$		1.2752	1.2982

The weekly index quality values of XY 9997's and XY 9998 are computed by weight-averaging $q_{index\_normalised}$ with the seat availability of each day. Therefore $q_{index\_normalised}$ of XY 9997 is $\frac{(4 \, x \, 180 \, x \, 1.2987) + (3 \, x \, 125 \, x \, 1.23)}{(180 \, x \, 4)+(125 \, x \, 3)} = 1.2752$ while it is $\frac{(4 \, x \, 180 \, x \, 1.3159) + (3 \, x \, 125 \, x \, 1.2644)}{(180 \, x \, 4)+(125 \, x \, 3)} = 1.2982$ for XY 9998. Table 11.22 summarises the parameters for each direction including the brand new XY 9997 and XY 9998 flights. In the JED–AMM route, XY's $q_{a\_index\_normalised}$ scores are different than $q_{index\_normalised}$ since the scheduled flight time of RJ for the direct flight is 120 minutes, whereas it is 125 for XY and 130 for SV. Therefore, while calculating $q_{a\_index\_normalised}$ for XY, its $q_{index\_normalised}$ is discounted by referencing to the shortest direct flight duration, which belongs to RJ. On the way back, in the AMM–JED direction, XY's $q_{a\_index\_normalised}$ is equal to $q_{a\_index\_normalised}$

as the carrier offers the shortest direct flight duration together with SV. (Most of the RJ's AMM–JED direct flights are scheduled to last 130 minutes, whereas the figure is 125 for SV and XY.)

Table 11.22: Results of the Selected Parameters from JED to AMM as of 2016 Including XY Flight.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4958	60.02 %	1.2974	62.73 %
SV	Direct	12	1749	21.18 %	1.2081	20.61 %
XY	Direct	7	1050	12.71 %	1.2241	12.53 %
AZ	Connecting	4	30	0.21 %	0.7106	0.12 %
ME	Connecting	14	176	2.13 %	0.7277	1.25 %
MS	Connecting	7	309	3.75 %	0.9143	2.76 %
Total		72	8272	100%	--	100%

Table 11.23: Results of the selected parameters from AMM to JED as of 2016 including U2 flight.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
RJ	Direct	28	4,958	61.36 %	1.2510	62.41 %
SV	Direct	10	1,485	18.39 %	1.2819	19.17 %
XY	Direct	7	1,050	13.01 %	1.2982	13.73 %
MS	Connecting	14	398	4.92 %	0.6987	2.80 %
ME	Connecting	7	176	2.18 %	1.0180	1.80 %
SV	Connecting	2	40	0.14%	0.8329	0.09 %
Total		68	8,107	100%	--	100%

The tables suggest that, in each direction, 1.050 additional seats became available due to the insertion of XY flights. (125 seats on Monday, Thursday and Sundays and 180 seats other days add up to 1050 seats per week) Using the information displayed in the above tables, it is possible to obtain the bidirectional market share estimation of the carriers competing in the JED/AMM market by merely averaging the directional ms values as shown in the table below. (The ms of the scenario is contrasted with the base case in the table.)

Table 11.24: Market Share Expectations of Carriers in the Bidirectional JED/AMM Market Including U2 Flight and Its Comparison With the Base Status

	ms for Scenario 2	Base Case ms
RJ (direct)	62.57%	72.14%
SV (direct)	19.89%	22.90%
XY (direct)	13.13%	N/A
ME (connect)	1.53%	1.95%
MS (connect)	2.78%	2.88%
AZ (connect)	0.06%	0.07%
SV (connect)	0.04%	0.06%

Table 11.24 implies that the new entrant airline, XY, managed to expect 13.13% of the entire market with a single direct flight per day. The home carrier of Jordan (RJ) and home carrier of Saudi Arabia (SV) lost considerable market share to the new entrant. This reality indeed justifies the rationale behind some nation states protectionist policies aiming to keep the competitiveness of their carriers against rivalry. On the other hand, the ms loss is expected to be negligible with the connecting products. The share of connecting flights is expected to decrease very slightly from 4.96% in the base status to 4.41% in the scenario.

The scenarios of this case have confirmed the impact of the physical capacity change on the market structure. In the first scenario, an analysis is performed by altering the seat supply through seat per frequency parameter whereas the second scenario examined a case where a different carrier launched a new direct flight. Being able to assess the consumer-centric capacity change in the market dynamics through these parameters proves the fulfilment of Objective 1 while the ability to calculate the new ms figures shows the accomplishment of Objective 3. Moreover, airline practitioners can use this tool to investigate the effect of certain parameters on market structures, fulfilling Objective 4 of the research.

11.2.6. Case 6: MAN/DOH:

The base case has shown that there existed both direct and connecting services between DOH and MAN where connecting itineraries were expected to form approximately one-fifth of the market. In the base case, Emirates (EK), Etihad (EY), Turkish Airlines (TK) and KLM Royal Dutch Airlines (KL) offered connecting itineraries in the market. The first scenario of this case introduces an assumption which permits one more carrier to enter into the market while the second scenario extends the MCT of the competing airlines' hub airports by 10 minutes to observe the changes with the results.

Scenario 1: In the first scenario, it is permitted for carriers to make a stop - in addition to connection - while reaching to the final destination. Under this assumption, British Airways (BA) would be able to offer a product on the route. BA has a domestic flight coded BA1385 from MAN to Heathrow Airport (LHR) that arrives in LHR at 8 am each day of the week. On the other hand, BA125 flight departs LHR airport each day of the week at 11 am and arrives in Bahrain (BAH) where the flight makes one-hour stopover (without disembarking passengers from the aircraft; they remain on the plane) and then continues to DOH. Therefore, BA offers a product from MAN to DOH by making one connection in LHR and a stopover in BAH. On the way back, BA124 departs DOH at 23:20 each day, makes a stopover again in BAH and arrives in LHR 06:15 am every morning which then could be connected to MAN flights via BA1370 or BA1386. The below tables show the routing type (i.e. direct or connecting), total weekly frequency (f), seat supply (s), adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) in the MAN–DOH and DOH–MAN routes respectively for each airline serving in the market as of summer 2016 schedule.

Table 11.25: Results of the Selected Parameters from MAN to DOH as of 2016 – Including BA Connections.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
QR	Direct	16	5170	65.13%	1.2846	72.94%
EK	Connecting	21	1680	21.15%	0.9204	16.97%
EY	Connecting	14	434	5.48%	0.9937	4.74%
KL	Connecting	5	157	1.40%	0.9806	1.20%
TK	Connecting	8	285	3.59%	0.7738	2.42%
BA	Connecting	7	257	3.24%	0.6105	1.72%
Total		71	7983	100%	--	100%

Table 11.26: Results of the Selected Parameters from DOH to MAN as of 2016 – Including BA Connections.

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
QR	Direct	16	5170	69.14%	1.2965	76.04%
EK	Connecting	21	1550	20.64%	0.9517	16.66%
EY	Connecting	14	375	5.03%	0.8473	3.62%
KL	Connecting	5	157	1.48%	0.9296	1.17%
TK	Connecting	3	107	0.60%	0.8476	0.43%
BA	Connecting	7	233	3.11%	0.7868	2.08%
Total		66	7592	100%	--	100%

It is observed in the tables that, by allowing stopovers into the acceptable product list, BA offered a connection in the market. Through this addition, the total frequency was up by 7 in each route where the total availability increased by 257 seats per week in MAN–DOH route and by 233 in the reverse direction. It is also observed in the table that, the BA connections reported a more inferior quality as its flights perform one more stop along the way which significantly reduces its schedule convenience score. For this reason, BA was expected to have a relatively lower ms in comparison to its adjusted seat share. The table below presents the market share estimations of the direct and connecting services in the bidirectional MAN/DOH route as of 2016 schedule information.

Table 11.27: Market Share Estimations of Carriers (Table Split in Direct Vs Connecting Services View)

Direct services		Connecting Services	
QR	74.49%	EK	16.81%
		EY	4.18%
		TK	1.43%
		KL	1.18%
		BA	1.91%
Total Direct	74.49%	Total Connect	25.51%

As per the table, with the addition of BA services into the product list, the expected market share of the direct services dropped to 74.49% which was 76.17% in the base case. The share of connecting services is expected to increase from 23.83% to 25.51%. Indeed, these results are closer to actual MIDT figures cited in the previous chapter which reported that the share of direct services amounted to 70.77%. Therefore, it can be concluded that, permitting stopover flights into the relevant product list enabled to fine-tune the methodology in the sense that some passengers may have no issues preferring such routing and flights. Indeed, the methodology suggests that BA could expect 1.91% of the passenger traffic in the market, which is corroborated again by the MIDT results reporting slightly above 2% market share for the airline in the route.

Scenario 2: In the second scenario, stopovers in connecting products are not permitted and the minimum connecting time (MCT) of the connecting airports are extended by 10 minutes to observe the effect of this parameter on the total consumer-centric capacity supply and market share estimation. The surge in the MCT of the hub airports may lead the elimination of certain connecting products as the flight combinations having less than 10 minutes of buffer time (t_{buffer}) would not be able to offer a product in the market under this assumption. The below table summarises the original and new MCT values of the airports that are used as hubs by the carriers offering connecting products in the market.

Table 11.28: The Original and Assumed MCT Values of the Airports

Airline	Hub	Original MCT	New MCT
EK	Dubai (DXB)	75 min	85 min
EY	Abu Dhabi (AUH)	60 min	70 min
TK	Istanbul (IST)	60 min	70 min
KL	Amsterdam (AMS)	50 min	60 min

The model was run by using the new MCT information displayed in the above table. In the MAN – DOH route, no connections are eliminated from the available product list as the connection time of all flight combinations is above the new MCT values of the corresponding airports. Therefore, the total frequency, seat supply, adjusted seat share, quality and market share estimations are identical to base status in the MAN–DOH direction. However, in the DOH – MAN route, the market structure changed slightly due to the increase with the MCT. One of EY's connection hits – EY398/EY15 offering daily connections with 190 seat availability per week is no more included in the available products set as the t_{conn} of this combination at the AUH airport is 65 minutes, which is less than the new MCT value of AUH airport. The following table summarises the parameters in the DOH – MAN after the elimination of EY398/EY15 hit. It should be noted that EY still offers a product in the route via its EY390/EY21 hit which has a t_{conn} of 4 hours and 5 minutes that is higher than the new MCT and less than the MaxCT.

Table 11.29: Results of the Selected Parameters from DOH to MAN as of 2016 – Under the New MCT Information

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
QR	Direct	16	5170	73.22%	1.2965	79.22%
EK	Connecting	21	1550	21.95%	0.9517	17.43%
EY	Connecting	7	185	2.62%	0.7663	1.68%
KL	Connecting	5	157	1.56%	0.9296	1.21%
TK	Connecting	3	107	0.65%	0.8476	0.46%
Total		52	7169	100%	–	100%

It is inferred from the above table that, EY's quality score in the DOH–MAN route has dropped to 0.7663 which was 0.8473 in the base status and scenario 1. Since the remaining hit of EY reports a longer journey time and less convenient departure and arrival times, the carrier is expected to offer lower $q_{a\_index\_normalised}$ in the market. Naturally, the adjusted seat share and ms of EY has also fallen due to the reduction in the quantity and quality of the carrier's available products. The table below presents the market share estimations of the direct and connecting services in the bidirectional MAN/DOH route as of 2016 schedule information obtained by simply averaging the carriers directional ms expectations. The ms values are also compared with the base status and scenario 1.

Table 11.30: Market Share Estimations of Carriers under the New MCT Information

Carrier	Scenario 2 ms	Scenario 1 ms	Base Status ms
QR	76.97%	74.49%	76.17%
EK	17.42%	16.81%	17.23%
EY	3.26%	4.18%	4.26%
TK	1.12%	1.43%	1.11%
KL	1.23%	1.18%	1.23%
BA	N/A	1.91%	N/A

It is observed in the table that, EY's market share estimation was reduced due to the increase in the MCT of the airports which affected one of the EY's connections. Testing the significance of the changed MCTs, implementing the paired proportion test on the carriers' ms scores scenario 2 and base status, a p value of 0.715 is obtained implying insignificance. Therefore, increasing the MCTs by 10 minutes does not have a significant effect on the market share estimations for the sake of this case. However, this finding should not infer that increasing MCT by 10 minutes does not always have a significant effect on market share estimation of the REMSET model. For a different O&D pair and competition scheme, such a scenario of increased MCT might have a significant effect on ms forecasts. Being able to assess the ms impact of the changing MCTs is a definite accomplishment Objective 3 and 4. Additionally, the model enabled the measurement of the supply and quality impact of this change for the carrier which serves as attainment of Objective 1 and 2 of the research.

11.2.7. Case 7: LGW/BKK:

The base case has studied the traffic between London's Gatwick Airport and Bangkok Suvarnabhumi airport which was found to be served by two of the listed carriers, Emirates (EK) and Turkish Airlines (TK). The scenarios of this case examine the traffic between other London airports and Bangkok Suvarnabhumi (BKK) airport as of 2016 schedules. The first scenario analyses the traffic between Heathrow Airport (LHR) to Bangkok where the second scenario examines the traffic between Stansted (STN) and BKK.

Scenario 1: This scenario investigates the LHR/BKK market. Unlike the LGW airport, the volume of competition between LHR and BKK is intense. The following table shows the total frequency, seat supply and the number of airlines competing in the market for each direction. The table also contrasts these values with the base case.

Table 11.31: Total Number of Airlines Competing in the Market, Weekly Frequency (f) and Seat Supply (s) for Each Direction and Comparison with the Base Case

	Competing Airline Count	Frequency (f)	Seat (s)
LHR – BKK	17	191	12,978
BKK – LHR	18	187	12,583
LGW – BKK (base status)	2	35	2,515
BKK – LGW (base status)	2	35	2,515

It is observed in the table that, for each direction, London Heathrow airport offer approximately 5 times more frequency and seats to BKK compared to Gatwick airport. On the other hand, 15 more carriers in comparison to the base case operate from LHR to BKK while there exists 16 more airlines flying from BKK to LHR. In the base case, EK was the dominant carrier in both directions with 76.84% ms in the LGW – BKK route and 83.39% in the BKK – LGW. The table below displays the top 5 carriers' market share estimation by averaging the figures in each direction in LHR/BKK with a comparison to the base status.

Table 11.32: Top 5 carriers' ms values in LHR/BKK market and its comparison with LGW/BKK.

	LHR/BKK	LGW/BKK
EK	21.59%	80.12%
BA	25.46%	N/A
QR	16.19%	N/A
EY	10.27%	N/A
TK	5.65%	19.88%

It is observed in the tables that, in the LHR/BKK market, the Middle Eastern carriers are reported to have a considerable market share expectation. EK reported being the market leader with 26.93% and 23.99% market share estimation in the LHR inbound and outbound services respectively. On the other hand, whilst TK was second in the LGW/BKK market, the carrier ranked fifth in LHR/BKK.

Scenario 2: In this scenario, another London airport, Stansted (STN) was selected to study its competition level to/from BKK route. However, as of 2016 schedule data, none of the listed carriers was able to offer a product from STN to BKK. On the reverse direction, only one carrier, Austrian Airlines (OS) operated a codeshare flight only on Thursdays where the seat availability of the carrier was limited to only 9. Due to this negligible capacity, it can be concluded that there existed almost no service in the STN/BKK market as of 2016 schedules.

The scenarios of this case showed that different airports of the cities might have different competitive dynamics which needs to be taken into account by the airline practitioners while designing their network and scheduling strategies. This process indeed refers to the fulfilment of Objective 4 of the research.

11.2.8. Case 8: LAS/MIA:

As studied in the previous chapter, LAS/MIA is an American domestic market where listed carriers only operate through their codeshare services. The first scenario of this case includes the assumption of an additional codeshare agreement while the second scenario involves the reduction of t_{buffer} from 30 minutes to 10 minutes, implying that passengers demand less time on top of the MCT to deem their journey more convenient and less stressful.

Scenario 1: For this scenario, a carrier which does not offer a codeshare product in the market is assumed to settle a codeshare deal with an American carrier in both directions. For this scenario, Qatar Airways (QR) signs off a codeshare deal that enables the carrier to offer direct non-operating services in both directions with 45 seats available on each route. The codeshare flight is scheduled to depart LAS at 10 am local time in the morning and arrive MIA at 19:45 local time. On the other direction, the codeshare flight of the QR leaves MIA at 19:30 local time and arrives in LAS at 21:30 local time. The tables below show the airline, routing, weekly frequency (f), weekly seat supply (s), adjusted seat share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) of the competing carriers including QR's brand new non-operating flight in the LAS – MIA market and MIA – LAS markets respectively.

Table 11.33: Parameters for LAS–MIA Market as of 2016 Schedule Including QR Flight

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AY	Direct	3	144	1.56%	0.8754	1.62%
BA	Direct	28	1393	35.27%	0.9273	38.70%
IB	Direct	14	721	18.25%	0.9060	19.56%
QR	Direct	7	315	7.98%	0.9362	8.84%
AF	Connecting	26	246	6.23%	0.7269	5.36%
AY	Connecting	5	48	0.87%	0.5783	0.60%
AZ	Connecting	9	82	2.07%	0.6982	1.71%
BA	Connecting	64	625	15.84%	0.7019	13.16%
EI	Connecting	4	32	0.46%	0.7281	0.40%
EY	Connecting	7	67	1.70%	0.7747	1.56%
KL	Connecting	31	288	7.30%	0.7594	6.56%
SK	Connecting	6	53	0.77%	0.6925	0.63%
TP	Connecting	8	78	1.69%	0.6592	1.32%

It is observed in the table that, the new non-operating QR flight is estimated to be the best schedule quality product in the market and is expected to gain 8.84% ms. It is also observed in the table that the $q_{a\_index\_normalised}$ of the competing carriers are identical to base status as the new joined QR flight does not offer the shortest t_{total} of the available itineraries in the market. Since $q_{a\_index\_normalised}$ is computed in reference to the lowest total journey time for direct and connecting services separately, QR's t_{total} which is not the smallest in the market keep $q_{a\_index\_normalised}$ intact for the competing carriers. In LAS – MIA route, among the listed carriers, the shortest t_{total} belongs to IB for direct flights, with 4 hours and 49 minutes while it is 5 hours for QR. The following table summarises the same parameters in the reverse direction.

Table 11.34 Parameters in the MIA–LAS market as of 2016 schedule

Airline	Routing	f	s	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AB	Direct	7	393	8.03%	0.9234	8.66%
BA	Direct	28	1393	28.46%	0.9451	31.41%
IB	Direct	21	1057	21.59%	0.9406	23.71%
QR	Direct	7	315	6.44%	0.9690	7.29%
AF	Connecting	23	230	4.70%	0.7435	4.08%
AZ	Connecting	14	134	2.75%	0.6779	2.18%
BA	Connecting	74	743	15.19%	0.7168	12.71%
EI	Connecting	1	9	0.11%	0.5432	0.07%
EY	Connecting	21	221	4.51%	0.6091	3.21%
KL	Connecting	35	324	6.62%	0.7243	5.60%
RJ	Connecting	4	38	0.45%	0.5331	0.28%
SK	Connecting	9	82	0.72%	0.5924	0.50%
TP	Connecting	4	37	0.43%	0.6131	0.31%

It is inferred from the table that, $q_{a\_index\_normalised}$ scores for direct service carriers (AB, BA and IB) have slightly dropped. This is due to newly added QR flight which offers the shortest t_{total} in the market among the listed carriers. While t_{total} of QR is 5 hours, the following shortest itinerary belongs to BA and IB with 5 hours and 4 minutes. QR is again calculated to offer the best schedule quality score in the market and is expected to gain 7.29% of the market despite its 6.44% adjusted seat share.

Scenario 2: In this scenario, the codeshare agreement of QR is cancelled and the buffer time request of passengers is reduced from 30 minutes to 10 minutes. Such an adjustment implies that passengers need less additional time on top of the MCT to make their journeys less stressful and more convenient. The below tables summarises the $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms parameters under the new t_{buffer} in each direction and includes the comparison with the base status.

Table 11.35: Parameters for LAS–MIA Market as of 2016 Schedule Under t_{buffer} = 10 Minutes Assumption

Airline	Routing	Scenario 2			Base Status		
		$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AY	Direct	1.70%	0.8754	1.79%	1.70%	0.8754	1.78%
BA	Direct	38.33%	0.9273	42.84%	38.33%	0.9273	42.45%
IB	Direct	19.84%	0.9060	21.67%	19.84%	0.9060	21.47%
AF	Connecting	6.77%	0.6990	5.70%	6.77%	0.7269	5.88%
AY	Connecting	0.94%	0.5554	0.63%	0.94%	0.5783	0.65%
AZ	Connecting	2.25%	0.6688	1.81%	2.25%	0.6982	1.88%
BA	Connecting	17.22%	0.6953	14.43%	17.22%	0.7019	14.43%
EI	Connecting	0.50%	0.7001	0.42%	0.50%	0.7281	0.43%
EY	Connecting	1.85%	0.7454	1.66%	1.85%	0.7747	1.71%
KL	Connecting	7.93%	0.7253	6.93%	7.93%	0.7594	7.19%
SK	Connecting	0.83%	0.6648	0.67%	0.83%	0.6925	0.69%
TP	Connecting	1.84%	0.6455	1.43%	1.84%	0.6592	1.45%

Table 11.36: Parameters for MIA - LAS Market as of 2016 Schedule under t_{buffer} = 10 Minutes assumption

Airline	Routing	Scenario 2			Base Status		
		$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
AB	Direct	8.58%	0.9361	9.46%	8.58%	0.9361	9.37%
BA	Direct	30.42%	0.9581	34.33%	30.42%	0.9581	34.01%
IB	Direct	23.08%	0.9535	25.92%	23.08%	0.9535	25.68%
AF	Connecting	5.03%	0.7248	4.29%	5.03%	0.7435	4.36%
AZ	Connecting	2.94%	0.6553	2.27%	2.94%	0.6779	2.33%
BA	Connecting	16.24%	0.6967	13.33%	16.24%	0.7168	13.59%
EI	Connecting	0.12%	0.5236	0.07%	0.12%	0.5432	0.08%
EY	Connecting	4.83%	0.5899	3.36%	4.83%	0.6091	3.43%
KL	Connecting	7.08%	0.6990	5.83%	7.08%	0.7243	5.98%
RJ	Connecting	0.48%	0.5170	0.29%	0.48%	0.5331	0.30%
SK	Connecting	0.77%	0.5730	0.52%	0.77%	0.5924	0.53%
TP	Connecting	0.46%	0.5937	0.32%	0.46%	0.6131	0.33%

Table 11.36 and 11.36 suggest that decreasing t_{buffer} does not impact the adjusted seat share and quality scores for direct services as the parameter is only concerned with the connecting itineraries. Furthermore, it does not affect $\%_{a\_s}$ for connecting services too as the criteria of being a valid hit is not concerned with the t_{buffer} but related with the MCT and the MaxCT. The reduction of t_{buffer} to 10 minutes is expected to change the quality scores of the connecting products depending on the MCT surplus figures of the itineraries. The adjusted quality score of the carriers would increase in case the stress time would fall due to the reduction with the t_{buffer}. Since t_{buffer} is set to 10 minutes, it is now impossible for carriers to report a stress time greater than 10 minutes. On the other hand, $q_{a\_index\_normalised}$ would decrease for the carriers whose waste time at the hub airport would increase due to the reduction of the t_{buffer}. For instance, an itinerary having 1 hour of MCT surplus time would have the waste time of 30 minutes under t_{buffer} = 30 minutes. The reduction of t_{buffer} to 10 minutes would increase the waste time of this itinerary to 50 minutes which has a negative effect on passenger convenience and thus the $q_{a\_index\_normalised}$ score. For this scenario, all connecting service providers' adjusted indexed quality score dropped after the reduction of t_{buffer} as the waste time of the itineraries has increased.

