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The Strategic Deployment of the Airbus A350-900XWB Aircraft in a Full-Service Network Carrier Route Network: The Case of Singapore Airlines

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Abstract: In the global airline industry, an airline's fleet routing affects its profitability, level of service and its competitive position. Using a qualitative research approach, this paper examines Singapore Airlines Airbus A350-900XWB fleet deployment and route network development for the period 2016 to 2018. The qualitative data was examined using document analysis. The study found that Singapore Airlines has deployed the Airbus A350-900XWB aircraft on new air routes from Singapore to Cape Town via Johannesburg, Düsseldorf and Stockholm via Moscow and return. The Airbus A350-900XWB aircraft are also replacing older, less efficient aircraft as part of the company's fleet modernization strategy. Singapore Airlines is also acquiring the new ultra-long-range variant of the Airbus A350-900XWB for use on its proposed new non-stop services from Singapore to Los Angeles and Newark Liberty Airport in New Jersey, USA. The longest flight stage length is the Singapore to San Francisco route which is 7339 nautical miles (13,594 km) in length. The shortest stage length is between Singapore and Kuala Lumpur (160 nautical miles or 297 km). The new non-stop services from Singapore to Los Angeles and New York City will be the longest non-stop services operated by Singapore Airlines. The flight stage lengths between Singapore and Los Angeles and Singapore and Newark Liberty Airport are 7621 nautical miles (14,114 km) and 8285 nautical miles (15,344 km), respectively. The greatest number of available seat kilometers (ASKs) are generated on Singapore Airlines Airbus A350-900 XWB service from Singapore to San Francisco (3.57 million ASKs). The smallest number of ASKs produced are on the short-haul service from Singapore to Kuala Lumpur (75,141 ASKs).

Keywords: airlines; Airbus A350-900XWB; case study; fleet deployment; route network development; Singapore Airlines

1. Introduction

The air transport industry provides the only rapid global transportation network, which makes it critical for global commerce and tourism. In addition, air transport plays a fundamental role in facilitating economic growth, this is especially so in developing countries [1]. In 2016, the world's airlines carried around 3.79 billion passengers and 52.6 million tons of air cargo [2]. Furthermore, the air transport industry is indispensable for tourism [1], which is also a strong driver of economic growth [3–5]. In 2016, around 55 per cent of all overnight visitors travelled to their destination by air [6]. In the global air transport industry, passenger airlines have defined and implemented two principal business models: the full-service network carrier (FSNC) and the low-cost carrier (LCC) models [7–9]. The full-service network carrier's business forms the focus of the present study.

Fleet composition and route networks are regarded as two of the most essential elements of an airline's business model. Route network and the aircraft fleet type employed are two of the

major elements defining the FSNC business model. FSNCs target large traffic catchment areas, while, simultaneously, bundling traffic from smaller catchment areas into their hubs to be able to operate profitable intercontinental air services [10]. The full-service network carriers typically structure their route networks based on the hub-and-spoke principle whereby they link together smaller peripheral markets via their major hub airports. This strategy enables them to optimize both passenger and air cargo connectivity. Furthermore, many airlines structure their route networks on short haul, medium-haul and long-haul services [11]. Prior to the end of the last century, the ability to traverse long distances was limited to just a few large capacity aircraft. However, aircraft manufacturers are now offering medium sized aircraft that can operate ultra-long-haul thin routes. For example, Airbus is offering the Airbus A350-900XWB aircraft as a competitive response to Boeing's 787 medium-sized, long range aircraft [12–14]. An ultra-long-range flight is defined as a flight carrying a meaningful payload of passengers and cargo over a distance that is more than 7000 nautical miles (12,964 km) in length [11]. Long-haul flights are typically around 3500 (6482 km) to 5000 nautical miles (9260 km) in length [15].

The aim of this study is to examine Singapore Airlines deployment of its fleet of Airbus A350-900XWB aircraft and to identify whether the airline is using these aircraft to pioneer new long haul or ultra-long-haul air routes as well as replacing older aircraft types. Airlines acquire new aircraft to replace older, less efficient aircraft in their fleet or to use the new generation aircraft to pioneer new air routes. An additional aim of the study is to quantify the stage length of the air routes that are operated by Singapore Airlines Airbus A350-900XWB aircraft and to identify whether these aircraft are being primarily operated on long-haul or ultra-long-haul flight stage lengths. A stage length is the distance travelled by an aircraft on a specific flight segment [16]. A final aim of the study is to identify the number of available seat kilometers (ASKs) produced on each Singapore Airlines Airbus A350-900XWB flight. Singapore Airlines took delivery of their first Airbus A350-900XWB aircraft on the 2 March 2016 [17]. The present study covers the period from the inception of Airbus A350-900XWB services by Singapore Airlines in 2016 through to May 2018. To achieve the study objectives, the following research questions were empirically examined:

1. How has Singapore Airlines route network changed following the commencement of Airbus A350-900XWB services in 2016?
2. Is Singapore Airlines using its fleet of Airbus A350-900XWB aircraft to pioneer new long-haul and ultra-long-haul air routes?
3. What are the flight stage lengths of Singapore Airlines Airbus A350-900XWB services?
4. What are the available seat kilometers (ASKs) generated on each of Singapore Airlines Airbus A350-900XWB services?
5. What are the trade and tourism benefits of Singapore Airlines new long-haul Airbus A350-900XWB routes?

The remainder of the paper is organized as follows: the literature review presented in Section 2 commences with a brief overview of the full-service network carrier's business model, aircraft fleet mix and deployment, aircraft cabin configurations and airline route network design and a review of the Airbus A350-900XWB aircraft. The research method that underpinned the study is described in Section 3. The empirical examination of Singapore Airlines A350-900XWB aircraft deployment and route network development is presented in Section 4. The key findings of the study are presented in Section 5.

2. Background

2.1. The Key Elements of the Full Service Network Carrier Business Model

A "full service network carrier" (FSNC) or "legacy" carrier is an airline that focuses on providing a wide range of both pre-flight and onboard services, including different service classes and connecting

flights. Since most FSNCs operate a hub-and-spoke route network model, this group of airlines is generally referred to as hub-and-spoke carriers [18]. Air France/KLM, All Nippon Airways (ANA), Cathay Pacific Airways, Emirates Airline, Etihad Airways, Qantas Airways, Qatar Airways and Singapore Airlines are examples of full service network carriers. FSNCs generally focus on the same operational, strategic and economic features: operating a complex network of air services, combining many regional services with intercontinental services using a hub-and-spoke route system. This is normally accompanied by a product/service strategy predicated on discrete travel class differentiation, by offering a full range of services to all passengers [10].

As previously noted, FSNCs target large traffic catchment areas, while, simultaneously, bundling traffic from smaller catchment areas into their hubs. This enables them to operate profitable intercontinental air services [10].

2.1.1. Aircraft Fleet Mix and Deployment

Strategic fleet planning is a critical process for the world's airlines. It relates to the decisions made on size of the aircraft fleet and on the fleet composition. Investment costs are one of the principal factors considered in the fleet planning process. In addition, airlines need to decide which aircraft suit their network, when they are required and whether they are required to replace existing aircraft or alternatively enlarge the fleet size. A further critical factor considered in the fleet planning process is fleet commonality, that is, the number of aircraft of the same type, the same aircraft family, or the same aircraft manufacturer [19] (p. 639).

An airline's "*fleet*" is the total number of aircraft it operates at a given time, as well as by the specific aircraft types that comprise the total fleet of aircraft operated by the airline. An airline's aircraft fleet can be broken down into "sub-fleets", usually comprised of specific aircraft types, for example, Airbus A320, A330, A350, A380 and Boeing B737, B777 and B787 aircraft. Each aircraft type has different technical performance characteristics, for instance, their ability to operate services on short haul thin air routes or long haul major routes [20,21].

While several aircraft may be able to serve a specific route, certain aircraft will be better matched to those unique market conditions, be it time of day, day of week and so forth. A fleet that comprises aircraft that can serve all market needs effectively and efficiently should place that airline in a strong financial position [22]. Aircraft size (as measured by the number of seats) can be split into two discrete groups: the single aisle aircraft (these are commonly referred to as narrow-body aircraft) and the twin aisle aircraft (these are commonly referred to as wide-body aircraft) [23].

Since the FSNC route network is often designed to link regional, continental and intercontinental routes, the typical FSNC fleet is usually quite heterogeneous in nature. An FSNC aircraft fleet may comprise small regional jets right through to long range wide-body aircraft. The diversity in aircraft types operated is because FSNCs endeavor to have the right aircraft in place for each route alone. This results in a broad range of available seating capacities but often also suggests a multiple aircraft manufacturer strategy. Thus, flight and cabin crew, technical staff, spare parts, ground handling equipment and staff and other production factors need to be provided for entirely different aircraft types, adding to the cost base for the airline [10,24].

Commercial aircraft are commonly defined by their range and size. The range being the maximum distance an aircraft can fly with a full (or reasonable) payload of passengers and air cargo, while its size is represented by its weight and capacity (seats and air cargo) [20,24]. Broad categories like short-haul, long-haul and ultra-long-haul are used by aircraft manufacturers. Aircraft with similar characteristics are then more easily compared with the competitor's product offerings [20].