Implementing Mann-Whitney tests on the $q_{a\_index\_normalised}$ scores of the carriers for base status and scenario results, offering connecting products for both directions, a p value of 0.008 is calculated. Therefore, reducing t_{buffer} by 20 minutes would have a statistically significant effect on the schedule convenience scores of the competing connecting carriers in the LAS/MIA market. Although a reduction in the buffer time request does have a statistically significant effect on the quality scores of the connecting carriers, it is deduced from the tables that, it had a limited effect on market share estimation of the carriers. Implementing paired proportion test on the market share estimations of all carriers present in the route, a p value of 0.866 is observed implying insignificance with respect to the base status. As direct service operators dominate the market in terms of supply and their quality scores are unchanged in response to reduced t_{buffer}, observing a statistically insignificant change with the market share results is not unexpected. The ms change was positive for all direct service operators as the relative quality of connecting services worsened in comparison to the base case due to the longer waste time. The minor change in the ms estimation should not infer that t_{buffer} does not have a big effect on the market share estimation. t_{buffer}'s influence on ms might have been higher under different circumstances. Along with the absolute value of the t_{buffer}, parameters such as the number of competing airlines, their seat supply and MCT surplus figures shape the magnitude impact of t_{buffer} on the ms either positively or negatively depending on the specific conditions of the itinerary.

This first scenario of this case has shown that the effectiveness of an additional codeshare agreement can be analysed quantitatively in terms of the research outputs: $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms, fulfilling Objective 1, 2 and 3 of the research. Being able to assess these outputs offers an indispensable tool for airline planners in the sense that they could maximise the benefits of their codeshare agreements referring to the accomplishment of Objective 4. Furthermore, the second scenario demonstrated the effect of t_{buffer} on the quality scores and market share forecasts, further crediting the contentment of the research objectives.

11.2.9. Case 9: Portugal/Serbia:

The base case has shown that there existed no direct services between Portugal and Serbia and the home carrier of Portugal (TP) lacked service in the market. The first scenario of this case introduces a direct daily flight of TP between Lisbon and Belgrade with a narrow-body aircraft having 180 seats while the second case involves the upgrade of the aircraft type for the newly added flight from a narrow body to a wide-body jet having 300 seats.

Scenario 1: In this scenario, TAP Portugal Airlines (TP) places daily flights between Lisbon (LIS) and Belgrade (BEG) with a narrow-body aircraft having 180 seats. The flight leaves LIS at 07:30 am Portuguese local time and arrives to BEG at 11:40 am Serbian local time. After 80 minutes of ground time, the aircraft departs from BEG at 13:00 pm local time and arrives in LIS at 15:15 pm local time. The following table summarizes the routing, total weekly frequency (f), seat supply (s), seat share ($\%_s$), adjusted capacity share ($\%_{a\_s}$), adjusted normalised quality index ($q_{a\_index\_normalised}$) and market share estimation (ms) from Portugal to Serbia and Serbia to Portugal as of 2016 schedule data including the newly added flight of TP.

Table 11.37: Parameters from Portugal to Serbia as of 2016 Schedule Data Including TP Service.

Airline	Routing	f	s	$\%_s$	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
TP	Direct	7	1260	43.62%	47.08%	1.2815	62.30%
AB	Connecting	2	15	0.53%	0.16%	0.5422	0.09%
AZ	Connecting	11	97	3.37%	2.08%	0.6667	1.43%
EY	Connecting	25	196	6.77%	7.31%	0.5982	4.51%
IB	Connecting	1	10	0.35%	0.05%	0.7591	0.04%
KL	Connecting	11	84	2.92%	3.16%	0.5991	1.95%
LH	Connecting	27	621	21.51%	23.21%	0.7360	17.64%
LX	Connecting	4	43	1.50%	0.69%	0.5571	0.40%
OS	Connecting	6	58	2.02%	1.87%	0.5968	1.15%
SK	Connecting	16	141	4.87%	5.26%	0.5450	2.96%
TP	Connecting	7	197	6.81%	7.35%	0.7951	6.04%
U2	Connecting	5	166	5.73%	1.77%	0.8153	1.49%
Total		122	2888	100%	100%	--	100%

It is observed in the table that; the new direct flight of TP is estimated to receive 62.30% of the market from Portugal to Serbia. On the other hand, TP's addition of direct flights from LIS to BEG led some connecting traffic to occur from Portugal to Serbia as the domestic flights of Portugal could be connected to this new flight. For instance, TP1921 leaving Porto and arriving in Lisbon is connected to the new flight and offered a product from Porto to Belgrade. The connecting services of TP which are created due to the addition of the virtual LIS–BEG direct flight are estimated to obtain 6.04% of the market. Therefore, by inserting one direct flight, TP is expected to get 68.04% of the entire traffic from Portugal to Serbia. The following table summarises the same parameters on the reverse (Serbia-Portugal) direction.

Table 11.38: Parameters for the Serbia-Portugal Route as of 2016 Schedule Data Including TP Service.

Airline	Routing	f	s	$\%_s$	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
TP	Direct	7	1260	38.27%	40.17%	1.2987	55.88%
AB	Connecting	3	23	0.70%	0.21%	0.5144	0.12%
AF	Connecting	7	65	1.98%	2.08%	0.6327	1.41%
AZ	Connecting	10	78	2.36%	1.42%	0.6977	1.06%
EY	Connecting	16	134	4.08%	4.28%	0.5447	2.50%
KL	Connecting	7	54	1.63%	1.71%	0.5064	0.93%
LH	Connecting	38	739	22.46%	23.57%	0.7167	18.08%
LX	Connecting	20	300	9.11%	9.56%	0.7221	7.40%
OS	Connecting	2	34	1.02%	0.15%	0.7182	0.11%
SK	Connecting	28	262	7.96%	8.36%	0.5724	5.12%
TP	Connecting	7	209	6.34%	6.66%	0.7890	5.63%
U2	Connecting	4	134	4.08%	1.84%	0.8926	1.76%
Total		149	3292	100%	100%	--	100%

It is observed in the table that the TP's direct service is estimated to receive 55.88% of the market while the connecting products formed through the addition of this direct flight is forecasted to obtain 5.63% of the market. Therefore, TP's flight made the airline to obtain 61.51% of the traffic from Serbia to Portugal. The following table summarises the bidirectional market share estimation of this scenario calculated by averaging each direction's ms values. The table also compares the computed figures with the base status.

Table 11.39: Bidirectional Market Shares in Portugal/Serbia Bidirectional Market

	ms for Scenario 1	Base Case ms
TP (direct)	59.09%	N/A
AB (connect)	0.11%	0.31%
AF (connect)	0.70%	1.62%
AZ (connect)	1.25%	3.54%
EY (connect)	3.50%	10.12%
IB (connect)	0.02%	0.07%
KL (connect)	1.44%	5.04%
LH (connect)	17.86%	50.64%
LX (connect)	3.90%	11.23%
OS (connect)	0.63%	1.95%
SK (connect)	4.04%	10.67%
TP (connect)	5.84%	N/A
U2 (connect)	1.62%	4.81%

Table 11.39 shows the bidirectional market share estimation in the Serbia/Portugal market where the newly added frequency of TP leads the carrier to get 59.09% + 5.84% = 64.93% of the market through direct and connecting itineraries. Therefore, the addition of a single frequency by TP would yield the carrier to expect a very high market share. This is indeed a critical finding for the industry practitioners that refers to the accomplishment of Objective 4 of the research. Additionally, being able to track the whole airlines' consumer-centric capacity, schedule quality score and market share estimations after the addition of TP flights is a clear accomplishment of Objective 1, 2 and 3.

Scenario 2: The previous case has analysed the changing market dynamics after the insertion of daily TP flight with a narrow-body aircraft having 180 seats. In this scenario, TP's additional flight is upgraded to a wide-body aircraft having 300 seats while all other parameters including the departure and arrival times as well as the daily operation scheme are kept intact. The following table summarises the bidirectional market share estimation of this scenario calculated by averaging each route's ms values given the wide-body operation of TP. The table also compares the figures with the base status and scenario 1.

Table 11.40: Bidirectional Market Shares in Portugal/Serbia Bidirectional Market

	ms for Scenario 2	ms for Scenario 1	Base Case ms
TP (direct)	70.61%	59.09%	N/A
AB (connect)	0.07%	0.11%	0.31%
AF (connect)	0.51%	0.70%	1.62%
AZ (connect)	0.89%	1.25%	3.54%
EY (connect)	2.51%	3.50%	10.12%
IB (connect)	0.01%	0.02%	0.07%
KL (connect)	1.03%	1.44%	5.04%
LH (connect)	12.82%	17.86%	50.64%
LX (connect)	2.84%	3.90%	11.23%
OS (connect)	0.45%	0.63%	1.95%
SK (connect)	2.92%	4.04%	10.67%
TP (connect)	4.18%	5.84%	N/A
U2 (connect)	1.16%	1.62%	4.81%

It is observed in the table that, the upgrade of TP's direct services from a 180-seat narrow-body aircraft to 300-seat jet leads the ms of the carrier to increase from 59.09% to 70.61%. Although the per cent rise in the seat capacity is (300-180)/180 = 66.66% daily and weekly (as the flight is operated daily), the rise in the market share expectation is only limited to (70.61-59.09)/59.09 = 19.5% which is significantly less than 66.66%. Therefore, this scenario confirms that the return on capacity investment in terms of market share estimation is not proportional to the supply affirming the S curve principle mentioned in the literature review.

The scenarios of this case have demonstrated that the research methodologies can be implemented for different scenarios at the country-to-country market level. Being able to numerically assess the effect of a direct service insertion on the market dynamics accomplished Objective 1 (as the new capacity shares of the competing carriers were calculated) and Objective 3 (as the ms figures were successfully retrieved). Moreover, Objective 4 was also achieved as the methodology offered a distinctive tool for industry experts to review the market scheme at a broader level.

11.2.10. Case 10: The United Kingdom / Israel:

The base case has shown that multiple airlines competed through their direct and connecting services between the UK and Israel. While direct service operators, British Airways (BA), El – Al Israel Airlines (LY) and Easyjet (U2) composed a significant portion of the market, more than 16 airlines in each route competed for the remaining shares via their connecting products.

Scenario 1 & 2: The first scenario of this case increases the connecting seat factor, s_{conn}, from 20% to 100% implying that all seats of a flight can be allotted to connecting itineraries while the second scenario reduces the same parameter to 5%. $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms of the competing carriers for both directions are displayed in the table below.

Table 11.41: ms Expectations at the Routing and Market Breakdown in the UK/Israel Market as of 2016 Schedule Data for Scenario 1 (s_{conn} = 100%) and Scenario 2 (s_{conn} = 5%).

		Scenario 1 (s_{conn} = 100%)		Scenario 2 (s_{conn} = 5%)		Base Status (s_{conn} = 20%)	
		$\%_{a\_s}$	ms	$\%_{a\_s}$	ms	$\%_{a\_s}$	ms
UK–Israel	Direct Flights	*18.70%*	*26.94%*	*82.14%*	*88.06%*	*53.49%*	*64.84%*
	BA	7.46%	10.87%	32.75%	35.54%	21.33%	26.17%
	LY	6.08%	8.79%	26.72%	28.71%	17.40%	21.14%
	U2	5.16%	7.28%	22.67%	23.81%	14.76%	17.53%
	Connecting Flights	*81.30%*	*73.06%*	*17.86%*	*11.94%*	*46.51%*	*34.17%*
	TK	17.36%	15.22%	3.81%	2.49%	9.93%	7.32%
	LH	11.81%	11.63%	2.59%	1.90%	6.76%	5.60%
	PC	7.99%	7.17%	1.75%	1.17%	4.57%	3.45%
	LX	6.67%	6.93%	1.46%	1.13%	3.81%	3.34%
	OS	5.54%	4.46%	1.22%	0.73%	3.17%	2.15%
	Other 12 carriers	31.93%	27.65%	7.03%	4.52%	18.27%	12.31%
Israel–UK	Direct Flights	*16.70%*	*24.82%*	*80.04%*	*86.85%*	*50.06%*	*62.28%*
	BA	6.66%	10.03%	31.92%	35.10%	19.96%	25.17%
	LY	5.43%	8.02%	26.03%	28.06%	16.28%	20.12%
	U2	4.61%	6.77%	22.09%	23.69%	13.82%	16.99%
	Connecting Flights	*83.30%*	*75.18%*	*19.96%*	*13.15%*	*49.94%*	*37.72%*
	TK	15.58%	13.37%	3.73%	2.34%	9.34%	6.71%
	LH	10.29%	9.00%	2.47%	1.57%	6.17%	4.52%
	PC	6.75%	5.82%	1.62%	1.02%	4.05%	2.92%
	OS	4.95%	5.76%	1.18%	1.01%	2.96%	2.89%
	BA	5.34%	4.76%	1.28%	0.63%	3.20%	2.39%
	Other 13 carriers	40.39%	36.47%	9.68%	6.58%	24.22%	18.29%

Table 11.41 proves that depending on the s_{conn} value, the adjusted seat share and market share expectations of the carriers change significantly especially for a market like UK/Israel where a vast number of connecting products compete. As the s_{conn} drops, direct service providers dominate the market and obtain further additional market shares. The following table illustrates the bidirectional adjusted seat shares and market share estimations obtained by averaging the directional results.

Table 11.42 Bidirectional Adjusted Seat Share and Market Share Estimation as of 2016

	Scenario 1 (s_{conn} = 100%)		Scenario 2 (s_{conn} = 5%)		Scenario 2 (s_{conn} = 20%)	
	$\%_{a\_s}$	ms	$\%_{a\_s}$	Ms	$\%_{a\_s}$	ms
Direct	17.70%	25.88%	81.09%	87.55%	51.78%	64.05%
Connecting	82.30%	74.12%	18.91%	12.45%	48.22%	35.95%

As per the MIDT data, slightly more than 68% of the entire UK/Israel market was owned by the direct service providers while connecting products served the remaining 32%. As per the above results in Table 11.42, setting s_{conn} to 100%, the market share estimation for direct service carriers are calculated as 17.7% while the figure is 81.09% in case s_{conn} is set to 5%. The real market share of the direct service operators are 68% which is accurately estimated as 64.05% assuming s_{conn} to be 20%. Therefore, it can be concluded that the base case reported a closer market share estimation to the actual figures in comparison to scenario 1 and scenario 2, crediting the s_{conn} = 20% assumption in comparison to s_{conn} = 100% and s_{conn} = 5% assumptions. However, the scenarios of this case have successfully shown the impact of s_{conn} on $\%_{a\_s}$ and ms, fulfilling Objective 1, 3 and 4 of the research.

11.2.11. Case 11: Italy / Italy:

The base case has studied the Italian domestic direct market and addressed that many non-Italian carriers competed in the market through their non-operating services. The scenarios of this case analyse the changing market dynamics in codeshare operations which forms an integral aspect of the Italian domestic market.

Scenario 1: The first scenario of the case entirely cancels the codeshare agreements by setting s_{code} to 0%. Therefore any carriers lacking physical domestic flights within Italy are excluded from the competition. The following table summarises the frequency, seat count and market share expectations of the competing carriers under s_{code} = 0% assumption along with a comparison with the base case.

Table 11.43: Weekly Frequency, Seat Count and Market Share Estimation of Scenario 1

	Scenario 1			Base Status		
	f	s	ms	f	s	ms
AZ	2,610	347,203	53.54%	2,610	347,203	42.96%
FR	1,264	238,896	36.83%	1,264	238,896	29.59%
U2	388	62,448	9.63%	388	62,448	7.75%
Others	0	0	0	4,916	218,228	19.70%
Total	4,262	648,547	100%	9,178	866,775	100%

Table 11.43 suggests that the whole capacity available for sale in the market would be equal to the physical capacity under s_{code} = 0 assumption. Therefore, the elimination of the codeshare agreements enables Alitalia (AZ), Ryanair (FR) and Easyjet (U2) to obtain the entire Italian domestic market where AZ is estimated to hold more than half of the market. Compared to the base case, the elimination of codeshare operations increases AZ's ms by 10.58 points while the figure is calculated to be 7.24 points for FR and 1.88 for U2.

Scenario 2: The second scenario enables the full capacity of the operating carrier to be sold by the marketing airline which is achieved by setting s_{code} to 100%. The following table summarises the frequency, seat supply and market share estimation figures under s_{code} = 100% assumption, compared again with the base status.

Table 11.44: Weekly Frequency, Seat Count and Market Share Estimation of Scenario 1

	Scenario 2			Base Status		
	f	s	ms	f	s	ms
AZ	2,610	347,203	16.96%	2,610	347,203	42.96%
FR	1,264	238,896	8.03%	1,264	238,896	29.59%
U2	388	62,448	0.55%	388	62,448	7.75%
Others	4,916	727,429	74.46%	4,916	218,228	19.70%
Total	9,178	1,375,976	100%	9,178	866,775	100%

Enabling marketing carriers to sell the entire capacity of the operating airline enormously enhances the total weekly capacity available for sale above 1.3 million, despite the physical seat capacity of 648,547. On the other hand, the sum of market share estimation for the operating service providers (AZ, FR and U2) is expected to fall from 80.30% to 25.54%.

As per the MIDT data, as of 2016, slightly above 85% of the Italian domestic market was owned by AZ, FR, U2 and Meridiana Airlines. (Meridiana is not a listed carrier.) As the methodology assumed s_{code} to be 30% by default, and the sum of AZ's, FR's and U2's ms is computed to be 80.30% excluding Meridiana's shares, it can be inferred that s_{code} = 30% is a credible assumption justified by the MIDT results. Being able to assess the change in the airlines' ms values under different s_{code} assumptions, is a clear achievement of Objective 1 and 3. Moreover, the scenarios of this case have demonstrated the impact of codeshare seat factor on market dynamics, offering an essential decision-support tool for the industry practitioners, fulfilling Objective 4.

11.2.12. Case 12: Turkey / Turkey:

The base case has studied direct domestic Turkish market and demonstrated that unlike the Italian case, it was less open to competition in terms of codeshare agreements. The following scenarios investigate the variations with the ms in case the adjusted indexed quality scores of some carriers were altered.

Scenario 1: In this scenario, it is assumed that the codeshare operators ameliorate their adjusted index quality scores by 10% while all other supply related parameters remain intact. The increase with the adjusted index quality score could be achieved through several methods such as changing the timetable of the flights, shortening journey times or assuming a higher value perception concerning the codeshare flights (u_{dc}). Therefore, $q_{a\_index\_normalised}$ figures of Air Berlin (AB), SAS Scandinavian Airlines (SK), Austrian Airlines (AT) and TAP Portugal (TP) were escalated by 10%. Turkish Airlines' (TK) and Pegasus Airlines' (PC) $q_{a\_index\_normalised}$ are assumed to remain unchanged. The following table summarises the weekly frequency, seat supply, former and ameliorated indexed quality scores and market share estimations compared with the base case.

Table 11.45: The Parameters for the Turkish Domestic Market for Each Airline as of 2016 Schedule Information, Their Market Share Estimation and the Comparison with the Base Status

	Scenario 1				Base Status			
	f	s	$q_{a\_index\_normalised}$	ms	f	s	$q_{a\_index\_normalised}$	ms
TK	4,171	721,283	1.2941	64.88%	4,171	721,283	1.2941	65.04%
PC	1,923	359,721	1.2988	32.48%	1,923	359,721	1.2988	32.56%
AB	255	14,234	1.0363	1.03%	255	14,234	0.9421	0.93%
SK	287	15,047	1.0286	1.08%	287	15,047	0.9351	0.98%
AT	70	3,742	1.0451	0.27%	70	3,742	0.9501	0.25%
TP	63	3,646	1.0229	0.26%	63	3,646	0.9299	0.24%
Total	6,769	1,117,673	--	100.00%	6,769	1,117,673	--	100.00%

It is observed in the table that, as the $q_{a\_index\_normalised}$ scores of the carriers increased, so did the market share estimations of the codeshare operators by taking away from the shares of the operating carriers. While in the base case, the total sum of market share estimations for codeshare operators, AB, SK, AT and TP, was equal to 2.40%, a 10% increase with the $q_{a\_index\_normalised}$ score enabled these airlines to increase their market share estimation to 2.64%, contributing to 0.24 points increase or 10% surge in the estimated market share. Therefore, a 10% rise in the quality scores of the marketing carriers contributed to their ms sum by 10% proportionally.

Scenario 2: The second scenario of the case recovers the $q_{a\_index\_normalised}$ scores of the codeshare operators to their original values but decreases the operating airlines' $q_{a\_index\_normalised}$ scores by 10% and keeps all the remaining supply related parameters intact. Therefore only Turkish Airlines (TK) and Pegasus Airlines (PC) quality scores were affected under in this scenario. The reduction of the adjusted normalised quality scores for the operating services might have happened due to various reasons like a worse timetable or consumers' decreasing value perception towards direct and operating services (u_{dc}). The table below depicts the frequency, seat count and $q_{a\_index\_normalised}$ scores for Scenario 2 and its comparison with the base case.

Table 11.46: Parameters for Scenario 2 for Turkish Domestic Market as of 2016 Compared with the Base Case

	Scenario 2				Base Status			
	f	s	$q_{a\_index\_normalised}$	ms	f	s	$q_{a\_index\_normalised}$	ms
TK	4,171	721,283	1.1647	64.87%	4,171	721,283	1.2941	65.04%
PC	1,923	359,721	1.1689	32.47%	1,923	359,721	1.2988	32.56%
AB	255	14,234	0.9421	1.04%	255	14,234	0.9421	0.93%
SK	287	15,047	0.9351	1.09%	287	15,047	0.9351	0.98%
AT	70	3,742	0.9501	0.27%	70	3,742	0.9501	0.25%
TP	63	3,646	0.9299	0.26%	63	3,646	0.9299	0.24%
Total	6,769	1,117,673	--	100.00%	6,769	1,117,673	--	100.00%

Table 11.46 suggests that a 10% reduction in the adjusted index quality score of the operating carriers led to a very slight decrease with the market share estimation of those carriers. Although the sum of TK's and PC's market share summed to 97.6% in the base case, the figure is reduced to 97.34% in this scenario, contributing to 0.26 points of drop, referring to 0.27% decline. Although the first scenario suggested that, 10% rise in the quality score increased the market share expectations of those carriers proportionally by 10%, the second scenario proved that 10% drop in $q_{a\_index\_normalised}$ scores for operating carriers did not lead a similar and proportional 10% drop with the ms due to the overwhelming capacity of the direct services. It is also observed in Tables 11.45 and 11.46 that, the market share estimations of the carriers are almost identical in the first and second scenarios. Therefore it is implied that a 10% rise in the $q_{a\_index\_normalised}$ scores for codeshare operators produced the same market share estimation results where the $q_{a\_index\_normalised}$ scores of operating carriers were reduced by 10%.

The scenarios of this case have shown the impact of changing the adjusted indexed quality scores on the market share estimation, accomplishing Objective 3 of the research. Having such a powerful tool enables airline executives to review the schedule quality and the competitiveness of their product among rivals – a fulfilment of Objective 4.

11.2.13. Case 13: Canada/Pakistan vs Canada/India:

The base case has contrasted the competition level in Pakistan (PK) and India (IN) by analysing both countries market structure to/from Canada where only connecting products existed for the listed carriers. The first scenario of this case involves the cancellation of a carriers' entire products from/to Canada (CA) to observe the change in market structure in the aftermath of an airlines' withdrawal. The second scenario assumes a different connecting journey flight time split ratio to observe the factors' impact on the competing airlines' quality score.

Scenario 1: In this scenario, Turkish Airlines (TK) cancels all of its flights to Canada and therefore loses all connections in the Canada/Pakistan and Canada/India markets. The following table summarises the $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms of the scenario along with a comparison with the base status for Pakistan (PK) and India (IN) respectively.

Table 11.47: Listed Parameters of Competing Carriers from Canada to Pakistan and Pakistan to Canada as of 2016

		Scenario			Base Status		
	Airline	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
CA – PK	EK	46.34%	0.9761	47.49%	20.97%	0.9428	21.10%
	EY	20.07%	0.9606	20.24%	9.12%	0.9259	9.02%
	QR	33.59%	0.9152	32.28%	15.18%	0.8827	14.31%
	TK	0.00%	--	0.00%	54.73%	0.9511	55.57%
	Total	100%	--	100.00%	100%	--	100.00%
PK – CA	EK	34.28%	0.9414	34.02%	13.16%	0.9414	13.36%
	EY	32.57%	0.9525	32.70%	12.50%	0.9525	12.84%
	QR	23.43%	0.9193	22.70%	8.98%	0.9193	8.90%
	SV	9.71%	1.0339	10.58%	1.25%	1.0339	1.39%
	TK	0.00%	--	0.00%	64.11%	0.9187	63.50%
	Total	100.00%	--	100.00%	100.00%	--	100.00%

TK's removal from the market enabled Emirates (EK) to lead the market with a 47.53% market share expectation from Canada to Pakistan and 34.02% on the route back. It is also observed that the adjusted index quality score of all carriers have improved slightly from Canada to Pakistan. Because TK was the shortest itinerary offering carrier in the CA-PK market, the removal of the carrier from the market made EK's duration shortest and the other carriers' $q_{a\_index\_normalised}$ scores were computed referencing to the EK's journey time index. In the PK – CA market, since QR offered the shortest product, the removal of TK from the market did not change the $q_{a\_index\_normalised}$ scores of the competing airlines. The following table displays the same analysis in the Canada/India market.

Table 11.48: Listed Parameters of Competing Carriers from Canada to India and India to Canada as of 2016

		Scenario 1			Base Status		
		$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms	$\%_{a\_s}$	$q_{a\_index\_normalised}$	ms
Canada – India	LH	38.88%	0.8692	38.48%	35.05%	0.8692	34.95%
	BA	20.47%	0.9191	21.43%	18.46%	0.9191	19.47%
	AF	12.41%	0.9833	13.90%	11.19%	0.9833	12.62%
	TK	0.00%	--	0.00%	9.84%	0.8128	9.18%
	KL	9.25%	0.7756	8.17%	8.34%	0.7756	7.43%
	SK	6.69%	0.7385	5.62%	6.03%	0.7385	5.11%
	LX	5.60%	0.8806	5.62%	5.05%	0.8806	5.10%
	EK	1.91%	0.9463	2.06%	1.72%	0.9463	1.87%
	EY	1.49%	0.9597	1.62%	1.34%	0.9597	1.47%
	Other 3	3.29%	--	3.10%	2.97%	--	2.80%
	Total	100%	--	100%	100%	--	100%
India – Canada	BA	22.90%	0.9497	24.74%	20.52%	0.9497	21.97%
	LH	23.19%	0.8129	21.45%	20.78%	0.8129	19.04%
	KL	18.89%	0.8784	18.87%	16.92%	0.8784	16.75%
	AF	12.70%	0.9317	13.46%	11.38%	0.9317	11.95%
	TK	0.00%	--	0.00%	10.41%	0.9553	11.21%
	SK	5.54%	0.7797	4.91%	4.96%	0.7797	4.36%
	IB	4.81%	0.7518	4.11%	4.31%	0.7518	3.66%
	EK	2.88%	0.9341	3.06%	2.58%	0.9341	2.71%
	EY	2.23%	1.0292	2.61%	2.00%	1.0292	2.32%
	Other 3	6.85%	--	6.78%	6.14%	--	6.03%
	Total	100%	--	100%	100%	--	100%

It is inferred from the above table that, the impact of TK's removal from the market has increased the market share expectation of all carriers competing in the Canada/India market. However, the surge in the ms expectation of the airlines is not vast compared to Canada/Pakistan market as there exist more players in the Indian market. Furthermore, the quality scores of the carriers were unchanged as TK did not offer the shortest itinerary in both directions.

Scenario 2: In this scenario, TK's flight to Canada are recovered back and the connecting journey flight time split ratio ($\%_{q\_split}$) is changed from 80% to 50%. Such a change implies that in case one leg of the journey is greater than or equal to 50% of t_{total}, the itinerary qualifies for an additional quality score (q_{split}). Practically, setting $\%_{q\_split}$ to 50% enables all connecting itineraries to qualify for q_{split} as at least one leg of the connecting itinerary is longer than or equal to 50% of the total flight time. The following table analyses the adjusted indexed quality scores and the market share estimations of this scenario for Canada/Pakistan market.

Table 11.49: Listed Parameters of Competing Carriers from Canada to Pakistan and Pakistan to Canada as of 2016

	Airline	Scenario		Base Status	
		$q_{a\_index\_normalised}$	ms	$q_{a\_index\_normalised}$	ms
CA – PK	EK	0.9428	20.84%	0.9428	21.10%
	EY	0.9354	8.99%	0.9259	9.02%
	QR	0.8935	14.30%	0.8827	14.31%
	TK	0.9683	55.87%	0.9511	55.57%
	Total	--	100.00%	--	100.00%
PK – CA	EK	0.9414	13.18%	0.9414	13.36%
	EY	0.9648	12.84%	0.9525	12.84%
	QR	0.9305	8.89%	0.9193	8.90%
	SV	1.0513	1.39%	1.0339	1.39%
	TK	0.9338	63.69%	0.9187	63.50%
	Total	--	100.00%	--	100.00%

As per the table above, although the adjusted index quality score of EK is unchanged, EY's, QR's and TK's $q_{a\_index\_normalised}$ scores improved slightly. The minor change with the quality scores led EY, QR and TK to report marginally higher ms scores in comparison to the base status. It is also observed in the table that only TK has managed to increase its market share estimation under the new $\%_{q\_split}$ assumption.

The scenarios of this case showed the impact of the research outputs in the aftermath of a carriers' exit from the market (Scenario 1) and the decrease of $\%_{q\_split}$ from 80% to 50% (Scenario 2) – serving as the fulfilment of Objective 2 and 3. Being able to observe such variations in the market quantitatively also proved the accomplishment of Objective 4 as a significant guidance is offered for industry practitioners.

11.2.14. Case 14: South America – Middle East:

The final case evaluates a directional market at the regional level, namely from South America to the Middle East. Since the case covers a broader range of available products competing in the market, a scenario having a wider assumption is introduced: All direct service providers' seat capacities are raised by 10% whereas all connecting carriers' seat capacities are reduced by 10%. The frequency and timetable of the flights are kept identical to the base case. The following table summarises the parameters under this assumption.

Table 11.50: Selected Parameters from South America to the Middle East as of 2016 Schedules

		Scenario			Base Status		
Airline	Routing	s	$\%_{a\_s}$	ms	s	$\%_{a\_s}$	ms
EK	Direct	6,160	28.43%	32.89%	5,600	25.51%	30.32%
EY	Direct	2,664	12.36%	14.70%	2,422	11.03%	13.48%
QR	Direct	1,994	9.18%	10.73%	1,813	8.26%	9.92%
AF	Connecting	2,068	9.53%	7.76%	2,298	10.47%	8.76%
LH	Connecting	1,614	7.43%	6.12%	1,793	8.17%	6.92%
EY	Connecting	1,328	6.09%	4.72%	1,475	6.72%	5.36%
KL	Connecting	1,155	5.30%	4.33%	1,283	5.84%	4.90%
EK	Connecting	1,008	5.62%	4.89%	1,120	5.10%	4.56%
QR	Connecting	761	3.49%	3.12%	846	3.85%	3.53%
AZ	Connecting	698	3.20%	2.56%	775	3.53%	2.91%
BA	Connecting	683	3.13%	2.40%	759	3.46%	2.73%
Others	Connecting	1,808	7.24%	5.78%	2,009	8.06%	6.61%
Total		21,941	100%	100%	22,193	100%	100%

According to Table 11.50, direct service provider airlines' market share estimation increased from 53.72% in the base case to 58.32%. The additional market share was transferred from connecting operators to direct service providers due to the relative increase of the adjusted seat share in favour of Etihad (EY), Emirates (EK) and Qatar Airways (QR). It is also observed that the total capacity in the market shrank by 1.13%. Despite the 10% growth with the direct seat capacity, the rise with the ms score of the direct carriers was summed to 4.60 points contributing to 8.56% (calculated as (58.32-53.72)/53.72). In other words, the per cent increase in the market share estimation was less than the per cent increase in capacity for the direct service operators. The supply changes worked best in favour of EK as the carriers' estimated market share increased from 30.32% to 32.89%. On the other hand, as expected, the ms figures for the connecting airlines have dropped in the region substantially. Being able to assess the macro level capacity changes' impact on ms, as achieved in this case, is an influential tool for airline executives in guiding their executive decisions, fulfilling Objective 3 and 4 of the research.

11.3. Discussion

In this Chapter, various scenarios were introduced for the cases addressed in Chapter 10. Each scenario of the cases built certain assumptions and analysed the results of the outputs involving supply, quality score and market share estimation. The assumptions included different schedule scenarios for particular carriers such as the addition of virtual flights or codeshare agreements as well as their removals from the timetable. Different capacity related parameters' impact on the research outputs were also assessed including aircraft type, s_{conn} and s_{code}. Besides, quality related input parameters were also parametrised in the scenarios to compute their quantitative effect on the research outputs. Some of these scenario results are statistically tested in comparison to the base status to comprehend the parameters' significance on the research outputs. While the change with the input parameters have reported significant differences with the research outputs in comparison to the base status, some cases have produced insignificant results. These findings imply that, any changes with the input parameters may lead to varying results specific to the markets and competition scheme. Furthermore, the statistical tests on certain cases (i.e. Case 10) have affirmed that, the base assumptions for certain parameters like s_{conn} were accurately set.

The adaptability of the consumer-centric capacity, schedule convenience and REMSET models successfully enabled to observe the deviations with the research outputs under different scenarios. This capability assisted to evaluate and justify the changing market dynamics and competition quantitatively. While some scenarios aided to fine-tune the results of the research methodology as addressed in Scenario 1 of Case 6, the scenarios of Case 10 and 11 proved that the adaptable research input assumptions discussed in Chapter 10 were accurate and in line with market realities. The reliable results of the scenarios discussed throughout this chapter also proved that the research objectives were accomplished under differing market situations. It was also confirmed that the inputs of the research model are adaptable – enabling industry experts to observe the results under varying market conditions.

The scenarios analysed in this Chapter showed that Objective 1, 2 and 3 were fulfilled under varying input parameters. The effect of any changes with s_{code}, s_{conn}, MCT, MaxCT, s_f, t_{buffer}, $\%_{q\_split}$ or $q_{a\_index\_normalised}$ as well as the schedule related variations could be assessed using the research's methodologies. Furthermore, the scenario analysis of the case studies has verified that being able to compare the results with the base case under different input parameter assumptions enabled to accomplish Objective 4 that can provide a unique commercial application for industry practitioners.

Chapter 12: Results - The Connectivity Analysis of the Selected Hubs

12.1. Introduction to the Connectivity Analysis Chapter

While Chapter 10 covered network performance results in the selected O&D pairs, Chapter 11 introduced scenarios on the same routes by altering the input parameters to observe the outputs' deviation from the base status. Unlike Chapter 10 and 11 which contrasted the airlines relative performance in terms of the research outputs in the selected O&Ds, namely, consumer-centric capacity, quality scores and realistic market share estimation, this Chapter aims to contrast the hub performance of the listed airlines with regard to schedule-convenience scores and frequency depth for connecting itineraries at a broader region-to-region level. Therefore, the Chapter assists in contrasting not only the airlines' connectivity quality but also their hub airports' attraction for the connecting passengers.

Certain airports were identified to run the research's models for testing their performance: Paris Charles De Gaulle – CDG (AF), Amsterdam Schiphol – AMS (KL), Brussels International – BRU (SN), London Heathrow – LHR (BA), Frankfurt International – FRA (LH), Munich International – MUC (LH), Zurich Kloten – ZRH (LX), Istanbul Ataturk – (TK), Istanbul Sabiha Gokcen – (PC), Dubai International – DXB (EK), Abu Dhabi International – AUH (EY), Vienna Schwechat – VIE (OS), Cairo International – CAI (MS) and Doha Hamed – DOH (QR). The airports were selected among the focus regions of the study. While determining the selected airports, major hubs in the Gulf region were chosen. Likewise, historically larger European hubs (i.e. AMS, LHR, FRA, MUC, CDG) and emerging transits (i.e. IST, SAW) were included into the set. Additionally, all of those selected airports serve as a hub for a listed carrier which is shown within the parenthesis following the three-letter code of the airport. Therefore, the analyses in this Chapter reflects not only the hub airports' performance but also the connection effectiveness of the airlines using these airports as their hub location.

12.2. Performance Results of the Hub Airports

Using the methodologies of the research, it is possible to benchmark the frequency share ($\%_f$) and adjusted normalised quality ($q_{a\_index\_normalised}$) scores of the selected hub airports using the base assumptions referred in Chapter 10. For this reason, the $q_{a\_index\_normalised}$ score of the airport can be regarded as the hub's connection quality score as the factor indicates the average quality score of the itineraries using the airport as the transfer point. The $\%_f$ is calculated by rebasing the percentages in reference to the sum of connecting frequencies available at the selected hub airports. $\%_f$ and $q_{a\_index\_normalised}$ are reported by including both the operating and codeshare itineraries. Since these factors are examined to assess the connectivity efficiency of the competing airlines' hub airports, only connecting flights were included in the analysis, eliminating direct services. The connectivity index, denoted by CI, of the competing hub airports can be calculated by

$$CI = \%_f \text{ x } q_{a\_index\_normalised}$$

As discussed in the literature review (Section 3.4.4.2.4), although there exists other connectivity measures used commonly in the industry such as Netscan and ACI Europe, the CI parameter deviates from these models due to the consumer-specific nature of the $q_{a\_index\_normalised}$ factor. ACI's connectivity index is calculated by weighting the schedule related parameters only like the f, MCT and t_{conn}. Similarly, the Netscan utilises schedule, transfer time MCT and great circle distance. However, different from existing mdoels, the $q_{a\_index\_normalised}$ and subsequently the CI is calculated by directly integrating the consumers' perspectives and preferences regarding schedule convenience.

Being able to assess the CI and the $q_{a\_index\_normalised}$ of the listed airlines' selected hub airports contributes to attaining Objective 4 of the research. Industry practitioners would be able to use these information as an integral market intelligence while conducting their high-level analyses. In the following sections, the $\%_f$, $q_{a\_index\_normalised}$ and CI scores are reported for the regional O&D pairs as of 2016 schedules for the selected hubs. The results of the selected O&Ds are reported in bidirectional form implying that both routes' $\%_f$, $q_{a\_index\_normalised}$ and CI scores were included in the analysis. As the majority of the listed airlines and the selected hub airports are located in Europe, the studied regions of the Chapter were selected from/to that continent.

12.2.1. Europe/Middle East

The frequency share, quality and CI scores of the competing airlines' hubs are reported in Table 12.1 for the Europe/Middle East market. (Turkey, Iran and Egypt are reported in the Middle East.) As per the table, the best schedule-convenience score for the connecting itineraries are actualised at VIE airport by OS flights followed by ZRH airport which is used as the hub airport of LX. Both airports central location in Europe, as well as OS's and LX's scheduling strategy, enable these carriers to get rank top with $q_{a\_index\_normalised}$ scores. However, as observed in Table 12.1 the airports frequency share is relatively disadvantaged in comparison to the rival hubs in the region.

Table 12.1: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports between Europe and the Middle East.

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
IST	30.6%	0.7685	23.52
FRA	12.2%	0.8128	9.92
DXB	8.6%	0.7354	6.32
CAI	7.0%	0.7223	5.06
VIE	4.9%	0.9093	4.41
MUC	5.3%	0.7945	4.22
CDG	6.2%	0.6747	4.19
SAW	6.2%	0.6549	4.07
AMS	4.7%	0.7786	3.66
DOH	4.5%	0.7867	3.54
ZRH	3.6%	0.8709	3.12
AUH	2.8%	0.6079	1.70
BRU	1.6%	0.8023	1.28
LHR	1.9%	0.6471	1.23

As per Table 12.1, the $q_{a\_index\_normalised}$ is lowest at AUH airport in the bidirectional market. The geographical location of Abu Dhabi is relatively disadvantaged in comparison to other hubs located in Central or Eastern Europe for the itineraries in the Europe/Middle East region. Furthermore, the location of LHR is also disadvantaged for the connections in the market as the geography of London is not ideal for connections between Central (or Eastern) Europe and the Middle East. Moreover, the network structure of BA puts LHR in a disadvantaged position, ranking the carrier one before the last in the $q_{a\_index\_normalised}$ score and the last in the CI performance.

The frequency share and the CI score is highest at the IST airport. The ACI Europe report on airport connectivity (2017) suggests that IST has joined the major connected airline group replacing LHR as the 4th best connected European hub in the past decade. Indeed, this finding is in agreement with the CI score of the IST airport as TK reports a significant share of the Middle East/Europe connections. Furthermore, SAW airport of Istanbul, the base of an LCC, (PC) reports a considerable CI score, despite its poor $q_{a\_index\_normalised}$ score due to its advantage in the $\%_f$. The high frequency share of the SAW airport confirms that the geographical location of Istanbul which is located in between the two continents could be regarded as a crucial factor of effective connectivity in the Europe/Middle East axis. The advantage of Istanbul's geographical position in hub connectivity was justified in the work of Nenem and Ozkan-Gunay (2012).

12.2.2. Europe/America

The parameters are reported separately for the bidirectional North America / Europe and South America / Europe markets in Tables 12.2 and 12.3. Regarding adjusted index normalised quality scores, VIE reports the best performance in North America while LHR's $q_{a\_index\_normalised}$ is the highest in South America. Similar to results of the Europe/Middle East market, ZRH is again ranked second following VIE to/from North America. In the Europe/South America market, it seems that no connections were attained from VIE. LHR and CDG are found to have the best $q_{a\_index\_normalised}$ scores in the Europe/South America market.

Table 12.2: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports from Europe to North America.

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
LHR	20.60%	0.8002	16.48
FRA	17.10%	0.8318	14.22
AMS	17.50%	0.7174	12.55
CDG	17.40%	0.7055	12.28
MUC	7.90%	0.8444	6.67
ZRH	7.50%	0.8548	6.41
VIE	4.90%	0.9421	4.62
BRU	4.10%	0.8401	3.44
IST	2.10%	0.7259	1.52
DOH	0.90%	0.6179	0.56
DXB	0.00%	0	0.00
AUH	0.00%	0	0.00
CAI	0.00%	0	0.00
SAW	0.00%	0	0.00

Table 12.3: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports from Europe to South America.

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
LHR	27.0%	0.8152	22.01
AMS	22.0%	0.7922	17.43
CDG	19.7%	0.8012	15.78
FRA	10.4%	0.7421	7.72
ZRH	6.5%	0.7232	4.70
AUH	4.0%	0.5982	2.39
IST	3.3%	0.6883	2.30
DOH	2.8%	0.6223	1.73
DXB	2.2%	0.6122	1.36
MUC	0.0%	0	0.00
VIE	0.0%	0	0.00
BRU	0.0%	0	0.00
CAI	0.0%	0	0.00
SAW	0.0%	0	0.00

Between Europe and America (North and South), LHR's CI score ranks the highest. The hubs in the Gulf region namely DXB, DOH and AUH, are relatively disadvantaged in the Europe/America market due to their geographical location. It would be inconvenient for passengers to travel to the Middle East for a connection from Europe to America and vice versa. Furthermore, unlike its performance in the Europe/Middle East market, IST does not have a competitive connectivity pattern also due to the geography of the airport. The relatively poorer connectivity performance of IST and hubs in the Gulf were also confirmed in the ACI report

(ACI Europe, 2017). Furthermore, the supply advantage of the BA, LH and AF/KL assisted LHR, FRA, AMS, MUC and CDG to report higher CI scores. It is observed in Table 12.2 and Table 12.3 that BA via LHR offer the highest number of connecting frequencies in the North America. Besides, thanks to its partnership with IB, BA via LHR also reports the highest frequency share to/from South America. The geographic location of London between Europe and America is another aspect of LHR significant advantage in the connectivity for the market.