There are two fundamental reasons for airlines acquiring aircraft. Firstly, as noted earlier, airlines acquire aircraft to replace existing capacity. In replacing existing capacity, the task for the airline is to find an aircraft capable of performing a largely unchanged mission better than the aircraft that are being replaced [25,26]. An airline might find it necessary to replace part of its current fleet because of high operating costs, unacceptable aircraft noise or emissions, limited remaining aircraft structural

life, inadequate passenger appeal, fleet rationalization, or an ongoing fleet rollover policy that is intended to maintain a young fleet age. Normally the task for an airline is to find an aircraft capable of performing a largely unchanged mission more effectively than the aircraft to be replaced [25] (p. 458). The second reason why airlines acquire new aircraft is to grow their existing capacity. The growth in total capacity often interacts with the need for replacement and is further complicated by the fact that growing demand can in principle, be satisfied by using larger aircraft and maintaining flight frequencies. This can be achieved by operating the same size aircraft at higher frequencies (possibly optimizing additional utilization and/or higher load factors out of the existing fleet before adding further capacity), or by some combination of the two [24].

To satisfy growing air travel (and air cargo demand), airlines have the option to increase service frequency, aircraft size and/or the load factor. In the airline industry, high load factors are considered as a prerequisite for profitable operations [26]. On a route-by-route basis, it is generally true that additional frequencies have historically accounted for a significantly higher percentage of additional airline output supplied to satisfy the growth in demand growth than have larger aircraft. In addition, capacity might have to be added to satisfy a new mission requirement—for example hub-bypass by operating point-to-point (P2P) services [27] (p. 79). Additional capacity may be required by an airline to satisfy new mission requirements that are beyond the capability of the airline's existing fleet, such as the operation of ultra-long-haul services [25]. It is important to note, however, that on most air routes the choice of aircraft made by an airline is often relatively limited. This is because of the bundling of size and range in aircraft development [28]. On long-haul routes the choice of aircraft will be generally be restricted to the wide-body aircraft. These aircraft offer operators a high range. In contrast, in many short-haul markets, airlines typically opt for higher frequencies with smaller aircraft types rather than operating larger aircraft and a lower number of flight frequencies [23]. Consequently, airlines may decide to serve an origin-and-destination (O & D) or city-pair with a specific aircraft type and flight frequency. Air travel markets that have a concentration of passengers who have high time costs and business travelers, may be served by smaller aircraft with a high frequency of flights. Conversely, markets that are comprised of low time cost passengers (leisure travelers) may be served by larger aircraft with a lower number of flights [29].

Aircraft fleet assignment or deployment is the tactical decision made by the airline once the initial flight schedule has been produced and long after the decisions about fleet acquisition and route network have been made. The primary aim of fleet deployment by an airline is to minimize the combined costs of “spill” or rejected demand and aircraft operating costs [20]. The other important objective of fleet deployment is to assign as many flights as possible in a flight schedule to one or more aircraft types, whilst also optimizing some objective function and satisfying various operational constraints. Fleet deployment or assignment therefore involves the airline matching each aircraft type in its fleet with a specific route in the flight schedule [30]. Fleet deployment is restricted to a choice of the aircraft types from the airline's aircraft fleet [20]. In addition, Pei [29] (p. 169) notes that “distance is also a significant factor in the use of a particular aircraft type on a route”. This is because as the distance between the flight origin airport and the endpoint increases, longer-range (and hence, larger) aircraft are required [29].

2.1.2. Airline Route Network Design

An airlines route network design is the most important attribute of its product offering [31,32] as it is the primary driver for generating an airline's revenues and costs [33,34]. The route network also represents the airline's production plan [32]. In addition, route network design is also a source of competitive strength or weakness for an airline [33] (p. 29).

In deregulated or liberalized air travel markets, the hub-and-spoke route network has proved to be the dominant network strategy adopted by airlines [35]. Indeed, the FSNC business model is generally based upon the operations of a hub-and-spoke route network [11,36]. In the FSNC hub-and-spoke system, airlines develop their networks by combining features from non-stop and multi-stop routing

patterns. The hub operational system is based on flights arriving from multiple points (spokes) at a hub airport where passengers, baggage and air cargo connect to flights departing to multiple points. So, after a short turnaround period, an equally substantial number of turn-around departures travels out along spoke routes from the hub. The hub airport thereby acts as a gathering and consolidation point for flights operating to multiple destinations [37,38]. The hub-and-spoke system, by offering a wide variety of origins- and-destinations (O & Ds), therefore, assists airlines to exploit other economies of market presence. Combining substantial volumes of domestic traffic with international traffic through hubs further enhances this advantage [39] (p. 20).

The hub-and-spoke strategy of FSNCs leads to a focus on primary airports, being those airports, which belong to a highly populated urban area/region or business center and typically serving more than several million passengers per annum. While these airports guarantee sufficient passenger traffic to fill the number of flights necessary to efficiently operate the hub and hence, provide the infrastructure required to cope with the peaks resulting from hub operations, this strategic focus often results in disadvantages for airlines when it comes to punctuality. Primary airports, being a preferred destination for all types of airlines, tend to suffer from congestion and generate flight delays and operational bottlenecks [10].

Hub operations are amongst the most valuable assets that a FSNC owns. They enable an airline to operate routes which could never be profitably served by local traffic alone. In total they form the economic basis for a network density typically exceeding a point-to-point coverage by a substantial amount [10]. Hence, the hub-and-spoke system encourages airline growth. By using hub-and-spoke operational systems, airlines can increase traffic density on certain routes to take advantage of economies of traffic density and to lower unit costs. The benefits also arise on the demand side, as passengers prefer to travel with larger airlines, so an airline with an extensive hub-and-spoke system possesses an advantage over a new entrant and smaller airlines due to the larger network of points served [40] (p. 30).

Many long-haul air travel markets often have low volumes of passenger traffic and thus, the FSNC business model is still viewed as the most appropriate one to provide adequate flight frequencies and economic sized aircraft. Importantly, Morrell and Lu [41] have noted that there are two key developments that may cause a change in airline aircraft deployment on long-haul hub-to-hub routes. Firstly, the introduction into commercial service of the Boeing 787 family and the Airbus A350-900XWB aircraft. These aircraft types offer significantly improved unit costs for long haul aircraft configured to carry 200–250 passengers as compared to existing types of aircraft in this category. Consequently, these aircraft offer the potential for a considerable number of profitable non-stop hub by-pass services with adequate flight frequencies. Secondly, the internalization of external environmental costs, including both aircraft noise and aircraft emissions, may lead to a shift in the pattern of services towards hub by-pass and more direct air services [41] (p. 144).

Furthermore, in the airline industry, there are often “thin” routes, that is, routes that have a small number of passengers per day and “dense” routes, where there are significant numbers of passengers travelling each day. Typically, dense air routes are served by point-to-point (P2P) service, whilst thin routes are combined using the hub-and-spoke system [42].

2.2. The Key Characteristics of the Airbus A350-900XWB Aircraft

When Boeing committed to developing the 7E7 (now the B787), Airbus launched the Airbus A350, which was derived from the Airbus A330-200/-300, in response [43]. The Airbus A350 was therefore based on the same fuselage and fuel capacity as the A330-200/-300. The principal difference between the A350 and the A330 was the use of carbon fiber in the A350’s wing structure and the A350 used the General Electric (GE) (GENX) engines [16]. However, the Airbus A350-900 program was relaunched in 2006, with Airbus distinguishing this larger aircraft by underlining the greater spaciousness afforded by its “extra wide body (XWB)” [44]. The aircraft is now referred to as the Airbus A350-900XWB. On 1

December 2016, Airbus SAS officially announced the go-ahead for the industrial launch of the Airbus A350XWB Family (-800, -900 and -1000) [45].

The Airbus A350XWB family now comprises the A350-900XWB and -1000XWB. The sole engine option for these aircraft is the Rolls Royce Trent XWB [46]. The maiden Airbus A350 extra wide body (XWB) test flight took place on 14 June 2013. The Airbus A350XWB aircraft was awarded its European Aviation Safety Agency (EASA) certification in September 2014. The United States Federal Aviation Administration (FAA) certification was awarded in November 2014 [44]. The first Airbus A350-900 aircraft was scheduled to be delivered to Qatar Airways in late 2014 [47–49]. The aircraft entered commercial service with Qatar Airways on the 15 January 2015. The entry of the aircraft into commercial service marked the end of a 12-year long development program [50].

The Airbus A350XWB aircraft has composite wings, tail, fuselage and other primary infrastructure. Overall the breakdown in the materials used in the aircraft approximates to 50 per cent composite, 20 per cent aluminum, 15 per cent titanium and five per cent other materials [51].

The Airbus A350-900XWB aircraft is being offered as an aircraft with a range of up 8500 nautical miles, with a nominal 270 seating configuration. The larger A350-1000XWB aircraft has a range of around 8300 nautical miles (15,742 km), with a nominal seating configuration of 350 passengers [52,53]. The A350 aircraft enables operators to optimize and expand their medium- and long-haul and intercontinental route networks. This is achieved by opening new low-density, long-distance routes that were previously regarded as being uneconomic to operate with larger aircraft types at low flight frequencies. Many of these new low-density routes will be operated from major hubs to secondary airports. This is a different strategy to the traditional long-haul route structure of hub-to-hub services [54] (p. 18).

3. Research Method

3.1. Research Approach

The research undertaken in this study used an instrumental case study approach [55,56]. Creswell [57] (p. 74) notes that in an “instrumental case study, the researcher focuses on an issue or concern and then selects one bounded case to illustrate this issue”. Thus, an instrumental case study is the study of a case, for example, a company, to provide insights into a specific issue, redraw generalizations, or build theory [55,58]. The present study was designed around established theory [55]. The issue examined in the present study was the deployment of the Airbus A350-900XWB aircraft by Singapore Airline. Singapore Airlines was the study’s case company.

The research followed an inductive approach using a qualitative case study research design [59,60]. The goal of such an approach is to expand and build theories rather than perform statistical analysis to test a certain hypothesis [61].