12.2.3. Europe/Africa

$\%_f$, $q_{a\_index\_normalised}$ and CI scores are disclosed for Europe/North Africa and Europe/Sub Saharan Africa markets separately in the Tables 12.4 and 12.5 ordered by the CI score. It is observed in the tables that LH via its hubs FRA and MUC offers the most number of connecting frequencies from/to North Africa while AF via CDG has the highest connecting frequency share from/to Sub Saharan Africa followed by its partner KL via AMS. Concerning adjusted index normalised quality scores, LX's hub, ZRH, reports the best performance in $q_{a\_index\_normalised}$ score despite its lower frequency share in the entire Europe/Africa market. BRU's $q_{a\_index\_normalised}$ ranks second following ZRH in both North and Sub Saharan Africa. This finding is in line with the SN Brussels business strategy concerning the carriers' active presence in the African continent.

Table 12.4: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports in Europe / North Africa Market

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
FRA	14.1%	0.8171	11.52
CDG	15.5%	0.6856	10.63
LHR	12.5%	0.7065	8.83
IST	9.3%	0.6688	6.22
CAI	9.8%	0.6212	6.09
AMS	7.9%	0.6144	4.87
ZRH	5.5%	0.8831	4.85
DOH	5.8%	0.5998	3.47
AUH	5.5%	0.5648	3.10
VIE	3.0%	0.8611	2.63
MUC	3.4%	0.8005	2.68
BRU	2.1%	0.8651	1.85
SAW	3.0%	0.5544	1.69
DXB	2.4%	0.5212	1.27

Table 12.5: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports in Europe / Sub Saharan Africa Market

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
CDG	20.7%	0.6968	14.42
AMS	21.6%	0.6504	14.05
BRU	12.5%	0.7402	9.25
IST	11.4%	0.6159	7.00
FRA	7.7%	0.7095	5.46
LHR	5.1%	0.6903	3.52
CAI	4.6%	0.6829	3.11
DOH	5.2%	0.5984	3.11
AUH	4.1%	0.6146	2.52
MUC	2.9%	0.6922	2.01
DXB	2.5%	0.5407	1.36
ZRH	1.4%	0.7499	1.07
VIE	0.4%	0.5225	0.18
SAW	0.0%	0	0.00

The work of Logothetis and Miyoshi (2018) finds that TK provides more transfer opportunities between Europe and Africa, but EK attains considerably higher hub efficiency. TK's superiority in transfer opportunities are verified in Table 12.4, and 12.5 as TK's $\%_f$ scores are more significant than the EK's. However, unlike Logothetis and Miyoshi's findings, TK's connectivity index and CI scores were calculated to be relatively higher than the EK's values. Additionally, in the Europe/Sub Saharan Africa market, DXB's $q_{a\_index\_normalised}$ score was calculated to be inferior to the connectivity index of AUH although both airports are located in the same country and are only 123 kilometres away from each other. Therefore, it could be concluded that, although the the $q_{a\_index\_normalised}$ is influenced by the geography of the airports, it is not the sole parameter that shapes the connection quality of the hub airport.

12.2.4. Europe/South Asia & Far East

In the bidirectional Europe/South Asia & Far East market -which includes India but excludes Commonwealth of Independent States (CIS) countries and Australia-, OS via VIE is calculated to report the best $q_{a\_index\_normalised}$ score again, and TK via IST is estimated to have the highest $\%_f$ share and the CI score as depicted in the table below.

Table 12.6: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports from Europe to the South Asia & Far East

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
IST	13.7%	0.8670	11.88
DOH	12.7%	0.9089	11.54
DXB	13.5%	0.8112	10.95
FRA	12.7%	0.8191	10.40
AMS	12.2%	0.8150	9.94
LHR	10.4%	0.8008	8.33
AUH	8.6%	0.8056	6.93
CDG	7.4%	0.7669	5.68
ZRH	5.0%	0.8583	4.29
MUC	1.8%	0.8022	1.44
BRU	0.9%	0.6500	0.59
VIE	0.6%	0.9666	0.58
CAI	0.5%	0.9128	0.46
SAW	0.0%	0	0.00

According to Table 12.6, in the Europe/Far East market, the CI of the top-ranking airports are not far from each other, and the dominance of the Gulf hubs (DOH, DXB) and IST in the market is apparent. ZRH again reported a relatively superior $q_{a\_index\_normalised}$ score in comparison to many other European hubs while CDG and BRU did not report a competitive quality score. FRA, MUC and AMS's $q_{a\_index\_normalised}$ were found to be very similar to each other. Although CAI reported an attractive $q_{a\_index\_normalised}$ score like VIE, the airport almost reported no CI score due to its inadequate level of traffic in comparison to the rival hubs.

12.2.5. Europe/Europe

In the bidirectional intra-European connections, the results are overwhelmingly influenced by the domestic flights as shown in Table 12.7.

Table 12.7: %f, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports from Europe to Europe

Airline	%f	$q_{a\_index\_normalised}$	CI
FRA	32.5%	0.8043	26.14
MUC	14.7%	0.8432	12.4
CDG	13.0%	0.7421	9.65
ZRH	8.9%	0.8821	7.85
AMS	9.5%	0.7766	7.38
LHR	8.2%	0.7224	5.92
VIE	5.1%	0.8511	4.34
IST	4.9%	0.6761	3.31
BRU	1.9%	0.7021	1.33
SAW	0.7%	0.5831	0.41
CAI	0.6%	0.6652	0.4
DXB	0.0%	0	0
AUH	0.0%	0	0
DOH	0.0%	0	0

As per Table 12.7, Europe/Europe connections are dominated by the LH group due to its relatively larger domestic market. Additionally, FRA's and MUC's central location in the European continent is another advantage of those airports in achieving comparably higher CI scores. As expected, the hubs in the Gulf region can not report a CI score due to the geographical inconvenience of those airports. In terms of the $q_{a\_index\_normalised}$ scores, ZRH ranked top, followed by VIE and MUC.

12.2.6. Europe/CIS

The results for the bidirectional Europe/CIS route (CIS countries include Russia and ex-Soviet Union countries) is shown in Table 12.8 below.

Table 12.8: $\%_f$, $q_{a\_index\_normalised}$ and CI Scores of the Selected Hub Airports from Europe to CIS

Airline	%f	$q_{a\_index\_normalised}$	CI
IST	33.5%	0.9086	30.44
FRA	24.9%	0.8765	21.82
CDG	6.8%	0.8007	5.44
SAW	6.9%	0.7321	5.05
AMS	6.4%	0.7763	4.97
MUC	4.2%	0.7654	3.21
ZRH	3.8%	0.7965	3.03
VIE	2.8%	0.8128	2.28
LHR	3.0%	0.7569	2.27
CAI	2.8%	0.5609	1.57
BRU	1.7%	0.7075	1.20
DXB	1.6%	0.6769	1.08
AUH	1.0%	0.6534	0.65
DOH	0.6%	0.6888	0.41

As observed in Table 12.7 TK via IST and LH via FRA have a significant advantage in the market due to their vast frequency share in comparison to rivals. Additionally, IST is reported to have the highest $q_{a\_index\_normalised}$ in the market followed by VIE. Due to geographical inconvenience, the hubs in the Gulf region did not produce competitive connectivity indexes in the market.

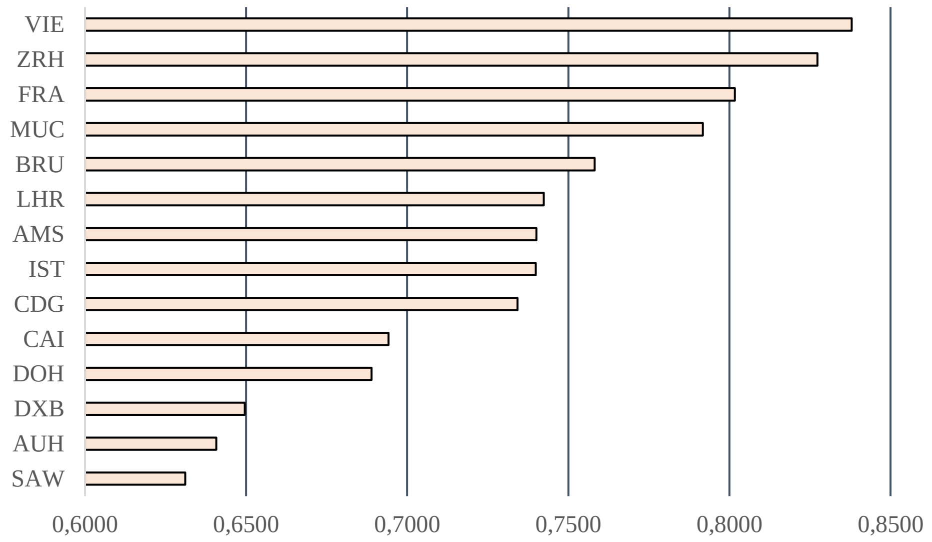
12.3. Discussion

It is shown in the cases of this Chapter that, the research's methodologies can be applied to benchmark the effectiveness of the listed airlines' hub airports from a consumer-centric perspective. While the $q_{a\_index\_normalised}$ score of the itineraries was used as a metric of connectivity quality, $\%_f$ was used to reflect the volume of traffic in terms of frequency at the hub airport. The $q_{a\_index\_normalised}$ and $\%_f$ score together composed the connectivity index (CI) of the airports which referred to a capacity blended hub quality performance.

By using the calculated $q_{a\_index\_normalised}$ scores referred in the tables of section 12.2, it is possible to develop the aggregate Europe/world-wide quality index score of the competing hubs. This has been achieved by simply averaging the each selected hub airports' $q_{a\_index\_normalised}$ shown in Table 12.1 to 12.8. The average $q_{a\_index\_normalised}$ are depicted in Figure 12.1 below. As

Europe/Australia is not routinely served one-stop, the Australian continent was not included in the computation. (The zero values of $q_{a\_index\_normalised}$ are not included in the average.)

Figure 12.1: Worldwide Average $q_{a\_index\_normalised}$ Scores of the Selected Hubs (Europe/World Market)



It is observed from Figure 12.1 that VIE and ZRH scored the best average $q_{a\_index\_normalised}$ scores while the hubs of LH, FRA and MUC ranked third and fourth respectively. LHR, AMS, IST and CDG were placed at the middle rankings as the competitiveness of these hubs in $q_{a\_index\_normalised}$ scores varied depending on the analysed market route. The Gulf hubs ranked lower primarily due to their geographical location. The relatively lower $q_{a\_index\_normalised}$ scores for the Gulf hubs do not necessarily imply that those airports lack good quality connections. Indeed airports like IST, DOH, AUH and DXB are not in an ideal location to connect in the Europe/America or Europe/Africa. However these airports can offer better connection quality in other markets.

As per the results, although VIE and ZRH were reported to offer "high-quality" connections, the carriers using those airports as hubs (OS and LX respectively) were disadvantaged in the volume of supply which led those airports' CI score to be relatively less in comparison to their rivals. IST was found to be a competitive hub in the Europe/Middle East and Europe/Far East connections whereas the hubs in the Gulf region were discovered to be advantaged in the Europe/South Asia & Far East axis. Furthermore LHR was relatively competitive in both Europe/North America and Europe/South America connections.

Additionally, AF/KL group was found to be relatively active in the Sub Saharan Africa market although BRU's performance was conspicuous in the region too.

In order to observe the effect of frequency volume in the connectivity of the hubs in the bidirectional Europe/World market, it is possible calculate the percentage CI (denoted as $\%_{CI}$) of each airport. $\%_{CI}$ could be calculating by summing each airports CI values shown in Table 12.1 to 12.8 and then diving it with the total sum of all CI's. Therefore, $\%_{CI}$ of an airports refers to its share of the CI scores in the selected markets. The $\%_{CI}$ values of the selected hubs in the Europe/World market is depicted in Figure 12.2 below.

Figure 12.2. $\%_{CI}$ Values of the Selected Hubs in the Europe/World Market

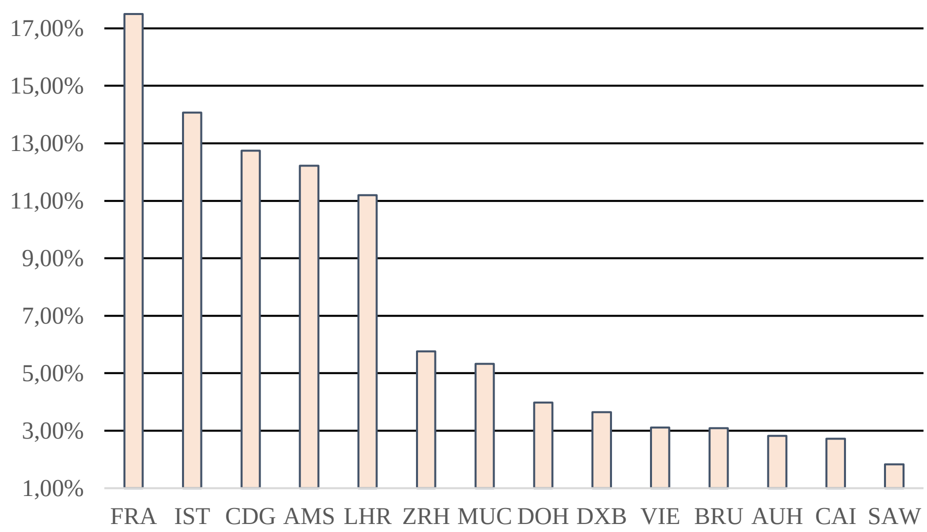


Table 12.2 illustrate that FRA holds the highest share of $\%_{CI}$ in the Europe/World market, followed by IST and CDG. Despite their advantage with the $q_{a\_index\_normalised}$ scores VIE and ZRH could not report a higher $\%_{CI}$ share as the airports are relatively disadvantaged in terms of their frequency supply. As expected, the Gulf hubs reported a lower $\%_{CI}$ below 4% sourced primarily due to their geographical position.

The results of this Chapter have shown that the volume of traffic in frequency, scheduling quality and geographical position of the hub airports determined their connection quality and connectivity index. The $q_{a\_index\_normalised}$ which is an essential component of the CI was calculated by incorporating the direct feedback of the consumers whose methodology was covered in Chapter 9. From this perspective, the research not only presented a practical tool for airline executives to assess their networks' efficiency from the passengers' perspective but also to airport authorities anticipating to benchmark their hubs' relative performance and connectivity. The ability to assess the competing hub airports' $\%_f$, $q_{a\_index\_normalised}$ and the CI performance is a clear achievement of the research's Objective 4.

Chapter 13: Conclusion

13.1. Introduction

"The airline industry is complex, dynamic and very competitive. Decisions need to be taken every day by the whole organisation" (Aracs MIS, 2018, s. 1). Airline executives must make timely and wise decisions to remain competitive in the market. The content of these decisions ranges from recruiting the right human resources to selecting the best and most recent technological infrastructures to adapt to rapidly changing industry dynamics. Air carriers' decisions are key to ensure their success, especially in an environment that eliminates uncompetitive firms from the market.

> "Structurally, the airline industry is characterised by high fixed costs, cyclical demand for its services, intense competition, and vulnerability to external shocks. As a result, airlines have been more prone to failure than many other businesses, and the sector's financial performance has continually been very weak" (United States Government Accountability Office, 2005, s. preface).

As addressed in Chapter 3, competition in the airline industry has intensified, especially amid deregulation. Liberalisation and deregulation of the sector facilitated the entry of new firms, positively impacting competition and innovation (OECD, 2018). The high volume of LCC entries into the market has significantly altered the competitive structure of the sector. In this situation, strategic, tactical and responsive decisions of the airlines have helped them maintain their competitiveness. In the post-deregulation era, therefore, the focus has turned from operations to passengers as airlines had to prioritise customer satisfaction to be successful.

The rise in competition has positively influenced consumers as passenger numbers have soared globally. As the air transport product has been commoditised, even the lower-income social groups have begun to afford air travel. Today, with the increased competition in the airline industry, passengers have multiple flight options, and their ability to access information about competing products has risen tremendously. Through the use of the Internet and web marketing, carriers can openly publish their products and fares. Previously, passengers had to contact travel agencies to search for flight options and enquire fares. Today, passengers can quickly access information about factors beyond products and fares that can detrimentally influence their itinerary decision making. For instance, they are better informed about airlines' on-time performance indicators, safety record, in-flight amenities and the timetable. Therefore, compared to previous decades, today's consumers are better informed about possible itineraries on the shelf before making their purchasing decisions.

While designing network arrangements, airlines need to consider consumers' convenience to compete effectively. The airline network determines the timetables, so how the network is organised heavily affects the consumer welfare. Each itinerary has its characteristics determining the level of convenience for passengers. For instance, while a passenger intending to fly from City A to City B might conveniently travel direct and non-stop via Airline 1, another carrier, Airline 2, could offer a connecting service between those cities routed through City C. However, Airline 1's departure time from City A and arrival time in City B might be unattractive if it requires the passenger to pay for an extra night at a hotel, and in this case, Airline 2's departure and arrival time might well fit with the consumer's expectations. Furthermore, Airline 1's direct service might be a codeshare flight operated by an airline other than the consumer's preferred choice, while Airline 2's flight might be an online service provided by the consumer's favourite airline. Therefore, each itinerary derived from the carriers' network has its own characteristics that determine consumer convenience. For these reasons, this research was aimed at developing a solid understanding of the relationships among airlines' network efficiency, schedule convenience and consumer welfare affecting their purchasing decisions.

13.2. Revisiting the Aim and Objectives of the Research

This research focused on airline network and schedule efficiency from a consumer-centric perspective. As the carriers' network arrangement is a key driver of its business model, revenue and cost structure, its efficient organisation is an element of the airline's performance that also impacts consumers' schedule convenience. Undoubtedly, as airlines' primary objective is to maximise profitability, they must also design their network with the objective of maximising revenues and minimising costs. For this reason, airline executives must plan their network arrangement to enable the highest levels of passenger traffic and thus revenue. Whilst the cost of establishing an efficient network arrangement and its revenue expectation is beyond the scope of this research, the efficiency and commercial performance is parametrised through the market share estimation scheme.

13.2.1. The aim of the Research – To Develop a Passenger Centric Methodology for Analysing the Schedule and Network Performance of Air Services

This study aimed to analyse the effectiveness of airline schedule/networks and their impact on consumer choice. Throughout the research, the relationship between airlines' core product, the schedule and consumer choice was elaborated in detail. In this context, a passenger survey was implemented to understand the key drivers of the schedule convenience. The survey was designed carefully after a detailed review of the literature and involved a large and wide-ranging sample of passengers. The analysis of approximately a thousand questionnaire responses verified that schedule is indeed a critical attribute of consumer decision making and has a central role in making purchasing decisions. It was also found that schedule-convenient flights are valued higher by the consumers and they are willing to pay more for the “better” services.

In broad terms, the research has developed a model using the survey findings to study the effectiveness of airline networks and their effect on consumer choice. The introduced methodology required the schedules of airlines to compute their relative supply and quality related scores. The relative scores were then used as the inputs to the REMSET model to produce market share estimation of each carrier competing in a market. While the schedule information of the listed airlines was retrieved from the OAG database, relative supply and quality related scores are developed as part of the study’s model. Therefore, the aim of the research was attained by the development of the relative supply and quality determination scores as well as the REMSET model.

13.2.2. Objective 1: To Determine a Consumer-Centric Capacity Share Estimation Model

The first objective involved the determination of a consumer-centric capacity share estimation model which is one of the key inputs of the REMSET. The capacity is a key determinant of product supply available for sale in the market. The research brought a fresh perspective to the capacity determination in the sense that a consumer perspective was inserted into the physical capacity. Since for non-direct and non-operating flights, the physical capacity determination is not a straightforward process, using the inputs retrieved from the survey results, a new passenger-centric approach was brought to the supply determination process. Additionally, for connecting services, not all flight connections were counted as a viable product in case an itinerary is reported to be beyond the scope of "schedule convenience". As iterated in Chapter 8, the capability of computing consumer-centric capacities enabled the benchmarking of capacity shares of different carriers competing in a market. If all other parameters influencing consumer decision were identical, the expected market share of the airlines would be equal to their capacity shares. However, in practice, this is extremely unlikely as each carrier operating in a market has different schedule characteristics or in other words each has a different quality.

13.2.3. Objective 2: To Quantify Airline Schedule & Network Quality

The second objective covered the quantification of airline network quality. The first objective was related to the quantity of the available capacity which was customised based on consumers' expectations. The second objective in broad terms was concerned with the quality of the supply available for sale. Chapter 9 was dedicated to the quality score determination methodology. The abstract concept of "good" or "bad" schedules was translated into numerical values enabling the benchmarking of relative superiorities of competing itineraries in terms of schedule quality.

13.2.4. Objective 3: To Determine A Realistic Market Share Estimation Tool (REMSET)

The REMSET required two inputs: Supply and quality scores. The capacity share and quality scores of the prospective itineraries competing in a market were calculated as part of the first and second objective respectively. The third objective covered the modelling of the REMSET using consumer-centric supply and quality scores. As referred in Chapter 9, the REMSET adjusted the supply share with respect to the relative quality scores of each capacity; deeming the output of the model to be an indication of the airline's relative performance against rivals present in an O&D.

13.2.5. Objective 4: To Develop A Tool for Industry Practitioners to Assess Schedule and Network Competitiveness in Their Route and Capacity Planning

Market share is an indispensable performance indicator for company executives that enable them to comprehend and benchmark their company's competitive position. Given their schedules, airline executives can forecast their potential market share by utilising the REMSET model. Since the market share parameter incorporates both the carriers' network efficiency and their product's level of appreciation from the consumers' standpoint, higher market share estimations refer to better relative positioning of the service provider against competitors while the opposite case signals less likelihood for that product to be selected by the passengers for their journeys.