3.2. Data Collection

Data for the study was obtained from a range of documents, company materials available on the internet and records. These documents provided the sources of case evidence. The documents collected and examined in the study included Singapore Airlines annual reports, flight schedules and timetables, press releases and the airline’s websites. An exhaustive source of the air transport-related magazines—*Air Transport World*, *Airline Business* and *Flight International* was also conducted. These industry publications were accessed from the Proquest ABI/INFORM and EBSCO Information Sources databases. An exhaustive search of the *Aviation Week and Space Technology* magazine was also conducted. A search of the SCOPUS and Google Scholar databases was also undertaken. The key words used in the database searches included “Singapore Airlines Airbus A350-900XWB aircraft”, “Singapore Airlines Airbus A350-900XWB routes”, “Singapore Airlines commences Airbus A350-900XWB services to” and “airline route network development”.

The study therefore used secondary data. The three principles of data collection as recommended by Yin [62] were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

3.3. Document Analysis Process

The empirical data collected for the case studies was examined using document analysis. Document analysis is often used in case studies and focuses on the information and data from formal documents and company records [63–65]. The documents collected for the study were examined by four key criteria: authenticity, credibility, representativeness and meaning [66,67].

Before commencing the formal analysis of the documents that were collected for the study, the context in which the documents were created was determined and the authenticity of the documents was assessed [68]. Authenticity involves an assessment of the collected documents for their soundness and authorship. Scott and Marshall [69] (p.188) note that ‘soundness refers to whether the document is complete and whether it is an original and sound copy. Authorship relates to such issues as collective or institutional authorship. In this study the source of the case study documents was primarily from Singapore Airlines as well as relevant articles published in the leading air transport industry-related magazines: *Air Transport World*, *Airline Business*, *Aviation Week and Space Technology* and *Flight International*. The documents were available in the public domain. The credibility criterion concerns the accuracy and sincerity of a document [69,70]. In the present study, the evidence for the case study was corroborated using various kinds of documents that were sourced from various sources [71]. The representativeness criterion involved an assessment of the availability and survival of the documents gathered. No major difficulties in obtaining documents was experienced in the current study as all the relevant documents could be readily accessed in the public domain. The fourth criterion, meaning, is a most important aspect of document analysis and occurs at two levels. The first is the literal understanding of a document, by which is meant its physical readability, the language used and whether it can be read, as well as the date of the document [69,70]. When conducting document analysis in a study, it is important to interpret the understanding and the context within which the document was produced. This enables the researcher to interpret the meaning of the document. The evidence found in the documents gathered and used for the study were all clear and comprehensible [72].

The document analysis process in the study was undertaken in six distinct phases which followed the recommendations of O’Leary [73] (Table 1).

Table 1. The phases and activities undertaken in study’s document analysis process. Source: adapted from [73] (p. 179).

Phase of the Document Analysis Process	Activity
Phase 1	This phase involved planning the types and required documentation and their availability
Phase 2	The data collection involved gathering the documents and developing and implementing a scheme for the document management
Phase 3	Documents were reviewed to assess their authenticity, credibility and to identify any potential bias
Phase 4	The content of the collected documents was interrogated and the key themes and issues were identified
Phase 5	This phase involved the reflection and refinement to identify and difficulties associated with the documents, reviewing sources, as well as exploring the documents content
Phase 6	The analysis of the data was completed in this final phase of the study

The documents gathered for the study covered the period 2016 to 2018, that is, the documents covered the period from the inception of Airbus A350-900XWB services by Singapore Airlines through to the present time of the study.

All the gathered documents were downloaded and stored into a case study database [66]. The documents collected for the study were all in English. Each document was carefully read and key themes, such as, “Singapore Airlines Airbus A350-900XWB”, “Singapore Airline launches Airbus A350-900XWB service”, “Singapore Airlines route development”, “flight stage length” and “airline route network” were coded and recorded. This study followed the recommendation of van Schoor [72] (p. 94), to “avoid bias, documents of different sources were analyzed”. Triangulation is used to add discipline to a study in both qualitative and quantitative research. One of the primary reasons for the use of triangulation in a case study is the recognition that bias can be introduced if only one way of obtaining and interpreting data is used in the study. Triangulation is also used in qualitative research as a procedure to ensure stronger accuracy and to demonstrate the verification of the data. This study used data triangulation with the documents being collected from various sources. This approach helped verify the themes that were detected in the documents gathered in the study [74]. The data collection in the present study was also guided by the case study protocol [62].

4. Results

4.1. A Brief Overview of Singapore Airlines

Singapore Airlines (IATA Airline code: SQ) was established on 28 January 1972. This followed the emergence of Singapore as a Republic that was independent of the Federation of Malaysia. Consequently, this resulted in the division of Malaysia-Singapore Airlines (MSA) into two individual airlines that became the national flag carriers of Singapore and Malaysia, respectively [75]. Singapore Airlines commenced operations on 1 October 1972 [76], serving the same international destinations that had been previously served by Malaysia-Singapore Airlines (MSA). The airline used a fleet of Boeing B707 and Boeing B737 aircraft on these services [75].

On 2 April 1973, Singapore Airlines launched daily services between Singapore and London and this was followed shortly thereafter when on 31 July 1973, the airline commenced a major expansion program following the delivery of its first wide body aircraft type, the four turbo-fan powered Boeing B747-212B aircraft. This was followed quite soon by another wide body aircraft, the McDonnell-Douglas DC10-30. These aircraft were deployed on the airline’s medium-and-high density air routes. On 20 December 1980, Singapore Airlines received its first Airbus A300B4-203 aircraft; this aircraft complemented the airlines Boeing B747-212B and McDonnell Douglas DC10-30 aircraft [75].

Currently, Singapore Airlines operates a modern passenger fleet of over 100 aircraft. The Singapore Airlines Group, which comprises the wholly-owned subsidiaries SilkAir, Scoot, Tiger Airways (which operates as Tigerair) and SIA Cargo, has a combined fleet of almost 180 aircraft. The airlines combined passenger network covers 131 destinations in 35 countries. The Singapore Airlines Group carried over 31 million passengers in the 2016/17 fiscal year [77]. Figure 1 presents Singapore Airlines total annual enplaned passengers and total annual revenue (Singapore dollars) for the period covering the 2007/08 to 2016/17 annual fiscal years.

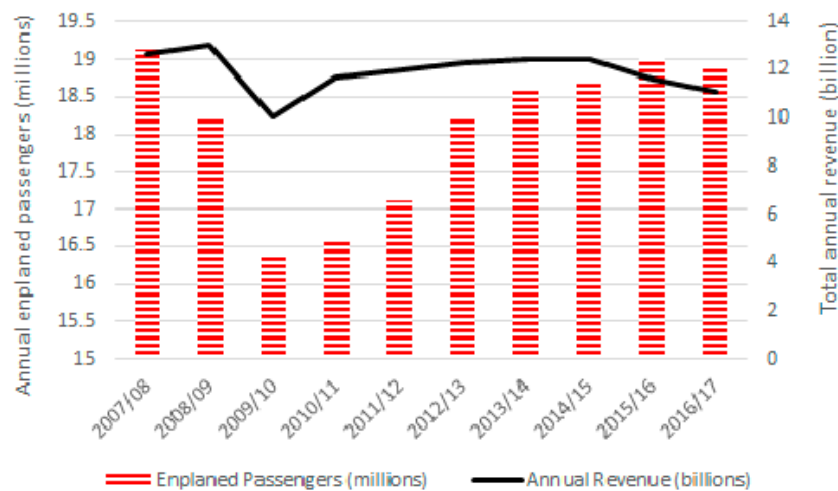


Figure 1. Singapore Airlines total annual enplaned passengers and annual total revenues: 2007/08–2016/17. Source: data derived from [77].

4.2. Singapore Airlines Long-Haul Route Network 2015

Prior to examining Singapore Airlines Airbus A350-900XWB fleet and their fleet deployment, it is important to note the Singapore Airlines long-haul route network in 2015, the year prior to the introduction of Airbus A350-900XWB services. As noted earlier, the focus of this study is on examining how the Singapore Airlines route network has evolved over the period 2016 to 2018 following the introduction of the Airbus A350-900XWB aircraft. Figure 2 presents Singapore Airlines 2015 long-haul network. As can be observed in Figure 2, due to aircraft range limitations the following services incorporated an immediate stop en route:

- Singapore to Cape Town via Johannesburg and return;
- Singapore to Houston via Moscow and return;
- Singapore to Los Angeles via Seoul's Incheon International Airport and return;
- Singapore to Los Angeles via Tokyo's Narita International Airport and return;
- Singapore to New York's John F. Kennedy Airport via Frankfurt and return; and
- Singapore to San Francisco via Hong Kong and return.

During 2015, Singapore Airlines operated long-haul services to Copenhagen, London Heathrow Airport, Manchester, Munich, Paris and Zurich primarily using a mix of Airbus A380-800 and Boeing B777-300ER aircraft. The airline also operated a dense Australasian route network (Figure 2) using a similar mix of aircraft types.

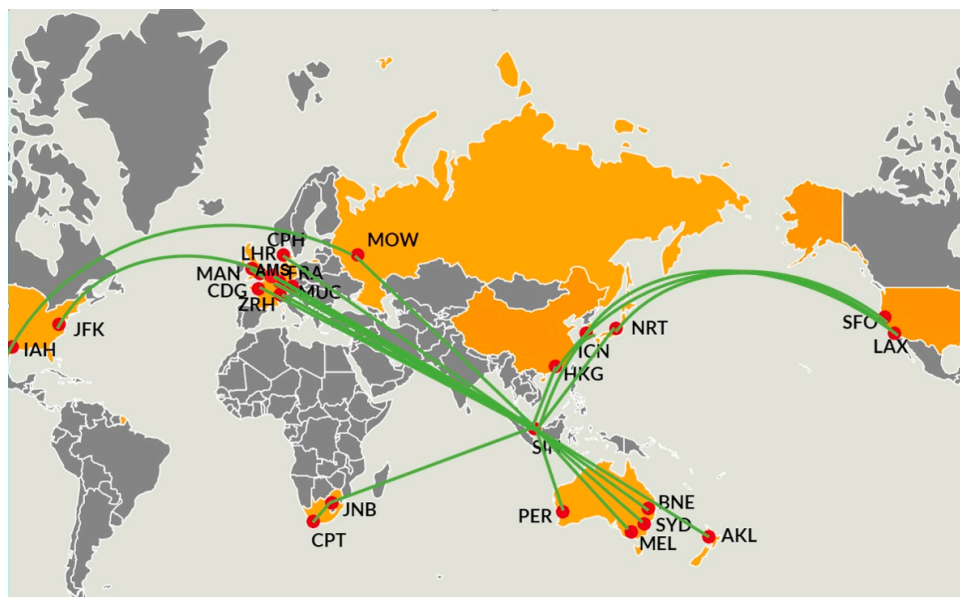


Figure 2. Singapore Airlines 2015 long-haul network. Legend: AKL = Auckland, AMS = Amsterdam, BNE = Brisbane, CPH = Copenhagen, CPT = Cape Town, HKG = Hong Kong, IAH = Houston, ICN = Incheon International Airport, JFK = John F. Kennedy International Airport, JNB = Johannesburg, LAX = Los Angeles International Airport, MAN = Manchester, MEL = Melbourne, MOW = Moscow, NRT = Narita International Airport, PER = Perth, SFO = San Francisco, ZRH = Zurich.

4.3. Singapore Airlines Airbus A350-900XWB Aircraft Fleet

In 2005, Singapore Airlines issued a request for proposals (RFP) to both Airbus and Boeing for mid-size wide-body twin-jet aircraft as well as for additional ultra-large aircraft. The RFP was based on 20 firm orders for the Airbus A350 or the Boeing 787 aircraft [78,79]. In July 2006, Singapore Airlines signed a letter of intent (LOI) with Airbus for up to 40 A350XWB aircraft: 20 firm orders and options for a further 20 aircraft [80,81]. It was envisaged that Singapore Airlines would take delivery of its first Airbus A350XWB aircraft in 2012 [82]. The formal agreement for the 40 aircraft was signed in early 2007 following the launch of the reworked version of the Airbus A350-900XWB aircraft in December 2006. Deliveries of the new aircraft were subsequently due to commence in 2013 [83]. Singapore Airlines indicated that the Airbus A350 aircraft will provide the airline with more hub-to-point options in both Australia and Europe [83].

On the 24 October 2012, Singapore Airlines announced an order for 20 additional Airbus A350-900XWB aircraft which were to be deployed on medium and long-haul routes [84]. Singapore Airlines subsequently firmed this order with Airbus SAS on 11 January 2013. Following this order, Singapore Airlines doubled its backlog of Airbus A350-900XWB to 40 aircraft [85]. On 30 May 2013, Singapore Airlines placed its third order for Airbus A350-900XWB aircraft when it ordered up to 50 more aircraft. The order covered 30 firm orders and options for an additional 20 aircraft. Under the terms of the deal, Singapore Airlines could select the Airbus A350-900XWB or the larger -1000 variants when exercising its options [86].

On 13 October 2015, Singapore Airlines became the launch customer for the Airbus A350-900XWB ultra-long-range (ULR) aircraft. Singapore Airlines converted 7 of its existing backlog 63 Airbus A350-900XWB orders to the A350-900ULR aircraft [87]. Singapore Airlines announced that it intended to use the new ultra-long-range aircraft on long-haul, non-stop services from Singapore to Los Angeles and New York, following their delivery in 2018 [88]. Singapore Airlines had previously used the older Airbus A340-500 with a lower seat count on its non-stop services to the USA [89]. On 24 October 2012, Singapore Airlines announced their plans to cease these ultra-long-haul services [90]. The non-stop

Singapore to Los Angeles services ceased on 21 October 2013 and shortly after the Singapore to Newark non-stop services ceased on 13 November 2013 [91].

At the time of the current study, Singapore Airlines operated a fleet of 11 Airbus A350-900XWB aircraft and had a further 56 on order [77]. The aircraft on order will gradually replace the airline's fleet of medium wide body aircraft, which comprised leased Airbus A330-300 and fully owned Boeing 777-200ER aircraft [91].

Singapore Airlines Airbus A350-900XWB aircraft are operated in a 3-class seating configuration, comprising 42 business class, 24 premium economy and 187 economy class seats [92].

4.4. Singapore Airlines Airbus A350-900XWB Aircraft Fleet Deployment and Route Network Development: 2016

As previously noted, Singapore Airlines took delivery of their first Airbus A350-900XWB aircraft (hereafter Airbus A350) on the 2 March 2016 [15]. Upon receipt of the new aircraft type, services were operated on a short-term basis from Singapore to Jakarta and Kuala Lumpur. These services enabled crew to be trained on the new aircraft type [93]. The first route that the Airbus A350 aircraft was deployed on was from Singapore to Kuala Lumpur. The inaugural service took place on the 8 March 2016. The initial SQ106 services from Singapore to Kuala Lumpur and SQ107 services from Kuala Lumpur to Singapore were operated on a Monday, Tuesday, Wednesday, Thursday and Friday. These services were operated between 9 and the 15 March 2016. Effective from the 28 June 2016, the SQ118 (Singapore to Kuala Lumpur) and SQ119 (Kuala Lumpur to Singapore) services were scheduled to operate each Tuesday, Wednesday, Friday and Sunday [94]. Effective the 10 May 2016, Singapore Airlines commenced daily Airbus A350 services on the Singapore to Jakarta air route [92]. The initial routes that the Airbus A350 aircraft were deployed upon were previously operated by older aircraft types.

Singapore Airlines announced on the 1 March 2016, that new non-stop Airbus A350 services would be launched from Singapore to Amsterdam [94]. On the 9 May 2016, Singapore Airlines commenced its first long haul Airbus A350 service with the introduction of non-stop services from Singapore to Amsterdam and return [95]. The Airbus A350 aircraft took over the daily Singapore—Amsterdam services that were previously operated with Boeing 777-300ER aircraft [96].

Hong Kong was the next destination in 2016 to receive Airbus A350 services when Singapore Airlines commenced daily services (SQ890 Singapore to Hong Kong and SQ891 from Hong Kong to Singapore) on the 7 June 2016. These services changed to four times weekly (Wednesday, Thursday, Friday, Sunday) on the 28 June 2016 [94].

On 27 June 2016, Singapore Airlines commenced new Airbus A350 services from Singapore to Johannesburg and return. These services operated on Monday, Thursday and Saturday [97]. Effective 30 October 2016, Singapore Airlines commenced four new weekly Airbus A350 services from Singapore to Cape Town via Johannesburg. The Johannesburg to Cape Town sector was an extension of the Singapore to Johannesburg service. The addition of Cape Town enabled Singapore Airlines to extend its service offering into two of South Africa's most important air travel markets. Whilst the Airbus A350-900 aircraft could operate non-stop from Singapore to Cape Town with a meaningful payload, at the time of the present study it was Singapore Airlines strategy to service Cape Town via Johannesburg. Following the commencement of the new services, Singapore Airlines offered daily services to Johannesburg [98]. Like the Amsterdam route the Airbus A350 replaced the Boeing B777-300ER aircraft that had been previously operated on this route.

Singapore Airlines announced on the 9 November 2015, plans to launch Airbus A350-900XWB services to Düsseldorf effective 21 July 2016. Düsseldorf was a new European destination for the airline [99]. The thrice weekly services to Düsseldorf commenced as planned on the 21 July 2016. These new services by Singapore Airlines boosted the airline's seating capacity to Germany by 7.5 per cent [100].

From 10 August 2016 to 22 October 2016, Singapore Airlines introduced seasonal Airbus A350 aircraft services on the Singapore-Melbourne-Singapore route [101,102]. Melbourne had been previously served by a mix of older aircraft types.

Singapore Airlines announced on the 16 June 2016, that the airline would deploy the Airbus A350 aircraft on a non-stop, long-haul service from Singapore to San Francisco with effect from 23 October 2016. The new Singapore to San Francisco flights would be the longest flight in its route network until the second half of 2018, when the airline was due to receive its new ultra-long-range variant of the A350-900ULR aircraft, enabling even longer flights between Singapore and both Los Angeles and New York [103,104]. On 23 October 2016, Singapore Airlines, as previously planned, commenced nonstop service to San Francisco (IATA Airport code: SFO) from Singapore (IATA Airport code: SIN) using the airlines' newest Airbus A350- aircraft. The new service not only allowed Singapore Airlines to relaunch nonstop service between Singapore and the United States but it also marked the beginning of Airbus A350 flights by any airline to the west coast of the U.S.A [105]. Prior to the introduction of the non-stop Airbus A350 services the Singapore to San Francisco service had been operated on a Singapore/Hong Kong/San Francisco routing. Singapore Airlines has maintained the Singapore/Hong Kong/San Francisco routing thereby offering customers a direct non-stop service or a service with a stopover in Hong Kong. Also, this routing enables Singapore Airlines to carry passengers on the Singapore to Hong Kong sector as well as passengers from Hong Kong to San Francisco and from Hong Kong to Singapore on the return leg of the flight.

Singapore Airlines launched two additional Airbus A350 routes in December 2016. Effective from 13 December 2016, Singapore Airlines flight number SQ632 from Singapore to Tokyo's Haneda Airport and flight number SQ633 from Haneda Airport to Singapore were operated with the Airbus A350 aircraft [106]. On 15 December 2016, Singapore Airlines commenced four weekly Airbus A350 services from Singapore to Moscow's Domodedovo Airport but only the Monday and Thursday services were operated by the Airbus A350-aircraft [94]. Singapore Airlines was the first airline to operate the Airbus A350 aircraft to Russia [107]. The Airbus A350 replaced the Boeing B777-300ER aircraft that had been previously deployed on these services.