This research also aimed to offer a tool for industry practitioners to conduct scenario-based analyses. By referring to scenario analysis, the impact of any changes in the airline's network structure is stated. Such changes may involve parameters like variations in the departure/arrival times, introduction or cancellation of frequencies, changes with the aircraft type, addition or withdrawal of a codeshare agreement, launching a new destination or removing one from the network map and etc. The application of the consumer-centric schedule and network performance assessment models enabled certain comparative analyses including the connection quality and connectivity indexes for the selected hubs. The airline and airport executives can use such analysis as a decision support tool to gain a competitive advantage over their rivals.

13.3. Results and Discussion of Fulfilling Research's Aim and Objectives

By scanning the literature, an in-depth understanding of airline schedules and networks, as well as its central role in the planning process of the company, was developed. Additionally, the commoditisation process of the air transport product was examined, and the dynamics influencing consumer choice in itinerary decision making were studied in detail. The literature review was essential to comprehend the theoretical framework of airline networks and understand consumer perspectives towards the elements of airline schedules. The passenger survey was designed carefully which incorporated the previous findings available in the literature. The survey questions not only intended to test whether the parameters discussed in the literature survey indeed had an impact on consumer decision making but also intended to quantify the level of impact of those parameters. The survey results offered credible responses which were in line with the previous literature and also market insights. Furthermore, the results of the survey formed the basis of the research's methodology in the sense that relative capacity share and quality determination models used the survey findings as ingredients to the REMSET model.

The schedule information of the 36 listed carriers totalling over a million rows of data having more than 23 million attributes in total were uploaded into the web environment (www.phdsukru.com), and all the methodology concerning the capacity share, quality and market share estimation was coded. This programming enabled fast and error-free computation for the metrics of the listed carriers. The web environment enabled the running of the analyses on any O&D pair which could be at the level of airport-to-airport, country-to-country and region-to-region. In Chapter 10, fourteen different cases were introduced at different levels, and the outputs were studied in detail. In the following Chapter, specific scenarios were introduced to those 14 cases to observe the variations with the research's outputs.

Objective 1 of the research was achieved. The parameter, adjusted seat share, $\%_{a\_s}$, successfully measured the consumer-centric capacity share of a carrier in a given market. The total physical frequency (f), seat supply (s) and seat share ($\%_s$) can be calculated for each flight route using the consumer-centric capacity determination model. Different from $\%_s$, $\%_{a\_s}$ refers to the adjusted form of the seat share referencing the relative capacity share of the competing carriers. Moreover, as part of the methodology, the seat supply of the connecting services and codeshare flights were calculated in a unique consumer-centric manner where adaptable parameters like s_{conn} and s_{code} were used. As addressed in Chapter 10, the adaptable s_{conn} and s_{code} parameters' default values were set to certain pre-defined values. These values were changed in Chapter 11 to observe their impact on capacity related variables such as s, $\%_s$ and $\%_{a\_s}$. The scenarios of the cases in Chapter 11 credited the default values of s_{conn} and $s_{code.}$ As a result, the consumer-centric capacity share computation model was developed successfully and implemented into the real schedules as addressed in Chapter 10 and 11.

Objective 2 of the research was accomplished as the quality scores of the competing itineraries were calculated. The $q_{a\_index\_normalised}$ score provided a concrete indication of the relative quality performance of a carrier. While the highest $q_{a\_index\_normalised}$ referred to the most superior product available in the market regarding schedule convenience, the worst ones corresponded to the minimum $q_{a\_index\_normalised}$ score. The quality determination methodology covered numerous factors including time related parameters (t_{total}, t_{flight}, t_{conn}, t_{stress}, t_{waste}, q_{arr}, q_{dep} etc) as well as flight type (online or codeshare) and flight routing (direct or connecting) specified by u_{do}, u_{co}, u_{dc} and u_{cc}. Survey results enormously the shaped quality score calculation model in the sense that the willingness to pay values retrieved from the questionnaire offered direct insight about the perceived value of different flight options. The cases that were shown in Chapter 10 and 11 illustrated the relative quality performance of competing itineraries. Therefore, the abstract concepts of good and bad schedules were successfully translated into numerical values enabling benchmarking and the ranking of carrier's performance.

Objective 3 of the study was attained as the REMSET tool was prepared and produced credible and consistent forecasts. In Chapter 10, the market share estimations (ms) of several cases were undertaken using the model. The forecasts were then contrasted with the actual market share values obtained from the MIDT data. The comparison of the forecast and actual market shares has shown that the model generated accurate estimations. Therefore, the validity and credibility of the REMSET model were cross-checked and tested using actual market share data of the airlines operating on the route. As addressed previously, although there exist parameters other than capacity share and schedule quality that shape the actual market shares of the carriers, it was inferred from the cases in Chapter 10 that the quantity and quality of the supply formed an integral aspect of the actual market shares which can be accurately estimated by the REMSET. The other influential parameters other than the quantity and quality of the supply can assist to enhance the model.

Objective 4 was also achieved as a unique tool is offered to industry practitioners enabling to assess schedule and network competitiveness. The tool assisted in measuring competitive performance through the outputs covering $\%_{a\_s}$, $q_{a\_index\_normalised}$ and ms. Chapter 11 covered scenarios that were built upon the cases covered in Chapter 10. Each of the scenarios introduced a variation from the base status and the changes with the research outputs were observed with respect to changing schedule and network arrangements. Being able to assess supply, quality and market share estimations under changing network arrangements offered a unique decision support mechanism for industry practitioners. Airline executives can measure the impact of their potential schedule and network related decisions in terms of supply, quality and market share estimations by comparing these values with the original figures before any changes are made to their network structure. Therefore, the preparation of a tool enabling to run simulations over the airlines' network arrangement offered a unique commercial decision – support mechanism for industry practitioners.

Moreover, as the past timetables of the listed carriers were also uploaded into the research database, the airlines' performance development over the years were observed by running the research models for different years. Indeed, this capability aids airline executives to analyse their competitive performance development in return for their network investments. The historical information also assisted a deeper analysis of the competitive situation over the years, which indeed serves as a critical market intelligence information.

Being able to use the research methodologies to evaluate and benchmark the hubs' competitiveness in terms of connection quality and connectivity indexes was another accomplishment of Objective 4. The tool enabled the relative performance of the carriers' hubs to be contrasted and provided a benchmark analysis to rank the overall quality for connecting itineraties. As per the analysis performed in Chapter 12, in the bidirectional Europe/World market, VIE and ZRH airport offered the best quality connections as of 2016 schedules. However, the inadequacy of the connecting frequencies available at these airports reduced their connectivity index (CI) figures. On the other hand, while FRA and IST airport did not present the best connection quality $q_{a\_index\_normalised}$ scores in comparison to rival hubs, their competitive advantage in the frequency supply placed these airports in the top two rankings of the CI scores. It was also covered in the cases of Chapter 12 that the geographic location of the hubs are an essential component of their $q_{a\_index\_normalised}$ and CI scores. For instance, the hubs at the Gulf region such as DXB, AUH and DOH are relatively disadvantaged in the Europe/America market due to the higher detour ratios.

In sum, each of the research's objectives were successfully achieved and thus the aim of the research was attained. In this context, the effectiveness of the airline schedule and networks were successfully measured, and their impact on consumer choice was formulated through solid parameters whose validity, credibility and accuracy were tested and cross-checked with the actual market realisations. As part of the study, the strong correlation between network performance and consumer choice was observed and framed. The findings were also in line with the previous literature confirming that schedule convenience is a crucial parameter of consumer decision making while booking their itineraries. Additionally, the developed methodologies of the research were formulated in an adaptable manner in which both the parameters and input variables could be changed to observe their impact on the outputs providing a unique decision support tool for industry practitioners.

13.4. Contribution to the Literature & Achievements

The literature review has addressed the existence of mechanisms and methodologies offering an option to benchmark the service level of different flight options by quantifying consumer behaviour. In this context, the QSI (Quality Service Index) was discussed as the industry norm. However, the weaknesses associated with the QSI model was covered in Chapter 3. The weaknesses of the QSI stemmed from the fact it is a strictly mathematical model severely lacking consumer's attitudes towards schedule and network efficiency. The existing models that enable a comparison of relative superiorities of different carriers' products primarily rely on physical capacity supply and therefore lack an in-depth understanding of the consumers' needs and priorities. This research's focus on determining consumers' schedule related expectations and incorporating those factors into the model was a unique approach. The study's model was developed both using the theoretical framework retrieved from the previous literature and real consumer feedback obtained directly from the passengers. In other words, the methodology was constructed with the primary data gathered directly from the survey responses.

The consumer-centric capacity share determination methodology calculated not only the physical capacity supply available in a given market but also commercially viable capacities which were adjusted based on consumer preferences. As part of the model, the physical capacity offered by the airlines were not directly included in the available product set; they were customised based on the characteristics of the supply where infeasible seats were eliminated. This approach is also unique and has a substantial contribution to the literature.

The translation of schedule and network quality concept into numbers was another distinctive outcome of this study. Consumers' schedule quality perception was transformed into quantitative values enabling benchmarking of the relative performance of the competing carriers. Using survey findings, the methodology converted all the metrics that shape the attractiveness of an itinerary into a single unique index. The research model was developed using adaptable parameters implying that the model could be adjusted or modified with respect to changing priorities of different customer segments. Therefore, airlines can quantify the quality of their schedule's quality from the consumers' perspective and benchmark that value with those of the competitors in addition to the capability of measuring consumer-centric supply share.

REMSET is a significant contribution of this study both to academic literature and for the industry. The tool not only replaces the traditional QSI but also brings a fresh passenger focus to airlines’ competitive performance analysis. The tool assists airline executives in their network design process allowing them to measure the impact of any capacity and route investment quantitatively. Moreover, they can study the effect of any schedule related change in capacity share, quality scores and market share estimation. In this context, the tool also provides an insight for the revenue management while setting the fares as the understanding of their product performance in comparison to the rivals may assist in correct positioning and pricing. Furthermore, changing conditions beyond airlines’ control could also be captured using the research’s methodologies. For instance, an airport may extend or shrink its MCT which could affect the connections from/to that airport. Such a change could be handled within the models as the MCT of the airports were dynamically retrieved from the OAG database and all relevant computations can be performed automatically over the newest data obtained from the database. Additionally, as addressed in the quality determination process, the changes in consumer preferences can also be handled as part of the REMSET mechanism as the quality score forms an input the market share estimation procedure.

Apart from the objectives that achieved significant contributions to the literature, the survey findings offered distinctive academic findings. Before preparing the survey questions, papers were submitted to Air Transport Research Society (ATRS) in 2013 and 2014 held in Italy and France respectively. Both papers were accepted and presented. The papers received significant attention from the participants and the feedback of the society fine-tuned the intended survey questions. After the implementation of the survey, the results were drafted as two separate papers that were submitted to ATRS conferences held in Greece in 2016 and Belgium in 2017. The papers were presented in the conferences and the results were found exciting and convincing by the society. The participants confirmed that the study addressed a gap in the literature. Therefore, four different papers were submitted to the ATRS. Each of the papers was accepted and presented at the conferences. All the presentations received significant attention from the society.

The passenger survey has confirmed that the schedule convenience is among the essential factors of choice while making itinerary decisions. The survey analysis assisted in quantifying consumers' preference with certain schedule related factors. For example, it discovered that passengers can tolerate no more than 290 minutes connection time at the hub airport. The survey participants also expressed that, they demand an additional 30 minutes t_{buffer} on top of the MCT for their connecting itineraries in order to experience a less stressful journey. Moreover, respondents reported different levels of appreciation for different departure and arrival time intervals. They preferred morning departures and afternoon arrivals and avoided journeys departing or landing at the midnight hours. The survey findings affirmed that codeshare flights are less likely to be preferred in comparison to operating itineraries and the direct services were reported to be “better” than connecting trips. The survey findings also quantified the relative values of itineraries depending on the itineraries’ type and routing. Therefore, the survey results presented interesting findings which present invaluable information for industry practitioners while designing their products.

13.5. Limitations of the Research

Although the research’s aim and objectives were fulfilled successfully and the REMSET methodology produced credible and valid estimations corroborated by the MIDT data, it had some limitations worth covering. The limitations are grouped into four distinct categories discussed in the sections below.

13.5.1 Limitations Concerning Survey Design and Results

The survey was designed after a detailed review of the literature and receipt of valuable feedback from the ATRS society. The questions forced respondents to mark their answers that did not permit them to write their ideas, suggestions or comments if they had any. Therefore, the survey had no room for qualitative feedback which might have been useful to receive. The survey questions were designed to complete the model and fill up the parametric gaps in the model. In case, there existed a chance to interview the survey participants or get further feedback from them via open-ended questions; it might have been possible to reach different information concerning their decision-making process that might have been incorporated into the research's methodology. On the other hand, open-ended questions might have assisted to address the language bias of the survey question text that has been discussed in Chapter 7.

The survey was conducted in 9 different airports where 962 valid responses were recorded and included in the analysis of the results. As described in Chapter 6, survey administrators (or the assessors) based at the airports assisted in implementing the questionnaire and collecting the responses. They approached potential participants and enquired if they would be willing to take part in an academic study. The assessors did not take a role in the design and analyses of the survey. Their contribution was limited to the distribution and collection of the questionnaire handouts. Survey administrators were trained regarding the content of the questions and made clarifications in case the respondents demanded explanations. They were also trained to approach different segments and split the survey implementation to different time zones of the day and different days of the week to ensure a balanced harmony. Although the assessors were well informed concerning the procedures of the survey implementation and the questions' content, any incompliance to these procedures or any misleading information or instruction from the assessors to the respondents posed a risk that could bias survey results. Furthermore, as the survey assesors were an employee of Turkish Airlines, they have approached primarily to Turkish Airlines passengers and asked for their participation. However, the ultimate level of effort was shown to mitigate these risks by continuously being in contact with the survey administrators and by immediately responding to their questions or requests in case they looked for the assistance.

As in the case for all surveys, the participant sample's appropriate representation of the passengers was another concern. This representation issue was sourced due to several reasons. First, since the respondents were selected in no particular manner by the assessors at the airport, their responses might have been influenced by any inconvenience during their experience at the airport. Second, the assessors might have approached respondents having no or very limited interest to schedule convenience, or those with no recent flight experience or they may have approached to an unbalanced mix of age, sex and occupation group. This representation related risks were managed by taking several precautions. First of all, the sample set was kept large including 1,053 valid responses. 91 surveys were eliminated from the analysis (962 remained) if the participant did not have travel experience in the past 12 months or did not place at least some importance to schedule convenience. Unreadable surveys were also eliminated from the analysis. Therefore, it was ensured that the respondents of the survey had at least one flight experience in the past year and they reported at least some interest to schedule convenience. Among 1,053 survey results, only 25 respondents marked that schedule convenience as not an important parameter of itinerary decision at all, contributing to 2.37% of the entire set. Moreover, the survey was implemented in 9 different international locations which ensured a good representative harmony. Besides, the survey administrators approached different customer segments at the different time of the days and different days of the week and they did their best to diversify the customer segments they approached. The survey did not ask any question concerning the profile of the participants including sex, age, nationality or occupation. Therefore, it was not possible to report concerning the profile of the participants.

13.5.2 Limitations Concerning the Scope of the Listed Carriers

The models developed within the course of the study are global and can be implemented to any market and airline operating in that market. However, the cases of the research focused on Europe, the Middle East and Africa in order to focus more on international traffic as the predominant markets in Northern America and the Asia Pacific are domestic routes. In this context, the schedule information of 36 listed carriers in these focus regions was included in the research database. The listed airlines were chosen among major FSC, LCC and hybrid carriers operating in Europe, Middle East and Africa and they cover the major portion of the traffic flow in the selected regions. Therefore, throughout the cases in Chapter 10 and the scenarios of those cases in Chapter 11, the performance of those 36 listed carriers were contrasted and benchmarked. However, other carriers whose database information was not added into the research database and therefore not included in the benchmark analysis might operate in the markets analysed. In this case, the research outputs would only be calculated in reference to the listed carriers' schedule data without including the non-listed airline timetable into the computation. This limitation could be mitigated by including the relevant carriers' schedule information into the research database. The research methodology does not have a limitation on the number of carriers to be analysed. Therefore, although the inclusion of only 36 carriers limits the competition analysis to be bounded by these carriers only, it does not affect the accuracy and credibility of the research's model as any airline's schedule could be inserted into the database for calculation.

13.5.3. Limitations Concerning the Data Sources

The schedules of the airlines were uploaded into the research database by taking a weekly snapshot from the summer schedules. Since airline scheduled services are repeated every week, a representative week was selected for the carriers. In this context, for each year, the final week of June was chosen. Therefore, it was assumed that the final week of June for each year is a well representative of the yearly schedules. It is a fact that airlines usually form two schedule seasons: winter and summer. They often increase capacity in the peak (summer) season and cut supply in the low (winter) seasons. June which is part of the summer term may have greater capacity in comparison to the winter schedule season; it is not the “peak of peak” season as in the case of late July or August – therefore a good term to pick as the representative week. However, there might exist some minor concerns over this selection for different reasons. For example, some of the listed airlines such as South African Airlines are based in the Southern hemisphere with reverse seasonality. Moreover, for some carriers, the peak, off-peak and shoulder seasons might not match with the other airlines. For instance, while June may be one of the peak seasons for the European carriers, it may not be the case for the Middle Eastern carriers like Saudi Arabian Airlines or EgyptAir celebrating Ramadan season (which also shifts by some days each year) when the demand for air travel falls.

13.5.4. Limitations Concerning the Coverage of the Methodology

The research was focused purely on schedule and network efficiency analysis of the airlines. For this reason, the deviation from the schedule, (namely the on-time performance) is kept out of the research’s scope as passengers do not base their decisions with regard to delay expectations. Any positive or negative reputation of a carrier in terms of on-time performance was evaluated within the context of brand perception and thus was excluded from the analysis as the product, and brand related factors were not embedded into the research model. There also exists other influential parameters effective in the itinerary selection which were not included within the scope of the research’s methodology. For instance, although it was verified in the survey results that, the fare is an important decision-making factor for the consumers (actually it was reported to be the most important one), it was not taken into account while designing the model. As the research’s hypothesis relied on schedule convenience, the fare parameter was excluded from the analysis. Furthermore, although the supply formed an integral aspect of the designed methodologies, demand was not considered to be part of the developed model as the research intention was not focused on advising the ideal capacity in a market.

13.6. Recommendations to the Industry

This research managed to demonstrate a stable positive relationship between schedule convenience, network efficiency and consumer welfare. As the airlines' commercial performance is highly linked with network performance and customer satisfaction, the research provided an indispensable decision support mechanism for the airline executives implying a commercial application of the study. On the other hand, due to the addition of a brand-new customer-centric perspective to network efficiency, supply determination, quality scores and market share estimation, a significant contribution to academic literature was attained. Airline executives can utilise this methodology as a decision support mechanism during their planning processes. Through the research's tool, they can assess the market performance effect of:

- Inserting or removing a frequency in an O&D
- Inserting or removing a new destination into the network
- Adjusting the departure and arrival time of a flight
- Changing the aircraft assigned to an O&D
- Adding or removing of a codeshare agreement
- The entrance or withdrawal of a competitor
- Allocating less or more capacity for connecting passengers
- Amending a codeshare agreement to sell/buy less or more capacity
- Extending or a reducing the hub airport's MCT
- Changing passenger views towards schedule related parameters

Industry practitioners can conduct scenario-based analyses for each of the cases mentioned above and observe the changes in the market performance through the REMSET model.

Not only the airline executives but also the airport authorities can benefit from the findings of the research. For example, it is invaluable information for airport management that the connecting passengers experience stress in case their first flight to the hub is delayed, which is the principal rationale behind their additional 30 minutes request (referring to t_{buffer}) as uncovered in the survey. On the other hand, extending the MCT would lead the airport to lose certain connecting traffic. Therefore, the decision makers in the airport authorities can quantitatively assess the trade-off in terms of airline traffic in case they extend or shrink the MCT. Moreover, it was also found in the survey that the majority of the passengers cannot tolerate more than 290 minutes of connection time (referring to MaxCT) at the hub airport. The airport authorities can use this market intelligence information while planning the facilities of the airport. Furthermore, the connection quality and the connectivity index (CI) values of the hub airports provide essential key performance indicators for the industry practitioners. Hence, this research can be utilised by several parties including airline executives, airport management and other industry practitioners for their organisation's strategic goals. Likewise, academics can benefit from this study and contribute to the model with the further research areas summarised below.

13.7. Further Research Areas

The methodologies introduced in this study can be enhanced with further research. First of all, a fare component can be injected into the model but the objective of the research was not to assess the fare impact. The realistic market share estimation calculations at the O&D basis can be customised with respect to the fare levels of the competing airlines. In this context, secondary data sources that present average fares of the rival carriers at each market (such as Infare) could be utilised. Such a study would also require the customisation of the model based on different consumer segments and market routes to be analysed. On the other hand, airlines' efforts to attract new passengers or retain the existing ones may have positive outcomes which may supersede schedule convenience or any factors including fare. Therefore, separate studies at the airline/brand level may be conducted to further enhance the credibility of the outputs or recognise the underlying dynamics in case a significant divergence exists between the estimated and actual market share figures. Thus, the REMSET model could be customised with respect to the airline brand by utilising secondary data sources. In this context, several institutions' quantitative metrics on brand such as Skytrax can be used to adjust the $q_{a\_index\_normalised}$ scores. Skytrax offers extensive ratings of the airlines for various dimensions which could be integrated into the REMSET model. Moreover, other sources of secondary data could be obtained (like developing another survey to quantify airline brand related metrics) to integrate the results into the REMSET model.

It is discovered in the passenger survey that punctuality has a central role in the decision-making processes of the consumers. Throughout this study, punctuality has been referred to as a component of airlines' brand image. However, as an area of further research, by employing secondary data sources concerning the airlines' punctuality, the REMSET model could be enhanced by adding an "adherence to schedule" parameter. The lower performance of an airline with the on-time-performance parameter should negatively impact the $q_{a\_index\_normalised}$ scores. Although the brand related factors and the on-time-performance are not orthogonally evaluated by passengers, halo effects do pertain as interactions between parameters which could be analysed with further research.

Consumers' schedule related expectations and priorities may change over time. For this reason, passengers' needs and preferences should continuously be monitored and airlines should redesign their network strategies by considering this valuable information. As the models introduced in this research are formed through adaptable parameters, the model can be readjusted to accommodate the changing needs and priorities of the consumers.

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Appendix A – Passenger Survey

The passenger survey that was used in this research is presented in the following 2 pages.

Thank you for accepting to participate in our survey. Please help us to understand your views on your travel preferences. Your responses will only be used for academic purposes. Your personal information is not required as part of this survey.

How many flights have you taken in the last 12 months? Travelling to one destination and back count as 1 round trip.	To what extent are you able to decide or influence the decision makers of your flight plans?
☐ No flights	☐ I make or influence my ALL flight decisions.
☐ 1 round-trip flight	☐ I make or influence MOST of my flight decisions.
☐ 2 – 5 round-trip flights	☐ I make or influence SOME of my flight decisions.
☐ 6 – 9 round-trip flights	☐ I RARELY make or influence my flight decisions.
☐ More than 10 round-trip flights	☐ I NEVER make or influence my flight decisions.

Have you taken any of these air trips in the past 5 years? (Please check any if your answer is YES)	Please rank the factors shaping your travel decision from the most important one to the least from 1 to 10. (1 / most important, 10 / least important) Use each number once only.
☐ Connecting flight	__ Date and time convenience
☐ Connecting flight with limited connection time (due to short connection time or late arrival of the first flight)	__ Fare
☐ Codeshare flight (booked in one airline but flown with another one)	__ Duration of the journey
☐ Long haul flight (more than 8 hours)	__ Frequent flyer programme
☐ Business or first class flight	__ Airline reputation
☐ Premium economy class flight	__ Departure and/or arrival airport
☐ Low-cost airline flight	__ On-board services (catering, in-flight entertainment, cabin service etc.)
☐ Domestic flight	__ Before and after flight services (CIP lounge, shuttle services etc.)
	__ Availability of flight alternatives (such as higher frequency per day)
	__ On-time performance and consistent schedule times

For each time interval below, please state the degree of convenience for departures and arrivals. 1 referring to the worst, 2 poor, 3 good, 4 the best time of the day. For example if you believe departing a city at 5 am in the morning is terrible please tick ☑ option "1" for row 04:00 – 05:59 for departure time section on the left, and if you believe it is good to arrive at the city at 5 am in the morning please tick ☑ option 3 for the arrival time section on the right.

Departure Time	Departure Time	1 Worst	2 Poor	3 Good	4 Best	Arrival Time	Arrival Time	1 Worst	2 Poor	3 Good	4 Best
	00:00-01:59	☐	☐	☐	☐		00:00-01:59	☐	☐	☐	☐
	02:00-03:59	☐	☐	☐	☐		02:00-03:59	☐	☐	☐	☐
	04:00-05:59	☐	☐	☐	☐		04:00-05:59	☐	☐	☐	☐
	06:00-07:59	☐	☐	☐	☐		06:00-07:59	☐	☐	☐	☐
	08:00-09:59	☐	☐	☐	☐		08:00-09:59	☐	☐	☐	☐
	10:00-11:59	☐	☐	☐	☐		10:00-11:59	☐	☐	☐	☐
	12:00-13:59	☐	☐	☐	☐		12:00-13:59	☐	☐	☐	☐
	14:00-15:59	☐	☐	☐	☐		14:00-15:59	☐	☐	☐	☐
	16:00-17:59	☐	☐	☐	☐		16:00-17:59	☐	☐	☐	☐
	18:00-19:59	☐	☐	☐	☐		18:00-19:59	☐	☐	☐	☐
	20:00-21:59	☐	☐	☐	☐		20:00-21:59	☐	☐	☐	☐
	22:00-23:59	☐	☐	☐	☐		22:00-23:59	☐	☐	☐	☐

If you need to take a connecting flight, what would be your maximum tolerance to wait in the connecting airport from the landing of your first flight until the departure of your second flight? (E.g. You are travelling from New York to Rome via Heathrow. How long would you be willing to spend in Heathrow airport maximum ?) ☐ Up to 2 hours ☐ Up to 3 hours ☐ Up to 5 hours ☐ Up to 8 hours ☐ Connection time is less important than other factors	There is a minimum time required for each airport to connect from one flight to another. Some people find the minimum time challenging as with any irregularity such as the late arrival of the first flight, they may misconnect or feel stressed. How much minimum additional time would you prefer to have to make the connection less stressful? ☐ No extra time required ☐ Minimum time + 15 minutes ☐ Minimum time + 30 minutes ☐ Minimum time + 45 minutes ☐ Minimum time + 1 hour ☐ Minimum time + more than 1 hour
There are two flight alternatives to your destination, one operated by the airline of your choice and the other a codeshare flight where you book with the airline of your choice but travel on a different airline. Under which conditions would you choose the codeshare flight? ☐ I would never choose a codeshare flight. ☐ I would only choose it if I had no other choice. ☐ I might choose a codeshare flight if it is more convenient. ☐ It really does not matter to me.	Which of the flight itinerary would you prefer for your travel from City A to City B ? $ signs are a depiction of the flight cost factor where more number of $ signs refers to a more expensive option. ☐ A direct flight of my favourite airline costing $$$$ ☐ A codeshare direct flight operated by an airline other than my choice costing $$$ ☐ A connecting (longer) flight of my favourite airline costing $$$ ☐ A connecting (longer) flight of an airline other than my regular choice costing $$

Let's suppose you will fly from City A to City B by connecting through City C. This is a long haul connecting flight with *INCONVENIENT* departure and arrival times taking *18 hours* for the whole journey. You paid 500 USD or this flight. Please answer the below questions taking 500 USD as the reference fare.

How much would you pay for the below-mentioned flight alternatives from City A to City B referencing the above case costing 500 USD? Please tick ☑ the value in USD or each case below. The leftmost column refers to less than 400 USD, where rightmost column refers more than 700 USD.	< 400 $	401 – 450 $	451 – 500 $	501 – 550 $	551 – 600 $	601 – 650 $	651 –700 $	>700 $
A connecting flight with *convenient* flight times lasting 18 hours	☐	☐	☐	☐	☐	☐	☐	☐
A direct flight taking 12 hours with convenient flight times	☐	☐	☐	☐	☐	☐	☐	☐
A direct flight taking 12 hours with inconvenient flight times.	☐	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with convenient flight times taking 18 hours	☐	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with inconvenient flight times taking 18 hours	☐	☐	☐	☐	☐	☐	☐	☐
A codeshare connecting flight with convenient flight times taking 15 hours	☐	☐	☐	☐	☐	☐	☐	☐
A codeshare direct flight with inconvenient times taking 12 hours	☐	☐	☐	☐	☐	☐	☐	☐

For a different journey, which of the connecting flight itineraries would you prefer for your travel from City D to City E? Total duration of the journey from D to E is 10 hours. ☐ First flight leg lasts 8 hours, the second leg lasts 1 hour and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 6 hours, the second leg lasts 3 hours and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 3 hours, the second leg lasts 6 hours and the connection time at the connecting airport is 1 hour. ☐ First flight leg lasts 1 hour, the second leg lasts 8 hours and the connection time at the connecting airport is 1 hour. ☐ It does not matter to me at all.	Which of the connecting flight itineraries would you prefer for your travel from City F to City G? (Assuming all other parameters of choice like fares, airline preference, schedule are identical) ☐ A connecting flight with a total 12 hours of journey time of which 3 hours are spent at the connecting airport ☐ A connecting flight with a total 12 hours of journey time of which only 1 hour is spent at the connecting airport

Appendix B: Survey Responses by Airport

<u>Survey Question #1: Frequency of Flights</u>

Table B1: Responses to Survey Question 1 – Frequency of Flights per Airport Surveyed

Airport	Number of Round Trip Flights				
	1 RT	2 RT	3 - 5 RT	6 - 9 RT	> 10 RT
Delhi	38	20	16	18	6
Dubai	14	14	51	19	7
Frankfurt	10	40	40	11	8
Geneva	12	33	45	21	2
Hong Kong	14	36	50	12	2
Istanbul	42	32	21	6	4
Johannesburg	31	20	33	11	6
London	10	16	47	23	12
New York	10	13	41	24	21
Total	181	224	344	145	68

Table B2: Weighted Average RT Flights Per Year

RT	DEL	DXB	FRA	GVA	HKG	IST	JNB	LON	NYC
Weighted Average	3.56	4.50	3.93	3.88	3.50	2.69	3.53	5.06	5.79

<u>Survey Question #2: Itinerary Decision Making</u>

Table B3: Itinerary Decision Making per Airport Surveyed

Airport	Power on Itinerary Decision Making				
	ALL	MOST	SOME	RARELY	NEVER
Delhi	14 (14.3 %)	37 (37.8 %)	29 (29.6 %)	15 (15.3 %)	3 (3.0 %)
Dubai	9 (8.5 %)	40 (38.3 %)	40 (38.0 %)	12 (11.4 %)	4 (3.8 %)
Frankfurt	25 (22.9 %)	48 (44.1 %)	30 (27.6 %)	4 (3.6 %)	2 (1.8 %)
Geneva	28 (24.8 %)	45 (39.8 %)	31 (27.4 %)	9 (8.0 %)	0 (0.0 %)
Hong Kong	19 (16.7 %)	51 (44.8 %)	32 (28.0 %)	11 (9.7 %)	1 (0.8 %)
Istanbul	12 (11.4 %)	46 (43.8 %)	37 (35.3 %)	6 (5.7 %)	4 (3.8 %)
Johannesburg	8 (7.9 %)	39 (38.6 %)	33 (32.7 %)	16 (15.9 %)	5 (4.9 %)
London	17 (15.7 %)	53 (49.1 %)	30 (27.8 %)	6 (5.5 %)	2 (1.9 %)
New York	21 (19.3 %)	42 (38.6 %)	35 (32.1 %)	8 (7.3 %)	3 (2.7 %)
Total	153	401	297	87	24

Survey Question #3: Positive Previous Experience

Table B4: Positive Previous Experiences per Airport Surveyed

	Delhi	Dubai	Frankfurt	Geneva	Hong Kong	Istanbul	Johannesburg	London	New York
Connecting Flight	75 (%76,5)	80 (%76,2)	90 (%82,6)	81 (%71,7)	73 (%64,0)	77 (%73,3)	87 (%86,1)	71 (%65,7)	80 (%73,4)
Connecting Flight with Limited Connection Time	33 (%33,7)	29 (%27,6)	60 (%55)	57 (%50,4)	45 (%39,5)	26 (%24,8)	14 (%13,9)	26 (%24,1)	15 (%13,8)
Codeshare flight	22 (%22,4)	17 (%16,2)	44 (%40,4)	35 (%31,0)	37 (%32,5)	26 (%24,8)	15 (%14,9)	46 (%42,6)	44 (%40,4)
Long Haul Flight	67 (%68,4)	77 (%73,3)	63 (%57,8)	52 (%46,0)	80 (%70,2)	58 (%55,2)	69 (%68,3)	73 (%67,6)	72 (%66,1)
Business / First Class Flight	21 (%21,4)	39 (%37,1)	48 (%44,0)	62 (%54,9)	35 (%30,7)	25 (%23,8)	30 (%29,7)	41 (%38,0)	58 (%53,2)
Premium Economy Flight	45 (%45,9)	20 (%19,0)	71 (%65,1)	38 (%33,6)	55 (%48,2)	14 (%13,3)	26 (%25,7)	61 (%56,5)	58 (%53,2)
Low Cost Flight	88 (%89,8)	75 (%71,4)	102 (%93,6)	103 (%91,2)	78 (%68,4)	103 (%98,1)	87 (%86,1)	93 (%86,1)	85 (%78,0)
Domestic Flight	94 (%95,9)	72 (%68,6)	98 (%89,9)	95 (%84,1)	76 (%66,7)	98 (%93,3)	69 (%68,3)	92 (%85,2)	99 (%90,8)

Survey Question #4: Importance Ranking

Table B5: Weighted Index of Importance Rankings Scores per Airport Surveyed (Lower Score Implies Higher Importance)

	Delhi	Dubai	Frankfurt	Geneva	Hong Kong	Istanbul	Johannesburg	London	New York	*Average*
Date and Time Convenience	5,11	5,06	4,62	4,12	4,94	5,08	5,12	4,41	4,24	*4,73*
Fare	2,62	3,22	3,56	3,91	3,42	2,87	2,70	3,49	3,53	*3,27*
Duration of Journey	6,07	6,13	6,01	6,00	5,88	6,11	6,16	5,89	5,95	*6,02*
Frequent Flyer Programme	5,14	5,95	6,54	6,94	6,15	6,08	5,11	6,89	7,15	*6,24*
Airline Reputation	4,87	4,99	5,72	5,82	5,55	5,22	4,87	5,93	5,82	*5,44*
Departure and/or Arrival Airport	6,57	6,71	6,12	6,56	6,92	5,78	6,33	5,77	5,95	*6,30*
On-board Services	6,44	4,88	5,99	5,65	5,39	5,99	6,22	6,01	5,98	*5,83*
Before and After Flight Services	6,89	6,61	6,30	5,97	6,28	6,79	7,00	6,57	6,45	*6,53*
Availability of Flight Alternatives	5,61	5,74	5,65	5,53	5,65	5,88	5,60	5,89	5,35	*5,65*
On Time Per. and Consistent Schedule Times	5,71	5,70	4,44	4,50	4,79	5,21	5,92	4,19	4,53	*4,98*

Survey Question #5: Departure Time Quality

Table B6: Mostly Selected Departure Time Scores for Time Intervals per Airport Surveyed.1 (Worst), 2 (Poor), 3 (Good), 4 (Best) Time.

	Delhi	Dubai	Frankfurt	Geneva	Hong Kong	Istanbul	Johannesburg	London	New York	*Average*
00:00 – 01:59	2	2	2	1	2	1	2	1	2	*2*
02:00 – 03:59	2	1	1	1	1	1	1	1	1	*1*
04:00 – 05:59	1	1	1	1	1	1	1	1	1	*1*
06:00 – 07:59	3	3	3	3	3	2	3	3	2	*3*
08:00 – 09:59	4	4	4	4	4	4	4	4	4	*4*
10:00 – 11:59	3	3	3	4	3	3	4	3	3	*3*
12:00 – 13:59	2	2	2	2	2	3	3	2	2	*2*
14:00 – 15:59	3	2	2	2	3	2	2	2	2	*2*
16:00 – 17:59	3	3	3	3	4	3	3	3	3	*3*
18:00 – 19:59	4	4	4	4	4	4	4	4	3	*4*
20:00 – 21:59	4	4	4	4	4	4	4	4	4	*4*
22:00 – 23:59	3	4	3	4	3	3	2	3	3	*3*

Survey Question #6: Arrival Time Quality

Table B7: Mostly Selected Arrival Time Scores for Time Intervals per Airport Surveyed. 1 (Worst), 2 (Poor), 3 (Good), 4 (Best) Time of the Day.

	Delhi	Dubai	Frankfurt	Geneva	Hong Kong	Istanbul	Johannesburg	London	New York	*Average*
00:00 – 01:59	2	1	1	1	2	1	1	1	1	*1*
02:00 – 03:59	1	1	1	1	1	1	1	1	1	*1*
04:00 – 05:59	1	1	1	1	1	1	1	1	1	*1*
06:00 – 07:59	2	2	3	2	2	2	3	2	2	*2*
08:00 – 09:59	4	4	4	3	4	4	4	4	3	*4*
10:00 – 11:59	3	3	4	3	4	4	3	3	3	*3*
12:00 – 13:59	4	4	3	4	3	4	4	4	4	*4*
14:00 – 15:59	4	3	3	3	3	3	4	3	4	*3*
16:00 – 17:59	4	4	4	3	3	4	4	4	4	*4*
18:00 – 19:59	3	3	3	4	3	3	3	4	3	*3*
20:00 – 21:59	2	3	2	2	2	2	2	3	3	*2*
22:00 – 23:59	3	3	2	2	2	3	2	2	2	*2*

Survey Question #7: Maximum Connection Time (MaxCT) Determination

Table B8: Computed Weighted Average MaxCT per Airport Surveyed

MaxCT	DEL	DXB	FRA	GVA	HKG	IST	JNB	LON	NYC
minutes	305	304	268	277	294	304	307	277	271
Standard deviation		16.2 minutes							

Survey Question #8: Buffer Time (t_{buffer}) Request

Table B9: Computed Weighted Average t_{buffer} per Airport Surveyed

	DEL	DXB	FRA	GVA	HKG	IST	JNB	LON	NYC
minutes	30.4	29.7	27.3	26.7	29.5	28.8	29.2	31.1	30.2
Standard Deviation		1.42 minutes							

Survey Question #9: Codeshare Convenience Question

Table B10: Responses to Codeshare Convenience Question at the Survey Airport Level

	Never choose codeshare	Choose only if no other choice	Can choose if codeshare flight more convenient	It does not matter at all
Delhi	33 (33.7%)	25 (25.5%)	19 (19.4%)	21 (21.4%)
Dubai	46 (43.8%)	32 (30.5%)	19 (18.1%)	8 (7.6%)
Frankfurt	30 (27.5%)	24 (22.0%)	36 (33.0%)	19 (17.5%)
Geneva	30 (26.5%)	28 (24.8%)	33 (29.2%)	22 (19.5%)
Hong Kong	35 (30.7%)	25 (22.0%)	24 (21.0%)	30 (26.3%)
Istanbul	39 (37.0%)	26 (24.8%)	20 (19.1%)	20 (19.1%)
Johannesburg	46 (45.5%)	31 (30.7%)	17 (16.9%)	7 (6.9%)
London	30 (27.8%)	23 (21.3%)	32 (29.6%)	23 (21.3%)
New York	27 (24.8%)	24 (22.0%)	27 (24.8%)	31 (28.4%)

Survey Question #10: Fare, Schedule Convenience and Flight Type Relation Question

Table B11: Responses to Question 10 at the Survey Airport Breakdown

	Direct, operating, $$$$	Direct, non-operating, $$$	Connecting, operating, $$$	Connecting, non-operating, $$
Delhi	18 (%18.4)	19 (%19.4)	35 (%35.7)	26 (%26.5)
Dubai	25 (%23.8)	24 (%22.8)	28 (%26.7)	28 (%26.7)
Frankfurt	30 (%27.5)	24 (%22.0)	29 (%26.6)	26 (%23.9)
Geneva	24 (%21.2)	25 (%22.1)	30 (%26.6)	34 (%30.1)
Hong Kong	25 (%21.9)	26 (%22.8)	35 (%30.7)	28 (%24.6)
Istanbul	21 (%20.0)	24 (%22.8)	34 (%32.4)	26 (%24.8)
Johannesburg	15 (%14.9)	21 (%20.8)	37 (%36.6)	28 (%27.7)
London	26 (%24.1)	30 (%27.8)	33 (%30.5)	19 (%17.6)
New York	23 (%21.1)	27 (%24.8)	33 (%30.3)	26 (%23.8)

Survey Question #13: Flight Time or Connecting Time (%t_f or %t_c)

Table B12: Responses to Question 13 at the Survey Airport Breakdown

	... of which 3 hours is spent at hub airport	... of which only 1 hour is spent at hub airport
Delhi	46 (%46.9)	52 (%53.1)
Dubai	61 (%58.1)	44 (%41.9)
Frankfurt	62 (%56.9)	47 (%43.1)
Geneva	51 (%45.1)	62 (%54.9)
Hong Kong	65 (%57.0)	49 (%43.0)
Istanbul	49 (%46.7)	56 (%53.3)
Johannesburg	46 (%45.5)	55 (%54.5)
London	58 (%53.7)	50 (%46.3)
New York	60 (%55.0)	49 (%45.0)

Appendix C: Screenshots From www.phdsukru.com

The listed airlines' schedule, the airports MCT information, survey findings and research methodologies were uploaded to www.phdsukru.com. All the computations performed as part of this research were conducted via using this web platform to ensure error-free, fast and efficient computations. The following sections include some screenshots from www.phdsukru.com.