Figure 3 shows the Singapore Airlines Airbus A350 aircraft route network as at 31 December 2016.

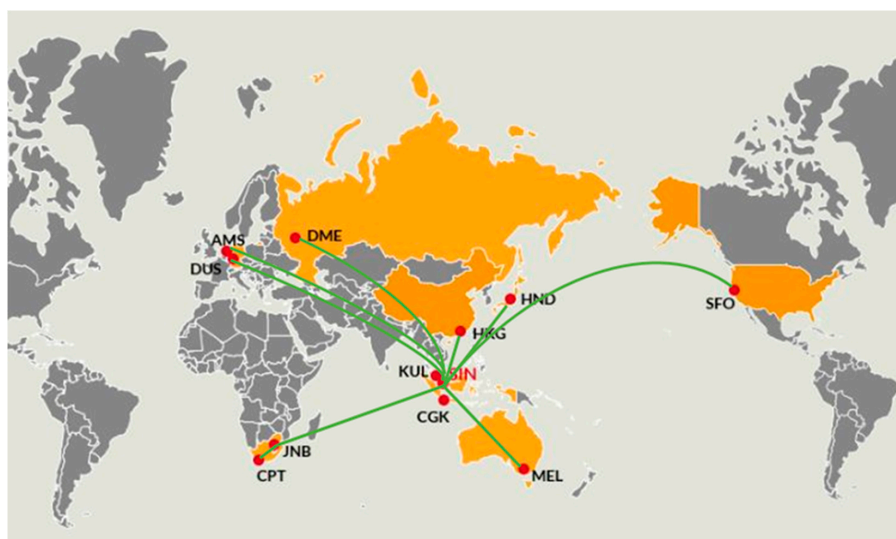


Figure 3. Singapore Airlines Airbus A350-900XWB aircraft routes as at 31 December 2016. Note: Singapore/Melbourne/Singapore was a seasonal service. Legend: AMS = Amsterdam, CGK = Jakarta, CPT=Cape Town, DME = Domodedovo Airport (Moscow), DUS = Düsseldorf, HKG-Hong Kong, HND = Haneda Airport (Tokyo), JNB = Johannesburg Airport, KUL = Kuala Lumpur, MEL = Melbourne, SFO = San Francisco, SIN = Singapore.

4.5. Singapore Airlines Airbus A350-900XWB Aircraft Fleet Deployment and Route Network Development: 2017

Singapore Airlines continued to expand its Airbus A350 aircraft route network in 2017, when on 17 January 2017, the airline replaced the Boeing B777-300ER with an Airbus A350 aircraft, on its services from Singapore/Manchester/Houston and return routing [108]. This new service was the first commercial Airbus A350 flight from Manchester Airport and was the inaugural flight for a Singapore Airlines Airbus A350 aircraft across the Atlantic Ocean [109].

On the 2 April 2017, Singapore Airlines launched Airbus A350 services on the Singapore-Milan (Malpensa Airport)-Barcelona and return routes. These services operate 5 times per week [109]. Effective 12 May 2017, an Airbus A350 replaced the Boeing 777-300ER aircraft on the weekly Singapore Airlines flight number SQ368 (Singapore to Malpensa Airport) and flight number SQ369 (Malpensa Airport to Singapore) services [110].

Singapore Airlines commenced year-round Airbus A350 services on the Singapore-Melbourne-Singapore air route on 11 May 2017 (Flight number SQ208 Melbourne to Singapore and flight number SQ207 Melbourne to Singapore) [111,112]. Also, in May 2017, Singapore Airlines continued the expansion of its European and Scandinavian network when, on 30 May 2017, the airline commenced five services per week on a Singapore-Moscow (Domodedovo Airport)-Stockholm and return routing. The new Airbus A350 flights were part of Singapore Airlines' 2013 Joint-Venture Agreement with Scandinavian Airlines (SAS). This agreement covered flights between Scandinavia and Singapore. Thus, SAS code-shares with Singapore Airlines on the new route from Singapore to Stockholm [113]. Code-sharing essentially means the use of a flight designator code of one airline on services performed by a second airline, which service is normally identified (and may be required to identify) as a service of and the service being performed by, the second airline [114] (p. 223). Importantly, Singapore Airlines was granted fifth freedom traffic rights allowing it to transport fare-paying passengers from Moscow Domodedovo Airport to Stockholm [115]. Fifth freedom traffic rights "grant the right or privilege, in respect of scheduled international air transport services, granted by one state to another state to put down and take on, in the territory of the first state, traffic coming from or destined to a third state" [116] (p. 10).

Effective from the 1 July 2017, Singapore Airlines expanded its Airbus A350 route network with the introduction of new services to Mumbai and Munich. From 1 July 2017, the daily morning flight SQ421/422 Mumbai—Singapore return replaced a Boeing B777-200ER aircraft that previously operated these services [117]. Singapore Airlines upgraded 4 of the weekly Singapore-Munich-Singapore services from a Boeing B777-300ER aircraft to the Airbus A350 aircraft (SQ328 Singapore-Munich, SQ329 Munich-Singapore) [115]. On August 7, 2017, Singapore Airlines services to Munich became an all Airbus A350-900XWB operation when the airline decided to replace the three weekly services previously operated with a Boeing B777-300ER with the Airbus A350 aircraft [118]. In addition, on 2 July 2017, Singapore Airlines commenced direct services between Singapore and Barcelona. This new service eliminated the previous stop-over in Milan. Flight number SQ388 (Singapore to Barcelona) and flight number SQ389 (Barcelona to Singapore) were scheduled to operate each Monday and Friday [119].

The Singapore Airlines four weekly Boeing 777-200ER aircraft services between Singapore and Rome and return were upgraded to Airbus A350 operations effective on the 1 September 2017 [120]. Effective from the 16 October 2017, Singapore Airlines began to progressively upgrade its Singapore-Brisbane-Singapore services with the introduction of the Airbus A350 aircraft on the airline's daily flight SQ235 (Singapore to Brisbane) and flight SQ256 (Brisbane to Singapore) services. The Airbus A350-900 aircraft replaced the Airbus A330-300 that previously operated these flights [121]. On 16 December 2017, the daily SQ245 flight (Singapore to Brisbane) and flight SQ246 (Brisbane to Singapore) services were upgraded from a Boeing 777-200ER aircraft to the Airbus A350 aircraft [122].

Figure 4 shows the Singapore Airlines Airbus A350 route network as at 31 December 2016.

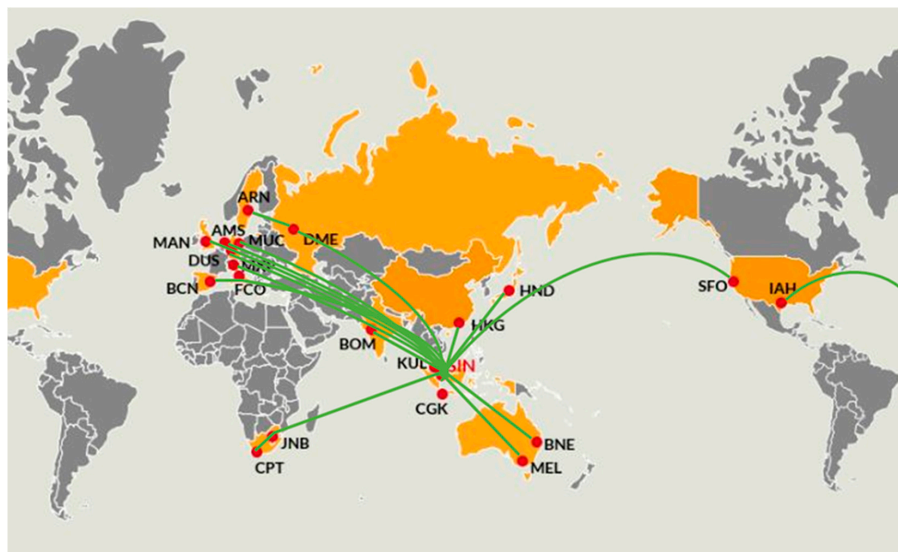


Figure 4. Singapore Airlines Airbus A350-900XWB aircraft routes as at 31 December 2017. Legend: AMS = Amsterdam, ARN = Stockholm Arlanda Airport, BNE = Brisbane, BCN = Barcelona Airport, BOM = Chhatrapati Shivaji International Airport (Mumbai), CGK = Jakarta, CPT=Cape Town, DME = Domodedovo Airport (Moscow), DUS = Düsseldorf, FCO = Leonardo da Vinci–Fiumicino Airport (Rome), HKG=Hong Kong, HND = Haneda Airport (Tokyo), IAH = George Bush Intercontinental Airport (Houston), JNB = Johannesburg Airport, KUL = Kuala Lumpur, MAN = Manchester Airport, MEL = Melbourne, MXP = Milan–Malpensa Airport, MUC = Munich Airport, SFO = San Francisco, SIN = Singapore.

4.6. Singapore Airlines Airbus A350-900XWB Aircraft Fleet Deployment and Route Network Development: 2018

Singapore Airlines upgraded its daily SQ255 flight from Singapore to Brisbane and SQ236 from Brisbane to Singapore from a mixture of Boeing B777-200ER and Airbus A330-300 aircraft to the Airbus A350 effective 16 January 2018 [123]. Effective 26 March 2018, Singapore Airlines increased the flight frequency to Cape Town from four services per week to a daily Airbus A350 service. The services are operated via Johannesburg [124].