Image C1: Login Page

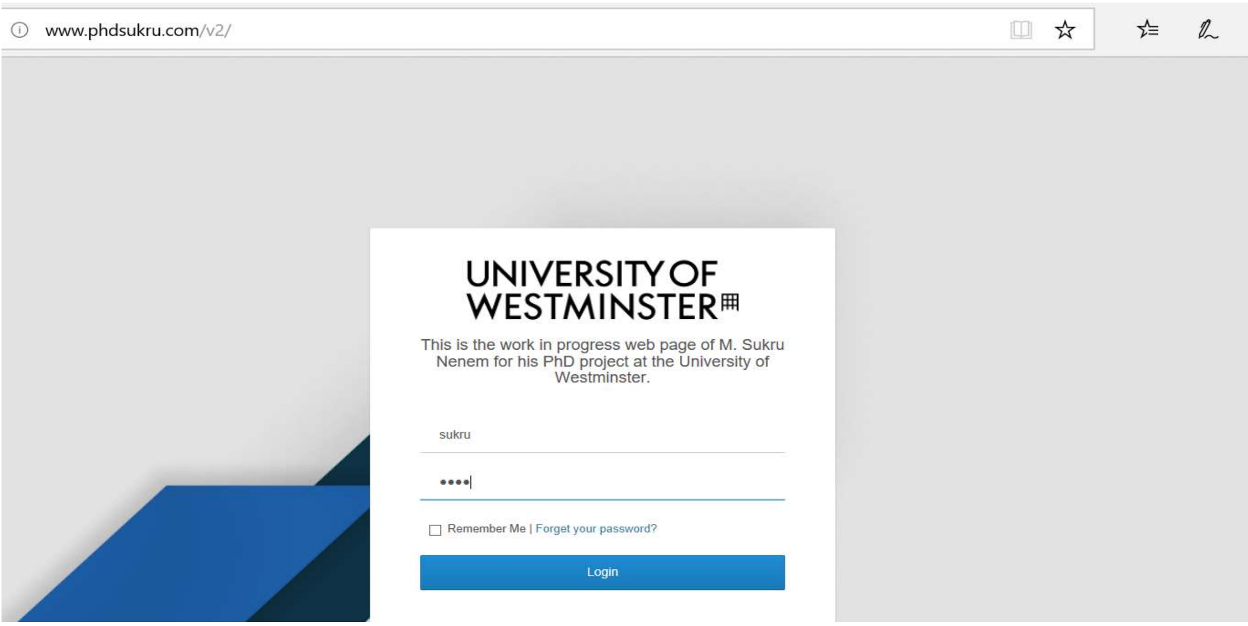


Image C2: Schedule Search

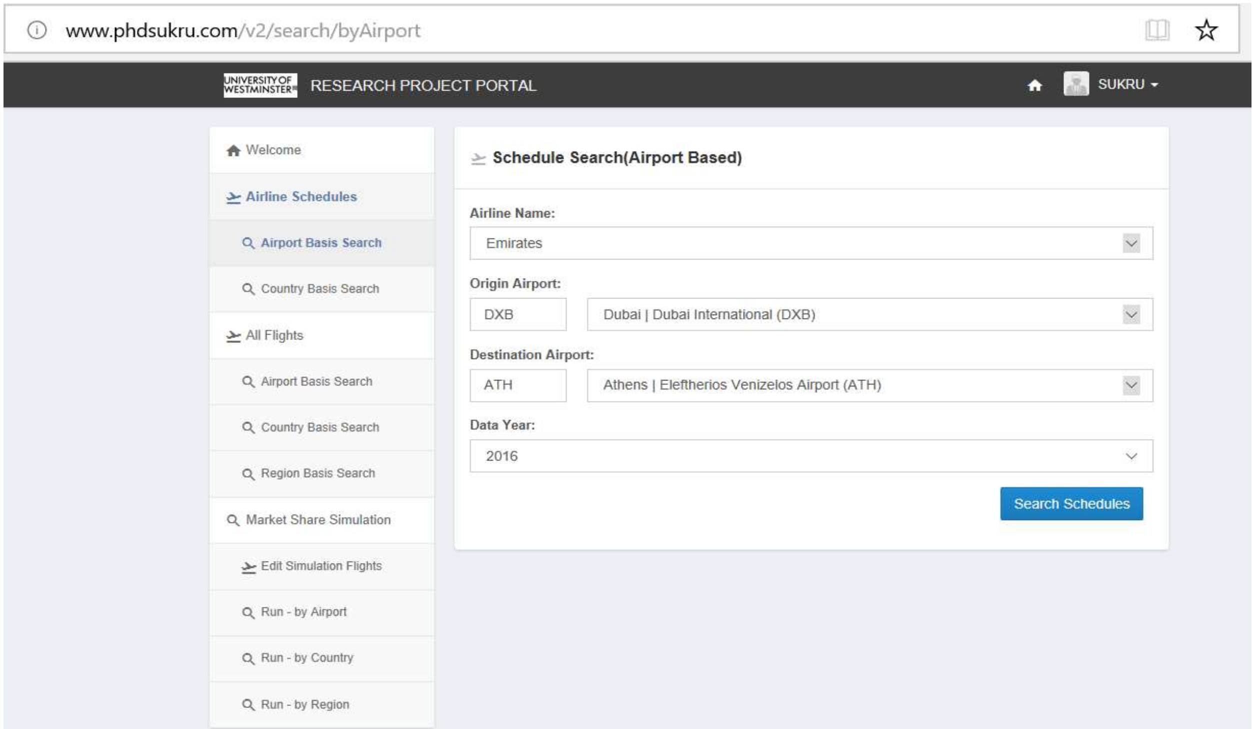
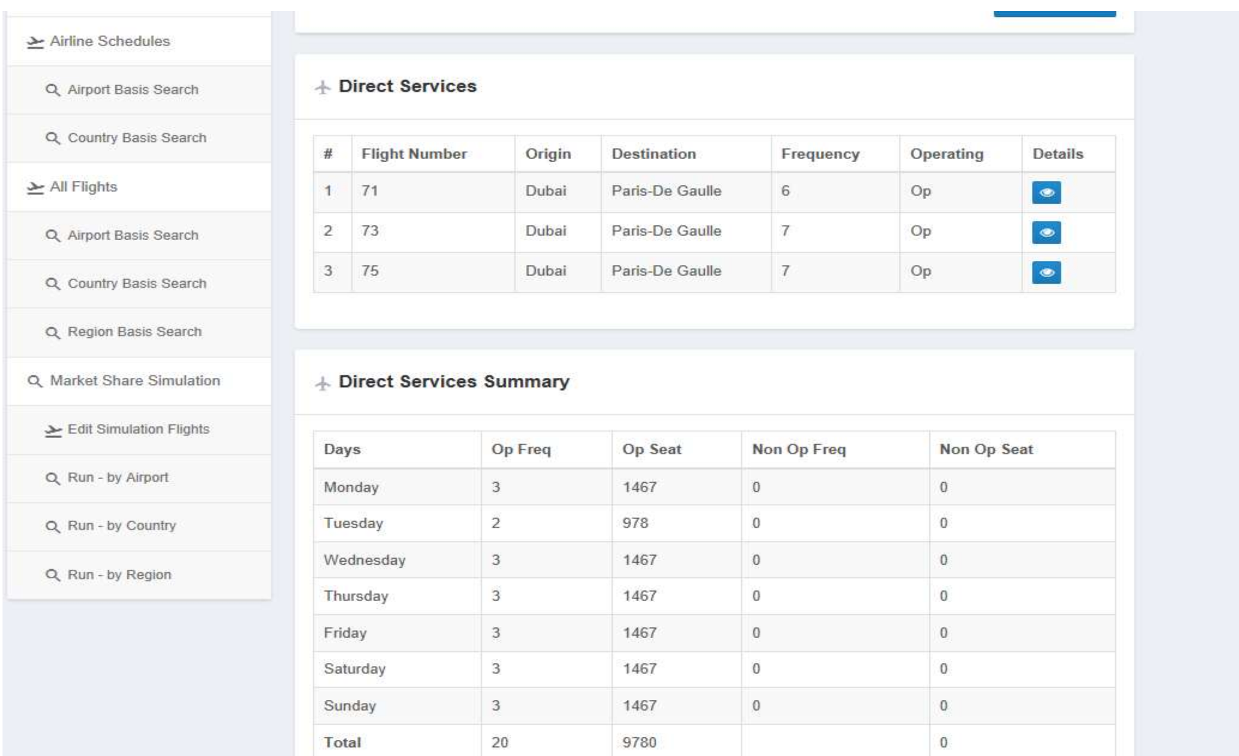


Image C3: Schedule Search Results



#	Flight Number	Origin	Destination	Frequency	Operating	Details
1	71	Dubai	Paris-De Gaulle	6	Op	
2	73	Dubai	Paris-De Gaulle	7	Op	
3	75	Dubai	Paris-De Gaulle	7	Op	

Days	Op Freq	Op Seat	Non Op Freq	Non Op Seat
Monday	3	1467	0	0
Tuesday	2	978	0	0
Wednesday	3	1467	0	0
Thursday	3	1467	0	0
Friday	3	1467	0	0
Saturday	3	1467	0	0
Sunday	3	1467	0	0
Total	20	9780		0

Image C4: Direct Flight Itinerary Reporting

Flight Details (Emirates EK 73 DXB CDG) Back to Results

Departure Dubai - Dubai International

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	08:20	08:20	08:20	08:20	08:20	08:20	08:20

Arrival Paris-De Gaulle - Charles De Gaulle

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Local Time	13:30	13:30	13:30	13:30	13:30	13:30	13:30

Seat Capacity

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
# of Seats	489	489	489	489	489	489	489

Time Quality

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure	4	4	4	4	4	4	4
Arrival	4	4	4	4	4	4	4

Some Reportings

Weekly Frequency	7
Operating / Non - Operating	OP
Total Average Number of Stops	0
Total Average Journey Time	07:10
Total Average Kilometers Travelled	5245
Total Number of Seats Per Week	3423
Does Flight Exist Everyday ?	Yes
Avg. Departure Time Quality Score	4.0
Avg. Arrival Time Quality Score	4.0
Consistent Departure Time	Yes
Consistent Arrival Time	Yes

Image C5: Connecting Services Search Results

Connecting Services

Flight Combin	Origin	Via (MCT)	Waiting Time	Destination	Freq.	1st Leg	2st Leg	Seats	Details
562 / 9201	Zurich	Vienna (30')	00:40	Antalya	1	Op	Op	35	
568 / 9201	Zurich	Vienna (30')	02:15	Antalya	2	Op	Op	70	
572 / 9201	Geneva	Vienna (30')	00:40	Antalya	1	Op	Op	20	
578 / 9201	Geneva	Vienna (30')	02:30	Antalya	2	Op	Op	32	
8802 / 9201	Zurich	Vienna (30')	02:55	Antalya	2	Non Op	Op	26	
8804 / 9201	Zurich	Vienna (30')	02:45	Antalya	1	Non Op	Op	6	
8806 / 9261	Zurich	Vienna (30')	01:20	Dalaman	1	Non Op	Op	11	

Image C6: Connecting Services Itinerary Reporting

Connecting Flight Details (OS 578 - OS 9201)

Back to Results

OS 578 Geneva - Geneva International Airport - Vienna - Vienna International

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	07:15	07:15	07:15	07:15	07:15	07:15	-
Arrival Time	08:55	08:55	08:55	08:55	08:55	08:55	-

OS 9201 Vienna - Vienna International - Antalya - Antalya

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	-	-	10:20	-	12:30	-	16:50
Arrival Time	-	-	13:55	-	16:10	-	20:30

Connecting Flights

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
First Departure	-	-	07:15	-	07:15	-	-
First Arrival	-	-	08:55	-	08:55	-	-
Waiting Duration	-	-	**01:25**	-	**03:35**	-	-
Second Departure	-	-	10:20	-	12:30	-	-
Second Arrival	-	-	13:55	-	16:10	-	-

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Available Seats	-	-	16	-	16	-	-

Time Quality

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure	-	-	3	-	3	-	-
Arrival	-	-	4	-	4	-	-

Some Reportings

Weekly Frequency	2
Operating Status	Op/Op
Total Average Number of Stops	1
Total Average Journey Time	06:47
Total Average Kilometers Travelled	2522
Total Number of Seats Per Week	32
Does Flight Exist Everyday ?	No
Avg. Departure Time Quality Score	3,0
Avg. Arrival Time Quality Score	3,3
Consistent Departure Time	Yes
Consistent Arrival Time	Yes

Image C7: Analysing a Route GYD – AMS Market

www.phdsukru.com/v2/search/all/byAirport/gyd/ams/2016

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Search Results (GYD | AMS)

Edit Search

All Flights | Flights Summary & Market Share Results

Export to Excel

Search

Flight(s)	Type	Origin	Destination	Via	Freq	Stops	Op Stat	Avg Con Time	Avg Flight Time	Total Time	Avg KM	Total Seats	Dep Score	Arr Score	Cons Arr Time	Cons Dep Time	1st Leg	2nd Leg	MCT Surplus
AF 8177 / 8234	Beyond	Baku	Amsterdam	Paris-De Gaulle (CDG)	4	1	Non Op/Non Op	04:30	06:45	11:15	4213	35	3	3	Yes	Yes	05:30	01:15	02:00
KL 2931 / 3181	Beyond	Baku	Amsterdam	Moscow-Sheremetyevo (SVO)	7	1	Non Op/Non Op	02:15	06:35	08:50	4109	59	1	4	Yes	Yes	03:05	03:30	00:40
KL 2933 / 3182	Beyond	Baku	Amsterdam	Moscow-Sheremetyevo (SVO)	7	1	Non Op/Non Op	02:30	06:40	09:10	4109	59	2	2	Yes	Yes	03:10	03:30	00:55
LH 613 / 988	Beyond	Baku	Amsterdam	Frankfurt (FRA)	6	1	Op/Op	00:55	06:20	07:15	3743	202	1	3	Yes	Yes	05:10	01:10	00:10
LH 613 / 992	Beyond	Baku	Amsterdam	Frankfurt (FRA)	6	1	Op/Op	04:00	06:20	10:20	3743	240	1	4	Yes	Yes	05:10	01:10	03:15
QR 248 / 273	Beyond	Baku	Amsterdam	Doha (DOH)	4	1	Op/Op	01:05	09:35	10:40	6614	106	1	4	Yes	Yes	02:50	06:45	00:20
SU 1853 / 2550	Beyond	Baku	Amsterdam	Moscow-Sheremetyevo (SVO)	7	1	Op/Op	02:15	06:35	08:50	4109	196	1	4	Yes	Yes	03:05	03:30	00:40

Image C7: Flights Summary in the GYD-AMS Market

Search Results (GYD | AMS)

Flights Summary

Type	Airline	Available Freq	Available Seats	Avg Con Time	Avg Flight Time	Total Time	KM	Daily Service	1st Leg Duration	2nd Leg Duration	Time Quality Score
Beyond	AF	4	35	04:30	06:45	11:15	4213	No (4/7)	05:30	01:15	0,7258
Beyond	KL	14	118	02:22	06:37	09:00	4109	Yes	03:07	03:30	0,7985
Beyond	LH	6	240	02:35	06:20	08:55	3743	No (6/7)	05:10	01:10	0,8887
Beyond	QR	4	106	01:05	09:35	10:40	6614	No (4/7)	02:50	06:45	1,0580
Beyond	SU	14	392	02:22	06:37	09:00	4109	Yes	03:07	03:30	1,0313
Beyond	TK	31	1055	02:43	06:50	09:34	4004	Yes	03:09	03:40	0,9376

Total 6 records, between 1 - 6

Image C8: Market Share Estimation in the GYD-AMS Market

Market Shares

Type	Airline	Freq Share	Seat Share	Adj Seat Share	Time Index	KM Index	PR & QU Normalized	UNAD Share	Total Share	Fair Market Share
Beyond	AF	5,48 %	1,80 %	1,08 %	1,260	1,126	0,5758	0,62 %	0,69 %	0,69 %
Beyond	KL	19,18 %	6,04 %	6,35 %	1,008	1,098	0,7920	5,03 %	5,59 %	5,59 %
Beyond	LH	8,22 %	12,34 %	11,11 %	1,000	1,000	0,8887	9,88 %	10,98 %	10,98 %
Beyond	QR	5,48 %	5,43 %	3,26 %	1,195	1,767	0,8854	2,89 %	3,21 %	3,21 %
Beyond	SU	19,18 %	20,15 %	21,18 %	1,008	1,098	1,0228	21,66 %	24,08 %	24,08 %
Beyond	TK	42,47 %	54,24 %	57,01 %	1,072	1,070	0,8746	49,86 %	55,44 %	55,44 %

Total 6 records, between 1 - 6

Image C9: Country Based Search from Germany to Japan

Search Results (DE | JP)

Edit Search

All Flights | Flights Summary & Market Share Results

Export to Excel

Search

Flight(s)	Type	Origin	Destination	Via	Freq	Stops	Op Stat	Avg Con Time	Avg Flight Time	Total Time	Avg KM	Total Seats	Dep Score	Arr Score	Cons Arr Time	Cons Dep Time	1st Leg	2nd Leg	MCT Surplus
BA 4602	Direct	Frankfurt	Tokyo-Narita	-	7	0	Non Op	-	11:20	11:20	9389	350	4	4	Yes	Yes	11:20	-	-
LH 710	Direct	Frankfurt	Tokyo-Narita	-	3	0	Op	-	11:35	11:35	9389	279	2	4	Yes	Yes	11:35	-	-
LH 714	Direct	Munich	Tokyo-Haneda	-	7	0	Op	-	11:35	11:35	9381	297	3	3	Yes	Yes	11:35	-	-
LH 716	Direct	Frankfurt	Tokyo-Haneda	-	7	0	Op	-	11:10	11:10	9382	364	4	4	Yes	Yes	11:10	-	-
LH 736	Direct	Frankfurt	Nagoya	-	3	0	Op	-	11:25	11:25	9316	279	2	4	Yes	Yes	11:25	-	-
LH 740	Direct	Frankfurt	Osaka-Kansai	-	7	0	Op	-	10:50	10:50	9284	371	2	2	Yes	Yes	10:50	-	-
LH 4912	Direct	Frankfurt	Tokyo-Haneda	-	7	0	Non Op	-	11:10	11:10	9382	212	4	3	Yes	Yes	11:10	-	-
LH 4924	Direct	Munich	Tokyo-Haneda	-	7	0	Non Op	-	11:25	11:25	9381	215	4	3	Yes	Yes	11:25	-	-
LH 4948	Direct	Frankfurt	Tokyo-Haneda	-	7	0	Non Op	-	11:25	11:25	9382	212	2	2	Yes	Yes	11:25	-	-
LH 4962	Direct	Duesseldorf	Tokyo-Narita	-	7	0	Non Op	-	11:25	11:25	9357	169	4	3	Yes	Yes	11:25	-	-
AB 4000 / 4058	Beyond	Frankfurt	Tokyo-Narita	Abu Dhabi (AUH)	5	1	Non Op/Non Op	02:10	16:50	19:00	12972	79	3	4	Yes	Yes	06:40	10:10	01:10

Image C10: Adding a Simulation Flight

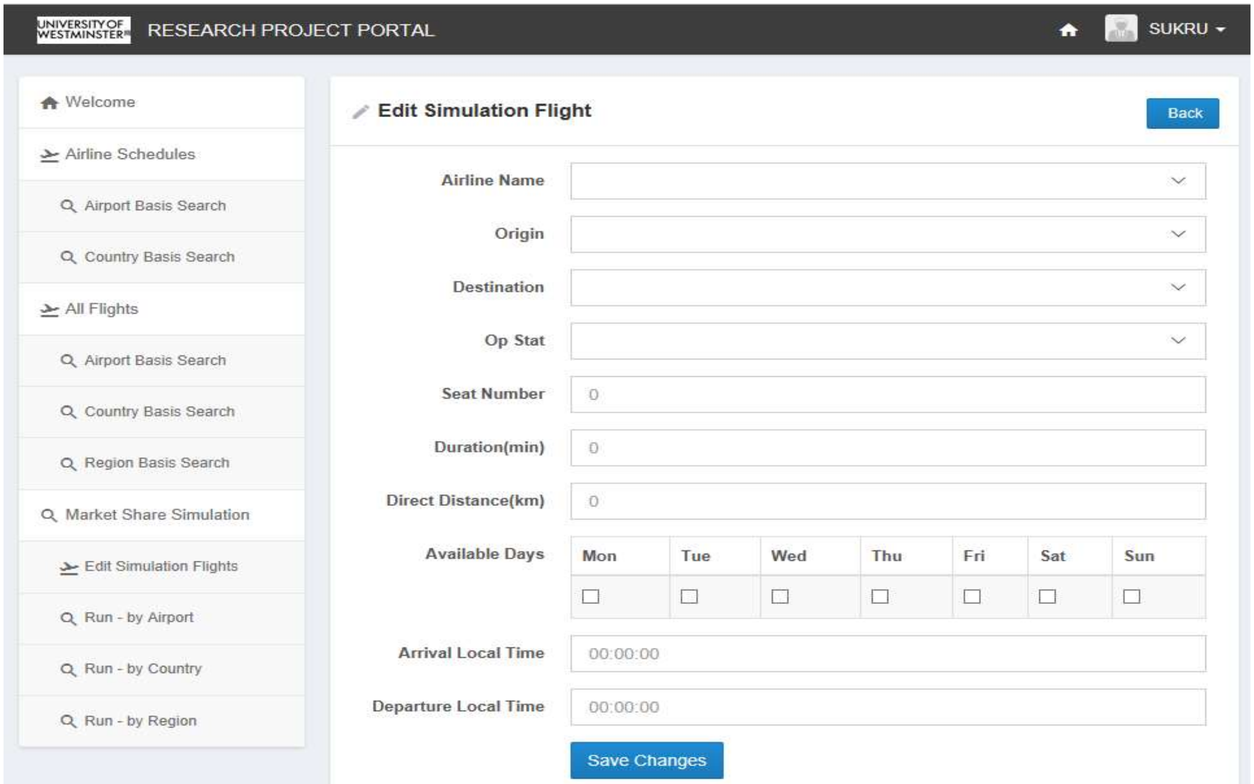
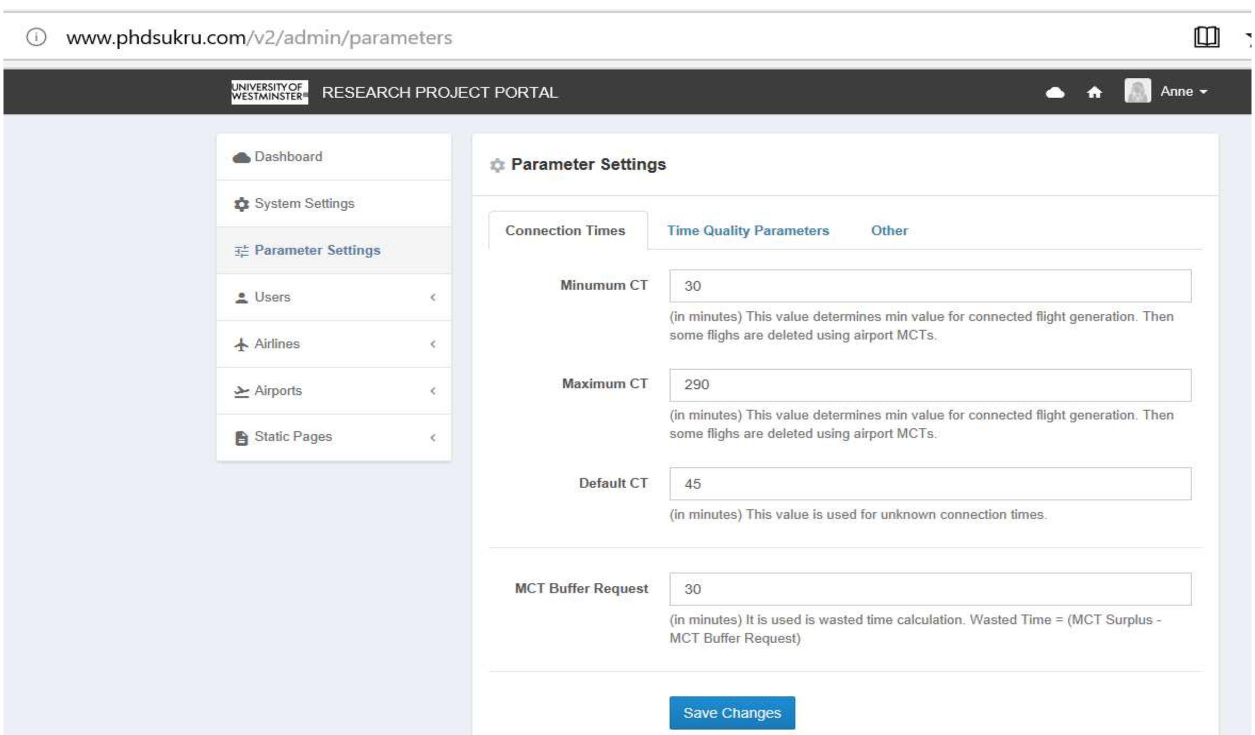


Image C11: Parameter Setting Page



Appendix D: Case Study

Having iterated through all steps of the REMSET in Chapter 9, this appendix introduces a case study from 2016 schedule data. As part of the case study, the competition from Almaty, Kazakhstan (ALA) to Milan-Malpensa, Italy (MXP) is analysed.

D.1. Capacity Share ($\%_{a\_s}$) Calculation of the Case Study

As per the schedule database of the listed airlines as of 2016, there were no direct services present from ALA to MXP. Considering the MaxCT to be 290 minutes as discovered in passenger survey, three airlines offered online connecting services: Lufthansa (LH) via Frankfurt (FRA), Aeroflot (SU) via Moscow-Sheremetyevo (SVO) and Turkish Airlines (TK) via Istanbul (IST). Daily seat availabilities for each combination under $s_{conn} = 0.2$ assumptions were as follows:

Table D.1: Daily Seat Availabilities from ALA to MXP for LH, SU and TK Combinations.

	Via	Mon	Tue	Wed	Thu	Fri	Sat	Sun
LH647/LH248	FRA		34		34		34	34
SU1947/SU2612	SVO	28	28	28	28	28	28	28
TK351/TK1895	IST	34	34	34	34	34	34	34
TK353/TK1875	IST			34		34		34

The above table shows four distinct hits, fetched from the daily capacities of the individual legs composing the connections. The daily seat capacities of the individual legs are shown in the table below.

Table D.2: Seat Capacities of Individual Legs Composing the Combinations.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
LH647		216		216		216	216
LH248	168	168	168	168	168	168	168
SU1947	170	170	170	170	170	170	170
SU2612	140	140	140	140	140	140	140
TK351	169	169	169	169	169	169	169
TK1895	178	178	178	178	178	180	178
TK353			169		169		169
TK1875	180	178	178	178	178	178	178

For LH, the LH647 frequency was the limitation as it was only operated four times a week, while LH248 was operated daily. On the other hand, the seating capacity of the ALA–MXP connection was limited by the LH248's capacity as its seats were less than the seat count of LH647 (capacity constraint). Therefore, the seating capacity of the LH647–LH248 combination was equal to (s_{conn} x s_{LH248}) for the days that LH647 flight was operated. Since LH248 operated with a 168 seat capacity aircraft, the number of connecting seats in the route was then calculated to be 168 x 0.2 =33.6 (rounded up to 34 in Table 9.20), operated on Tuesdays, Thursdays, Saturdays and Sundays. For the SU combination, the frequency was not limited as both legs were operated daily. However, connecting seats were bottlenecked by the SU2612 flight as its capacity was less than SU1947. The number of available seats for the SU connection was therefore equal to (s_{conn} x s_{SU2612}) = 140 x 0.2 = 28, for each day of the week. For the TK connections, there existed two combinations. The TK351-TK1895 combination was operated daily, where TK351 formed the seat constraint, therefore presenting s_{conn} x s_{TK351} = 169 x 0.2 = 33.8 (rounded to 34 in Table 9.20) seats daily. Moreover, the TK353-TK1875 combination was operated three times a week since TK353 only operates on Wednesdays, Fridays and Sundays. TK353 constrainted the combination in terms of seat availability, offering 169 x 0.2 = 33.8 (rounded up to 34 in Table 9.20) seats for those days. Therefore, the final table summarizing weekly frequencies and seat availabilities of the competing airlines in the ALA–MXP market were as follows: (Rounded numbers of available seats at the daily level are not summed together in order not to over escalate weekly capacity. Instead, daily figures are summed in decimals and then rounded up or down.)

Table D.3: Consolidated Frequency and Available Seat Table from ALA to MXP.

Airline	Frequency/week	Available Seats/week
LH / Lufthansa	4	134 (rounded down from 134.4)
SU / Aeroflot	7	196
TK / Turkish Airlines	10	237 from TK351/TK1895 (rounded up from 236.6) and 101 from TK353/TK1875 (rounded down from 101.4) therefore 338 seats in total
Total	21 frequencies	668 seats

As of the 2016 schedules of the listed carriers, there were 21 distinct frequencies from ALA to MXP offering a total of 668 seats. The capacity per cent shares in terms of weekly frequencies and available seats were calculated as follows:

Table D.4: Frequency and Available Seat Share of Carriers Offering Services from ALA to MXP.

Airline	Frequency Share ($\%_f$)	Available Seat Share ($\%_s$)
LH / Lufthansa	19.05%	20.06%
SU / Aeroflot	33.33%	29.34%
TK / Turkish Airlines	47.62%	50.60%

As observed in the above table, an airline's frequency share and seat share may differ because of divergences with the seats per frequency factor, s_f which is directly linked with parameters such as aircraft size, itinerary type and capacity constraints for the connecting services. In the case of ALA–MXP, the divergences with the s_f are sourced because of the different aircraft size of each carrier. It is inferred from Table 9.22 that SU offered the fewest seats available per frequency in the market, which was equal to 196 / 7 = 28. Seat per frequency for LH and TK was 33.5 and 33.8 respectively. It is also observed in the table that LH did not offer daily connections from ALA to MXP. It was operated only four days a week, whereas the other airlines offered daily services. Thus, an adjustment in seat capacity was required, employing waste capacity discount model. This adjustment intended to calculate effective seat supply for each airline serving in the market.

To calculate the effective seats, LH's seat count was needed to be discounted by 3/7, which corresponds to a decrease from 134 to 76.5 seats. Since 57.5 seats were wasted, for the sake of the adjusted capacity share calculation, the total amount of the available seats was reduced from 668 to 610.5 seats. Using the effective seats, the adjusted capacity share for each airline is calculated in the table below: (Numbers are not rounded, shown in decimals.)

Table D.5.: Adjusted/Effective Seats and Corresponding Percent Shares of Carriers Operating from ALA to MXP.

Airline	Effective Seats (s)	Adjusted Capacity Share ($\%_{a\_s}$)
LH / Lufthansa	76.5	76.5/610.5 = 12.53%
SU / Aeroflot	196	196/610.5 = 32.11%
TK / Turkish Airlines	338	338 / 610.5 = 55.36%
Total	610.5	100%

Up to this point, the capacity shares of each airline competing in the market were calculated. The next set of procedures intended to quantify the corresponding schedule related quality scores of those available capacities.

D.2. Quality Calculation of the Case Study

D.2.1. LH Flights: For the single LH647/LH248 combination, the below table shows the scheduled timetable of the individual legs composing the connecting itinerary.

Figure D.1: Schedule Information of LH Combination from ALA to MXP.

LH 647 Almaty - Almaty International - Frankfurt - Frankfurt International Airport

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	-	03:50	-	03:50	-	03:50	03:50
Arrival Time	-	07:00	-	07:00	-	07:00	07:00

LH 248 Frankfurt - Frankfurt International Airport - Milan-Malpensa - Malpensa

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	09:10	09:10	09:10	09:10	09:10	09:10	09:10
Arrival Time	10:20	10:20	10:20	10:20	10:20	10:20	10:20

The connecting LH service departs ALA at 03:50 and arrives in FRA at 07:00 in the morning. After 130 minutes of connecting time at FRA airport, the flight to MXP departs at

09:10 and arrives in final destination at 10:20. These timings are consistent for each of the four frequencies offered within the week, where all timings are local. Therefore this journey is completed in 10 hours and 30 minutes in total. In other words, t_{total} = 630 minutes. Of the 630 minutes, t_{conn} is calculated to be 130 minutes (2 hours and 10 minutes) and the remaining 500 minutes (8 hours and 20 minutes) is the t_{flight}. Since the daily seat capacity for each four days of the connections is identical, these figures are all the same for the weekly analysis of the LH647/LH248 combination.

The connecting time for the LH647/LH248 combination is greater than the sum of passengers' buffer time request and the MCT of FRA airport. The MCT of Frankfurt airport is 45 minutes and t_{buffer} was found to be 30 minutes by the passenger survey. Therefore, with t_{conn} = 130 minutes, travellers would be wasting some time at FRA airport. The wasted time is t_{waste} = t_{conn} – MCT - t_{buffer} = 130 – 45 – 30 = 55 minutes. Since the waste time is a non-zero parameter, passengers travelling from ALA to MXP via FRA with the LH connecting service do not experience any stress, deeming t_{stress} to be 0 minutes.

Since for each day of the week, the same seat capacity and departure - arrival times exist, weekly average values of t_{stress} and t_{waste} are also equal to 0 and 55 minutes respectively. Weight averaging with respect to seat supply would equate daily figures with the weekly averages, as both timings and seat supply within the days of the week are identical. With this information in mind, weekly average $t_{inconvenient}$ for the LH647–LH258 hit is equal to (t_{stress} + t_{waste}) = 55 minutes. Therefore, inconvenient time ratio $\%_{inconvenience}$ is ($t_{inconvenient}$ / t_{total}) = 55 / 630 equal to 8.73%.

LH passengers depart from ALA at 03:50 local time to their hub destination FRA. The survey found that such a timing is one of the least preferred time intervals to depart a city, scoring q_{dep} = 1. The passengers' local arrival time to MXP from FRA is 10:20. As per the survey results, this is a better timing compared to the departure time, scoring q_{arr} = 3. Moreover, it is required to determine if the itinerary qualifies for an additional q_{split} score. To be able to accomplish this calculation, the following table is prepared:

Table D.6: Flight Time Duration of LH647/LH248's Legs and Their Corresponding Per Cent Share Within t_{flight}

Flight	Duration	% within t_{flight}
LH647	430 minutes	86%
LH248	70 minutes	14%
Total t_{flight}	500 minutes	100%

Under $\%_{q\_split}$ is 0.8 or 80% assumption, it is deduced that the longer flight leg (LH647) composing the itinerary exceeds $\%_{q\_split}$, therefore qualifying for an additional q_{split} score which is set to be 1. Therefore time convenience quality, $q_{convenience}$, for this combination is computed as (q_{dep} + q_{arr} + q_{split}) = 1 + 3 + 1 = 5. Again the weekly average of $q_{convenience}$ is still equal to 5, as the departure-arrival times are unchanged within the days of the week.

To assess the quality index value of this combination, Table 9.11 is to be referred to. Considering the itinerary is a connecting service where both legs are operating flights of LH, as per the table, q_{index} value changes between 1.000 and 1.131. The lowest $q_{convenience}$ (which is equal to 2) would result in a q_{index} of 1.000 where the highest (that is equal to 9) would deem the figure to be 1.131. Assuming q_{index} is distributed linear within these boundaries, q_{index} is calculated as $(1.000 + \frac{(5-2)}{7} * (1.131 - 1.000))$ = 1.0561 as $q_{convenience}$ is equal to 5. In the next step, it is required to normalise the quality index as the itinerary encapsulate an inconvenient time ratio of 8.73% implying that q_{index} needs to be discounted by 8.73% to calculate the $q_{index\_normalised}$. Therefore $q_{index\_normalised}$ is measured as 1.0561 x (100% - 8.73%) = 0.9639.

D.2.2. SU Flights: For the single SU1947/SU2612 combination, the below table shows the scheduled timetable of the individual legs composing the connecting itinerary.

Figure D.2: Schedule Information of SU Combination from ALA to MXP.

SU 1947 Almaty - Almaty International - Moscow-Sheremetyevo - Sheremetyevo

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	05:50	05:50	05:50	05:50	05:50	05:50	05:50
Arrival Time	07:45	07:45	07:45	07:45	07:45	07:45	07:45

SU 2612 Moscow-Sheremetyevo - Sheremetyevo - Milan-Malpensa - Malpensa

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	11:10	11:10	11:10	11:10	11:10	11:10	11:10
Arrival Time	13:45	13:45	13:45	13:45	13:45	13:45	13:45

For each day of the week, the flight departs from ALA at 05:50, arrives at SVO at 07:45 local time. Daily seat capacities are also identical where 28 seats are offered each day. Therefore, the calculations performed at the daily level from here onwards also refers to weekly average values for all parameters.

After 205 minutes of t_{conn} at SVO airport, SU2612 flight departs 11:10 and arrives at MXP at 13:45 local time. Therefore, the total journey time is 715 minutes (11 hours and 55 minutes). The t_{flight} is equal to 715 – 205 = 510 minutes. As of 2016, considering the MCT for international connections at SVO airport is 95 minutes, MCT Surplus is calculated as 205 – 95 = 110 minutes. Since MCT Surplus is greater than t_{buffer}, travellers flying from ALA to MXP via SU would be wasting (MCT Surplus - t_{buffer}) = (110 – 30) = 80 minutes at SVO airport. Since no stress time is created with this itinerary, total inconvenient time is equal to 80 minutes. The inconvenient timeshare, $\%_{inconvenient}$, within t_{total} is calculated as 80 / 715 = 11.2%

Passengers travelling on this itinerary depart from ALA at 05:50, the most unpopular time to leave the city referring $q_{dep} = 1$, whereas they land to MXP at 13.45, the most convenient time to arrive, implying $q_{arr} = 4$. On the other hand, since the first leg's duration is 4 hours and 55 minutes and the second flight takes 3 hours and 35 minutes, none of the legs exceed $\%_{q\_split}$

of 80%, and hence no flight qualifies for an additional q_{split} score. Therefore, the $q_{convenience}$ score is 5.

Since the SU itinerary is a connecting service where both legs are operating flights, as per Table 9.11, q_{index} value changes between 1.000 and 1.131. The lowest $q_{convenience}$ (which is equal to 2) would result in a q_{index} of 1.000, where the highest (that is equal to 9) would deem the figure to be 1.131. Assuming q_{index} is distributed linear within these boundaries, q_{index} is calculated as $(1.000 + \frac{(5-2)}{7} * (1.131 - 1.000))$ = 1.0561. As the inconvenient time ratio of the SU product is reported to be 11.2%, 1.0561 is to be discounted by $\%_{inconvenient}$ and $q_{index\_normalised}$ is then calculated to be 1.0561 x (1 – 11.2%) = 0.938.

D.2.3. *TK Flights:* The timetable and parameter calculations for each two combinations of TK are displayed below:

Figure D.3: Schedule Information of TK351/TK1895 Combination from ALA to MXP.

TK 351 Almaty - Almaty International - Istanbul - Ataturk

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	06:45	06:45	06:45	06:45	06:45	06:45	06:45
Arrival Time	09:55	09:55	09:55	09:55	09:55	09:55	09:55

TK 1895 Istanbul - Ataturk - Milan-Malpensa - Malpensa

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	11:50	11:50	11:50	11:50	11:50	11:50	11:50
Arrival Time	13:45	13:45	13:45	13:45	13:45	13:45	13:45

The combination offers the same arrival and departure time as well as capacity supply, 34 seats for each day of the week. Therefore, weight averaging would result in daily figures equal to weekly averages. Going through the same procedures, for the TK351/TK1895 combination, t_{conn} equals 115 minutes while the t_{flight} is 545 minutes and t_{total} is then 11 hours

(660 minutes). Considering Istanbul airport's MCT is 1 hour, the MCT surplus is calculated as 55 minutes, also implying a waste and inconvenient time of (55 - t_{buffer}) = 25 minutes. $\%_{inconvenient}$ is equal to 25/660 = 3.8%. Departing at 06:45 is rated 3 while arriving at MXP is rated as one best time intervals scoring 4. Since none of the flight legs' durations exceed $\%_{q\_split}$, no flight qualifies for an additional q_{split} score. Therefore, the $q_{convenience}$ score is 7. Being an operating and connecting flight, as per Table 9.11, q_{index} value changes between 1.000 and 1.131. Assuming q_{index} is distributed linear within upper and lower boundaries of $q_{convenience}$, it is calculated as follows: $(1.000 + \frac{(7-2)}{7} * (1.131 - 1.000))$ = 1.0935. Discounting this number with $\%_{inconvenient}$, $q_{index\_normalised}$ is calculated to be 1.052.

The schedule information of the second TK combination, TK353/TK1875, is as follows: It should be noted that the departure and arrival times, as well as daily seat supplies, are identical in this combination too.

Figure D.4: Schedule Information of TK353/TK1875 Combination.

TK 353 Almaty - Almaty International - Istanbul - Ataturk

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	-	-	10:00	-	10:00	-	10:00
Arrival Time	-	-	13:10	-	13:10	-	13:10

TK 1875 Istanbul - Ataturk - Milan-Malpensa - Malpensa

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Departure Time	16:55	16:55	16:55	16:55	16:55	16:55	16:55
Arrival Time	18:55	18:55	18:55	18:55	18:55	18:55	18:55

Using the same procedures, time-related parameters and inconvenient time calculation of the TK353/TK1875 combination are reported as follows:

Table D.7: TK353/TK1875 Combination's Time-related Parameters, Inconvenient Time and Inconvenient Time Ratio Values.

t_{conn}	t_{flight}	t_{total}	MCT	MCT surplus	Inconvenient. Time	$\%_{inconvenient}$
225 min	550 min	775 min	1 hr	165 min.	135 min. (Waste Time)	17.4%

Both the departure and arrival time qualities of this itinerary score 3 with no extra q_{split} points, therefore resulting with a $q_{convenience}$ score equal to 6. Since both TK353 and TK1875 are operating flights, the whole itinerary is an operating product too. Therefore, $q_{convenience}$, equals to $(1.000 + \frac{(6-2)}{7} * (1.131 - 1.000)) = 1.074$. Discounting this figure by $\%_{inconvenient}$, $q_{index\_normalised}$ is calculated as 0.888.

While the $q_{index\_normalised}$ score for TK351/TK1895 is 1.052, it is calculated to be 0.888 for TK353/TK1875 combination. Since the calculation of a single quality score is required for all connecting services for a given airline, the weighted average of $q_{index\_normalised}$ by the available seat numbers has to be computed for each combination, as displayed in Table 9.27 below.

Table D.8: TK Combinations' Weighted Average $q_{index\_normalised}$ Calculation Table using Available Seats and Individual $q_{index\_normalised}$ Values of The Combinations

Combination	Available Seats	Normalised Quality - $q_{index\_normalised}$
TK351/TK1895	237	1.052
TK353/TK1875	101	0.888
Weighted Average $q_{index\_normalised}$		$= \frac{(1.052 \ x \ 237)+(101 \ x \ 0.888)}{(237+101)} = 1.003$

With all airlines' $q_{index\_normalised}$ scores computed, the final adjustment in quality scores in reference to total journey time is carried out to obtain each carrier's $q_{a\_index\_normalised}$ as the final step before implementing the REMSET. The below table summarises t_{total}, $q_{index\_normalised}$ and calculates $q_{a\_index\_normalised}$.

Table D.9: Each Airlines Average t_{total} And Normalised Quality Indexes

Airline	t_{total}	Normalised Quality - $q_{index\_normalised}$
LH	630 minutes	0.9639
SU	715 minutes	0.9380
TK	$\frac{(660\ x\ 237)+(775\ x\ 101)}{(237+101)}$ = 694 min.	1.0030

For airlines offering a single combination from ALA to MXP, the t_{total} value of the combination is at the same time the average total journey time for the airline. Therefore, average t_{total_LH} is 630 and t_{total_SU} is 715 minutes for LH and SU respectively. For TK, since there are two hits, to compute t_{total_TK} each combination's t_{total} needs to be weight-averaged by the corresponding seat supply. Making the necessary calculation as depicted in Table 9.28, t_{total_TK} is found to be 694 minutes. Therefore, LH offers the shortest journey time available in the market. SU's average journey time is 13.4% worse than LH, while this figure is 10.1% for TK. Therefore, for LH $q_{a\_index\_normalised}$ = $q_{index\_normalised}$. For SU and TK, their $q_{index\_normalised}$ needs to be discounted by 13.4% and 10.1% respectively to calculate their $q_{a\_index\_normalised}$ as shown in the table below.

Table D.10: Indexed Total Journey Time and Final $q_{a\_index\_normalised}$ Values

Airline	t_{total}	Indexed t_{total}	$q_{index\_normalised}$	$q_{a\_index\_normalised}$
LH	630 min	1	0.9639	0.9639
SU	715 min	1.135	0.9380	0.9388 x (1-13.5%) = 0.8264
TK	694 min	1.102	1.0030	1.0030 x (1-10.2%) = 0.9096

The above table shows that the schedule quality of LH is the best among competing airlines from ALA to MXP, with an adjusted and normalised quality index score of 0.9639. TK follows LH with $q_{a\_index\_normalised}$ = 0.9096, with SU reporting the lowest quality score.

D.3. Final Realistic Market Share Calculation of the Case by Using the REMSET Model

In the initial section of the analysis, adjusted capacity shares ($\%_{a\_s}$) of each combination is assessed followed by adjusted normalised quality score ($q_{a\_ndex\_normalised}$) calculation. These figures are relative scores and indicate the comparative performance of the airlines. Therefore, as previously outlined, the procedure to calculate the realistic market share proceeds by multiplying $\%_{a\_s}$ with $q_{a\_ndex\_normalised}$ for each airline's routing type (direct or connecting) combination. Translating these numbers into percentages produces the final market share estimation of each carrier. The final table summarising the capacities and normalised quality scores of all services from ALA to MXP is as follows: (Please note that since there are only connecting services in the market, no row is shown for direct flights.)

Table D.11: Final Realistic Market Share Computation of the Case

Airline	Routing Type	$\%_{a\_s}$ x $q_{a\_index\_normalised}$	Market Share Estimation (ms)
LH	Connect	12.53% x 0.9639 = 0.121	0.121 / 0.890 = 13.6%
SU	Connect	32.11% x 0.8264 = 0.265	0.265 / 0.890 = 29.8%
TK	Connect	55.36% x 0.9096 = 0.504	0.504 / 0.890 = 56.6%
Total		0.890	100%

The above table suggests that although the adjusted seat share of LH is 12.53%, its expected market share is slightly higher than this figure, which is 13.6% since the carrier reported a better quality index compared to the rivals. Remembering that LH offers 20.06% of the physical seat supply in the market, this is not proportionally reflected in the adjusted seat share and the realistic market share estimation as it only operates four days a week, whereas the competitors offer daily services. Although TK owns 50.6% of the entire physical seat supply in the market, due to LH's non-served days, its adjusted capacity share is raised to 55.36%. Incorporating the quality index figure with the adjusted capacity share, TK's ms is found to be 56.6%. Finally, although SU reports an adjusted capacity share of 32.11%, due to the relative disadvantage in the schedule quality of the SU flights, its market share is estimated to be 29.8%.