As noted earlier, Singapore Airlines has ordered seven Airbus A350-900XWB ultra-long-range aircraft and plans to deploy these on ultra-long-haul, non-stop services from Singapore to Los Angeles and Singapore to New York in the second half of 2018 [125]. Singapore Airlines announced that it would be commencing non-stop Airbus A350-900ULR services from Singapore to Newark on 12 October 2018 [126]. The non-stop service from Singapore to Los Angeles is scheduled to commence on 2 November 2018. In parallel with the commencement of the direct flights to Los Angeles, Singapore Airlines will cancel its daily Singapore-Seoul-Los Angeles service effective 30 November. The airline will still retain the Singapore-Tokyo-Los Angeles services [127]. The estimated flight time on the non-stop service from Singapore to Los Angeles is 17 h. In contrast the flight times on the Singapore/Tokyo /Los Angeles total 17 h 25 min to which the stopover time in Tokyo needs to be added. Thus, passengers wishing to travel directly (that is, without a stopover in Tokyo) can reduce their overall journey time by flying on the non-stop service. This may be especially important for premium passengers who often wish to get to their destination in the shortest amount of time. Similarly, passengers wishing to travel to New York will have two flight options available to them. The Singapore to Newark non-stop service has a scheduled flight time of 18:25 h. In contrast, passengers travelling on the Singapore to John F. Kennedy International Airport via Frankfurt will have a total scheduled flight time of 22:55 h with a stopover of 2:10 h at Frankfurt Airport.

Figure 5 shows the Singapore Airlines Airbus A350 actual and proposed route network as at 31 May 2018.

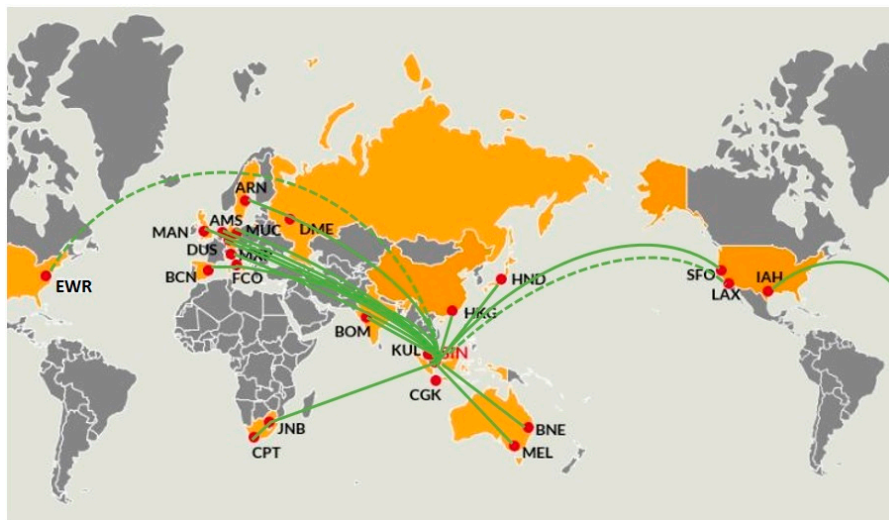


Figure 5. Singapore Airlines Airbus A350-900XWB aircraft actual and proposed routes as at 31 March 2018. Note: SIN-LAX and SIN/NYC services are proposed routes commencing in the second half of 2018. Legend: AMS = Amsterdam, ARN = Stockholm Arlanda Airport, BNE = Brisbane, BCN = Barcelona Airport, BOM = Chhatrapati Shivaji International Airport (Mumbai), CGK = Jakarta, CPT = Cape Town, DME = Domodedovo Airport (Moscow), DUS = Düsseldorf, EWR = Newark Liberty International Airport, FCO = Leonardo da Vinci–Fiumicino Airport (Rome), HKG = Hong Kong, HND = Haneda Airport (Tokyo), IAH = George Bush Intercontinental Airport (Houston), JNB = Johannesburg Airport, KUL = Kuala Lumpur, LAX = Los Angeles International Airport, MAN = Manchester Airport, MEL = Melbourne, MXP = Milan–Malpensa Airport, MUC = Munich Airport, SFO = San Francisco, SIN = Singapore.

4.7. Singapore Airlines Airbus A350-900XWB Fleet Acquisition and Deployment

Aircraft fleet composition and route network are two of the most critical elements of an airline's business model. As previously noted, many airlines structure their route networks on short, medium, long-haul and ultra-long-haul services [11]. The case study has shown that Singapore Airlines has used its fleet of Airbus A350 aircraft to pioneer new long-haul air routes to Barcelona, Düsseldorf and Stockholm and to launch services on several short-haul routes—Johannesburg to Cape Town and from Moscow to Stockholm. The long range of the Airbus A350 has also enabled Singapore Airlines to introduce non-stop services to San Francisco and to Newark Liberty Airport (commencing in October 2018) in the USA. In 2015, the San Francisco services were operated on a Singapore/Hong Kong/San Francisco routing. The non-stop services reduce the elapsed journey times for passengers and air cargo shippers. Interestingly, Singapore Airlines has also retained Singapore/Hong Kong/San Francisco routing thereby offering customers two choices of services. The ultra-long-range service from Singapore to Newark Liberty Airport that is planned to commence in October 2017 will provide customers with a non-stop service rather than having to make an intermediate stop en route. In 2015, Singapore Airlines operated a service to Houston via Moscow. Following the addition of the Airbus A350 to its fleet this service is now operated with an Airbus A350 on a Singapore/Manchester/Houston routing. During the period 2015 to 2018, the number of cities served by Singapore Airlines has grown whilst the routing of flights with an intermediate stop has also changed with the routing of such services enabling Singapore Airlines to optimize passenger loads as well as the Airbus A350 commercial payload. Furthermore, the addition of new spoke cities to Singapore Airlines route network exponentially increases the number of origin-and-destination (O & Ds) markets or city pairs that the airline can serve.

Airlines acquire new aircraft to replace older, less efficient aircraft in their fleet or to use the new generation aircraft to pioneer new air routes. The case study has shown that Singapore Airlines is using its fleet of Airbus A350-300XWB to replace older aircraft types, for example, Airbus A330-300, Boeing B777-200ER and Boeing B777-300ER aircraft. Singapore Airlines is following its strategy of operating a young and modern fleet of aircraft. This enables the airline to achieve cost savings due to lower fuel and maintenance costs. A young fleet is also an important advertising feature that the airline can use to attract customers. In addition, Singapore Airlines fleet strategy optimizes aircraft utilization to match its worldwide route network and optimizes the use of capital intensive assets [128].

4.8. Singapore Airlines Airbus A350-900XWB Route Network Design

As noted earlier, the major airlines typically structure their route networks based on the hub-and-spoke principle [11,129] whereby they link together smaller peripheral markets via their major hub airports. This strategy enables them to optimize both passenger and air cargo connectivity. Furthermore, many airlines structure their route networks on short haul, medium-haul and long-haul services [11]. Singapore Airlines uses a hub-and-spoke route network design. Hubbing is advantageous for several reasons. Hubbing enables enhanced marketing opportunities for airlines through the geometric proliferation of the number of origin-and-destinations (O & Ds) or city pairs which can be served [42]. Indeed, an important advantage of hub-and-spoke route network is the effect they have in multiplying by permutation the number of spoke cities that an airline can serve. Thus, when airports are connected to a hub, the number of origin-and-destinations (O & Ds) or city pairs is much higher than when they are linked directly [39,130]. This strategy enables Singapore Airline to carry both business and leisure travelers to their primary hub at Singapore's Changi Airport for subsequent transfer to their destination. This strategy also enables Singapore Airlines to feed both premium and leisure passenger traffic from peripheral markets onto its short, medium, long and ultra-long-haul services. This strategy also enables Singapore Airline to carry tourists to important tourism markets.

In addition, Singapore Airlines is a long-standing member of the Star global airline alliance. The airline's membership of the Star global alliance permits each alliance partner to expand the number of destinations that can be offered to customers [131]. Singapore Airlines non-stop Airbus A350 services to San Francisco, for example, enable passengers to connect at San Francisco with United Airlines, another Star Alliance partner airline. Passengers travelling on the Singapore Airlines A350 services from Singapore to Düsseldorf and Munich could connect onto Lufthansa service as Lufthansa is also a member of the Star Alliance. Also, as previously noted, SAS code-shares with Singapore Airlines on its Singapore to Stockholm Airbus A350 service.

4.9. Singapore Airlines Airbus A350-900XWB Flight Stage Lengths

Prior to examining Singapore Airlines Airbus A350-900 flight stage lengths, it is important to note the various categories of airline flight stage lengths (Table 2) as Singapore Airlines operates its fleet of Airbus A350 on a range of diverse stage haul lengths. It is also important to note that the Airbus A350 can operate flight stages of 8250 nautical miles (15,279 km) with a full passenger payload. These aircraft are therefore capable of operating long-haul sectors of 5000 nautical miles (9260 km) or more. The new ultra-long-range Airbus A350-900XWB ULR aircraft ordered by Singapore Airlines have a range of 9700 nautical miles (17,964 km) [132,133] and therefore can operate the proposed non-stop, ultra-long-range services from Singapore to Los Angeles and New York.

Table 2. The various flight stage categories in the global airline industry. Source: compiled from [11,16,134].

Stage Length Category	Distance (Nautical Miles)	Distance (Kilometers)
Short-haul	Up to 750	Up to 1389
Medium-haul	750 to 2500	1389 to 4630
Long-haul	3500 to 5500	6482 to 10,186
Ultra-long-haul	More than 7000	12,964

Figure 6 shows the existing and proposed Singapore Airlines Airbus A350 flight stage lengths. As previously noted, the planned Singapore to Los Angeles and New York City services will have the longest stage haul lengths when they commence in the second half of 2018. The flight stage length for the Singapore to Los Angeles and Singapore to Newark Liberty Airport services are 7621 nautical miles (14,113 km) and 8285 nautical miles (15,344 km), respectively (Figure 6). These two flights fall into the ultra-long-haul category. Singapore Airlines existing flight from Singapore to San Francisco is also an ultra-long-haul service, with a flight stage distance of 7340 nautical miles (13,593 km). Figure 6 also shows that the flight stage lengths for the Singapore Airlines services from Manchester to Houston are 4096 nautical miles (7586 km), Singapore to Moscow 4534 nautical miles (8395 km), Singapore to Johannesburg 4677 nautical miles (8661 km), Singapore to Rome 5430 nautical miles (10,056 km), Singapore to Munich 5432 nautical miles (10,060 km), Singapore to Milan 5568 nautical miles (10,313 km), Singapore to Düsseldorf 5612 nautical miles (10,394 km), Singapore to Amsterdam 5678 nautical miles (10,516 km), Singapore to Barcelona 5888 nautical miles (10,905 km) and Singapore to Manchester 5917 nautical miles (10,959 km) fall within the long-range flight stage length category. The stage lengths for Singapore Airlines flights from Singapore to Tokyo's Haneda Airport is 2857 nautical miles (5292 km), Singapore to Melbourne 3253 nautical miles (6025 km) and Singapore to Brisbane 3316 nautical miles (6142 km) whilst not being as great as the services to Europe also fall into the long-haul category (Figure 6).

The Singapore Airlines services from Singapore to Hong Kong (1379 nautical miles or 2555 km) and Singapore to Mumbai (2116 nautical miles or 3919 km) fall within the medium stage length category. As noted in the case study, Singapore Airlines also operates its fleet of Airbus A350-900XWB aircraft on several quite short haul services. These include the Singapore to Kuala Lumpur (160 nautical miles or 296 km), Singapore to Jakarta (475 nautical miles or 879 km), Moscow to Stockholm (686 nautical miles or 1271 km) and the Johannesburg to Cape Town (686 nautical miles or 1271 km) sectors (Figure 6).

Figure 6 also shows that Singapore Airlines has a hub—Singapore Changi Airport—at one end of the routes. All services originate at the airline's hub at Singapore Changi Airport and all returning Airbus A350 flights terminate at the airline's hub. Singapore Airlines also operates its fleet of Airbus A350 on several multi-sector flights that include Johannesburg to Cape Town, Moscow to Stockholm and Manchester to Houston routes. This is a similar strategy to that used in 2015 whereby, as noted earlier, several cities were served with an intermediate stop en route.

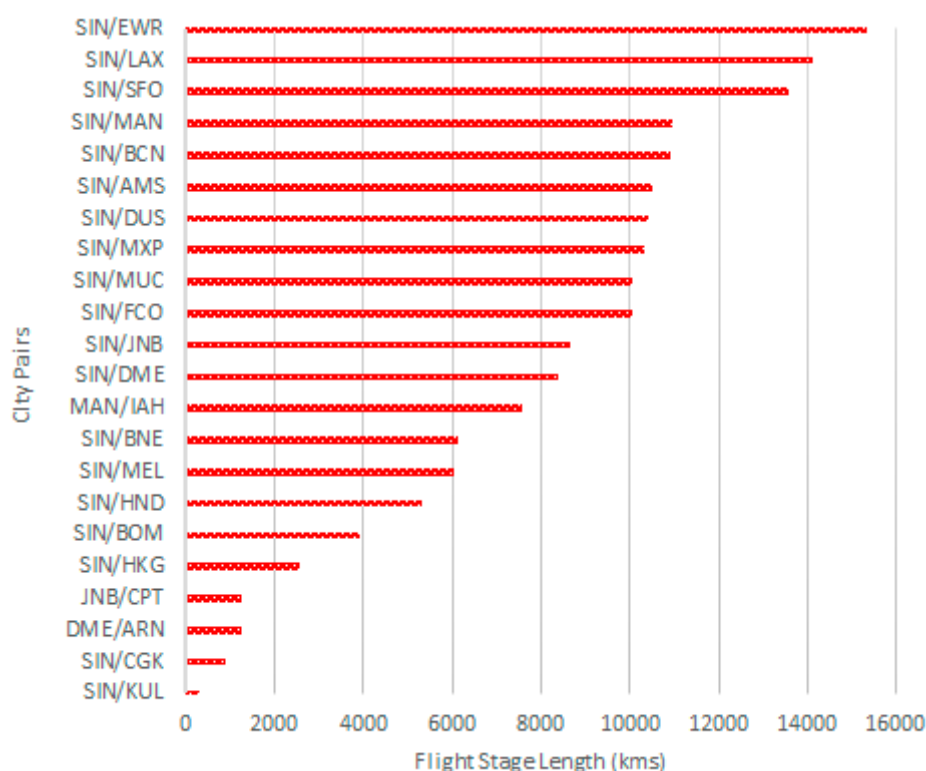


Figure 6. Singapore Airlines Airbus A350-900XWB flight stage lengths. Legend: AMS = Amsterdam, ARN = Stockholm Arlanda Airport, BNE = Brisbane, BCN = Barcelona Airport, BOM = Chhatrapati Shivaji International Airport (Mumbai), CGK = Jakarta, CPT-Cape Town, DME = Domodedovo Airport (Moscow), DUS = Düsseldorf, EWR = Newark Liberty International Airport, FCO = Leonardo da Vinci-Fiumicino Airport (Rome), HKG-Hong Kong, HND = Haneda Airport (Tokyo), IAH = George Bush Intercontinental Airport (Houston), JNB = Johannesburg Airport, KUL = Kuala Lumpur, LAX = Los Angeles International Airport, MAN = Manchester Airport, MEL = Melbourne, MXP = Milan-Malpensa Airport, MUC = Munich Airport, SFO = San Francisco, SIN = Singapore.

4.10. Singapore Airlines Airbus A350-900XWB Aircraft Available Seat Kilometers

The most common measure of an airline's output is the available seat kilometers (ASKs) or available seat miles (ASMs) [135,136]. ASKs are used as a measure of available passenger capacity [137]. Airlines produce seat kilometers but sell passenger kilometers, like revenue passenger kilometers (RPKs), available seat kilometers (ASKs) reflect the spatial nature of their output [135]. Available seat kilometers (ASKs) are the total number of seats offered on a flight multiplied by the stage length flown [137,138].

As can be seen in Figure 7, the existing Singapore to San Francisco flight produces the greatest number ASKs (3.43 million ASKs). The next most significant source of ASKs are those produced on the airlines services from Singapore to Europe and return. The greatest number of ASKs are produced on the Singapore to Manchester and Manchester to Singapore sectors (2.77 million ASKs on each service). This is followed by the Singapore to Barcelona and Barcelona to Singapore sectors which produce 2.75 million ASKs per flight, the Singapore to Amsterdam and Amsterdam to Singapore services (2.66 million ASKs) and the Singapore to Milan Malpensa Airport and Milan Malpensa Airport to Singapore services produce 2.60 million ASKs per flights. The Singapore to Rome and Rome to Singapore and the Singapore to Munich and Munich to Singapore services generate 2.54 million ASKs and 2.55 million ASKs, respectively. The service from Singapore to Moscow also produces just over 2 million ASKs per flight (2.12 million ASKs) (Figure 7).

The Singapore Airlines Airbus A350-900ULR aircraft that will be serving the non-stop Singapore to Los Angeles and Newark International Airport have a two-class seating configuration comprising 67 business class and 94 premium economy class seats (total 161 seats) [139]. Despite the very long flight stage lengths, the lower seating configuration influences the number of ASKs produced on these ultra-long-range services. As can be seen in Figure 7, the Singapore to Los Angeles and Singapore to Newark Liberty Airport services will produce 2.27 million and 2.47 million ASKs, respectively.

The Airbus A350 services operated to Brisbane and Melbourne in Australia generate 1.52 million ASKs and 1.55 million ASKs, respectively. The Singapore to Hong Kong services generate 646,415 ASKs per flight and the Singapore to Tokyo Haneda Airport services produce 1.33 million ASKs per flight. The Singapore to Mumbai flight produces slightly less than 1 million ASKs per service (992,013 ASKs) (Figure 6).

As previously noted, Singapore Airlines operates several short haul services with its Airbus A350 fleet and consequently, due to the short stage lengths the number of ASKs produced per flight are considerably lower than those on long haul services. As can be seen in Figure 5, the Johannesburg to Cape Town and return service produces 312,816 ASKs, the Moscow to Stockholm Arlanda Airport and return services generates 320,551 ASKs per flight and the Singapore to Jakarta and Jakarta to Singapore services produce 222,260 ASKs per flight. The smallest number of ASKs per flight are produced on the Singapore to Kuala Lumpur and Kuala Lumpur to Singapore services with just 75,141 ASKs being generated on each sector (Figure 7). The small number of ASKs produced on these services are due to the very short flight stage distance between the two cities.

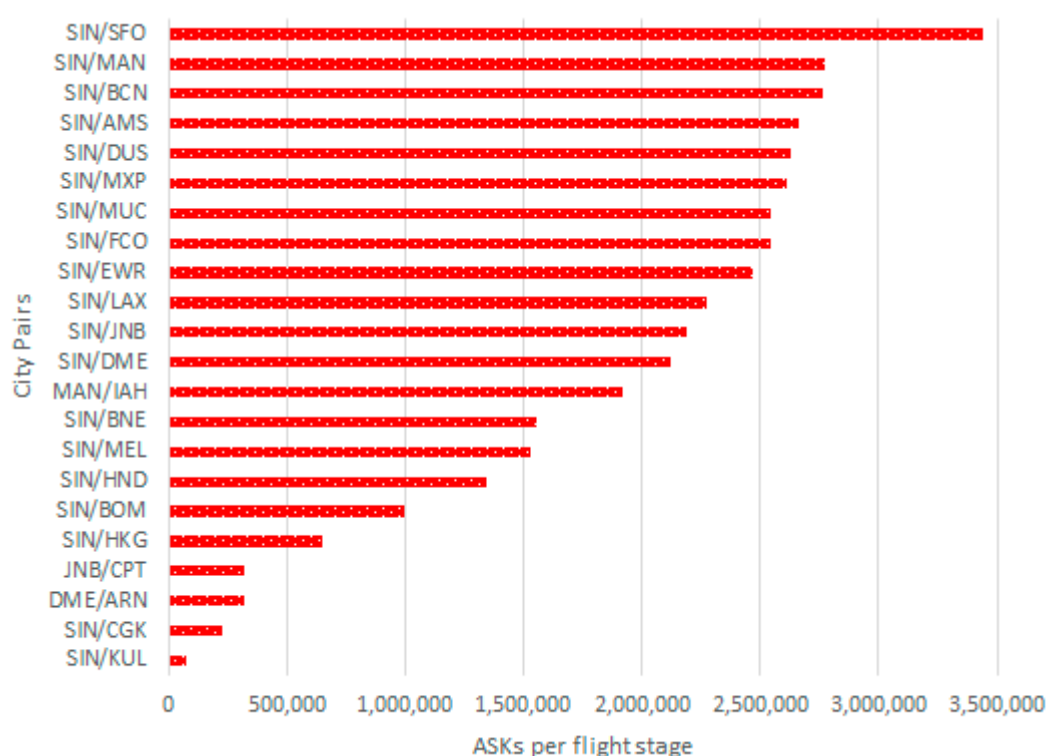


Figure 7. Singapore Airlines Airbus A350-900XWB ASKs per city pair. Legend: AMS = Amsterdam, ARN = Stockholm Arlanda Airport, BNE = Brisbane, BCN = Barcelona Airport, BOM = Chhatrapati Shivaji International Airport (Mumbai), CGK = Jakarta, CPT-Cape Town, DME = Domodedovo Airport (Moscow), DUS = Düsseldorf, FCO = Leonardo da Vinci-Fiumicino Airport (Rome), HKG-Hong Kong, HND = Haneda Airport (Tokyo), IAH = George Bush Intercontinental Airport (Houston), JNB = Johannesburg Airport, KUL = Kuala Lumpur, MAN = Manchester Airport, MEL = Melbourne, MXP = Milan-Malpensa Airport, MUC = Munich Airport, SFO = San Francisco, SIN = Singapore.

4.11. Airbus A350-900XWB Aircraft Rotation Patterns

In the global airline industry, aircraft utilization is a key measurement of productivity and operational efficiency [140]. According to Belobaba [141] (p. 146), “the ability of an airline to achieve a certain level of aircraft utilization depends on the characteristics of its network, its schedule and its efficiency in turning around an aircraft on the ground between one flight and the next departure”. The first factor that needs to be considered in aircraft assignment is the aircraft capability to serve the route. Long-haul intercontinental flights are normally operated by wide-body jet aircraft. A key aim of aircraft assignment is matching supply with demand. Higher capacity aircraft should therefore be assigned by the airline to flights with the highest level of demand [131]. In addition, one important way for an airline to increase daily aircraft utilization rates is to operate longer air routes [142].

To provide an insight into how Singapore Airlines deploys their fleet of Airbus A350-900XWB aircraft, Figure 8 shows the routes operated by one of Singapore Airlines Airbus A350-900 (aircraft registration 9V-SME) over a five-day operating period in the middle of July 2018. Over this 5-day period, the aircraft operated a Singapore to Johannesburg (10 h 40 min) and onto Cape Town (2 h 15 min) service (Day 1). On day 2 the aircraft operated multiple flight segments—Cape Town-Johannesburg (2 h 15 min), Johannesburg to Singapore (10 h 40 min), Singapore to Jakarta (1 h 50 min) and Jakarta to Singapore (1 h 50 min) and from Singapore to Kuala Lumpur (1 h) and from Kuala Lumpur to Singapore (1 h). On Day 3 the aircraft operated from Singapore to Munich (12 h 25 min) and Munich to Singapore (11 h 55 min). The aircraft did not operate any services on Day 4 and on Day 5 was once again scheduled to operate from Singapore to Munich and return. As can be seen in Figure 8, Singapore Airlines is striving to optimize the daily utilization of its aircraft fleet and, where time permits between long-haul stage lengths permit, the aircraft are assigned on short-haul regional services. Furthermore, the short haul sectors operated by Singapore Airlines enables them to carry traffic (both passenger and air cargo) to their Changi Airport hub for onward transportation to their destination.



Figure 8. Air routes operated by Singapore Airlines Airbus A350-900 (Registration 9V-SME): 11–15 July 2018. Source: adapted from [143].

4.12. The Tourism and Trade Benefits from Singapore Airlines Airbus A350-900XWB Air Routes

Budd [144] notes that air transport, like surface-based modes mobility, exists to facilitate both the movement of people and cargoes, between geographic locations and involves the complex interaction of both the physical and human environments. The author [144] (p. 15) further notes “that the resulting combination of liberalization, globalization and competition has stimulated unprecedented demand for flight, changed patterns of global connectivity and has altered consumer expectations and experiences of flight”. Singapore Airlines is contributing to the changing patterns of global air transport connectivity, whilst also satisfying both passenger and air cargo demand, through the pioneering of new long range or ultra-long-range air routes. These services are opening new opportunities for both passengers and air cargo shippers and are contributing to the globalization of the airline’s route network.

Furthermore, air transport and tourism have a symbiotic relationship [145,146] with the two being inextricably interlinked by mutual dependence and each fostering the development of the other [147]. The new air routes pioneered by Singapore Airlines have been carefully planned to optimize and grow tourism. Singapore has been very successful as an international destination with a steady increase in the number of tourist arrivals since the city-state became an independent republic in 1965. The government of Singapore have been very active and its pro-tourism policies have developed an infrastructure and supply of attractions which render the country as a center for leisure and business tourism [148]. Singapore Airlines has historically worked very closely with key tourism industry stakeholders to help facilitate the growth in tourism. For example, in 2017, Singapore Airlines and Singapore Tourism Board has launched a new campaign to promote Singapore as a stopover destination for Australians [149]. Singapore Airlines also offers passengers with a stopover in Singapore access to its *Singapore Explorer Pass*, which provides passengers with access to 20 tourist attractions [150]. The introduction of Airbus A350-900XWB services to South Africa (Johannesburg), Düsseldorf and Stockholm have opened new opportunities for both leisure and business travelers. Furthermore, the growth in Airbus A350-900XWB services in key markets, such as Australia and Malaysia have also enhanced tourism opportunities in not only Singapore but also at the airline’s other key destinations. Thus, the stimulation of new tourism and business markets through new air routes will contribute to Singapore’s economic growth. This is because tourism promotes economic growth [151].

Air transportation has a very close relationship with the growth in world trade. The continuing liberalization and globalization of the air transport industry is accelerating the growth trend in world trade [152]. The international air cargo mode is a trade facilitator that contributes to global economic development. The world economy is highly dependent upon the air cargo mode to deliver high-quality products at competitive prices to consumers located all around the world [153]. Singapore Airlines views air cargo as a core strategic business segment. This is reflected in the airline’s global air cargo rankings, for example, in 2016, Singapore Airlines was the world’s 13th largest air cargo carrier [154]. The introduction of new long and ultra-long-range services also opens new air cargo opportunities for Singapore Airlines. The introduction of Airbus A350-900XWB services from Singapore to Cape Town, Düsseldorf and Stockholm and return provided not only the opportunity for origin and destination (O & D) traffic between these city pairs but also opportunity for Singapore Airlines to carry air cargoes destined for key Asia/Pacific markets via its Changi Airport hub on its passenger or scheduled freighter services. Singapore Airlines is also able to leverage its extensive passenger and freighter route network throughout the Asia Pacific, USA and European regions to source traffic destined to the new destinations that the airline is opening with its fleet of Airbus A350-900XWB aircraft.

Air cargo is also an important revenue source for airlines [155]. In addition to assisting new trade opportunities, the air cargo revenues generated by Singapore Airlines on their new long or ultra-long-range services will contribute to both the route and company profitability.

5. Conclusions

This study has examined, for the first time, Singapore Airlines Airbus A350-900XWB fleet deployment and route network development for the period 2016 to 2018. Despite the trend by the full-service network carriers (FSNCs) to deploy their Airbus A350-900XWB aircraft on new or existing routes, there has currently been limited research undertaken on such strategies. Hence, this study adds some valuable insights to the literature. The study used a qualitative longitudinal case study research design. The data collected for the study was examined using document analysis. The study was underpinned by a case study protocol and research framework that followed the recommendations of Yin [66].

A key aim of this study was to explore how the Singapore Airlines route network has evolved following the introduction of its fleet of Airbus A350 aircraft into revenue service. In 2015, the year prior to the entry of the Airbus A350 aircraft, Singapore Airlines operated an extensive network of long-haul services to key markets in Australasia, Europe and North America. A number of these services incorporated an intermediate stop, for example, the Singapore to Houston flight was routed via Moscow with a Boeing B777-300ER aircraft. Since 2015, the airline has made several flight routing changes that incorporate the long-range and ultra-long-range potential of the Airbus A350 aircraft. The previous Singapore/Moscow/Houston flight is now operated with an Airbus A350 on a Singapore/Manchester/Houston routing. Singapore Airlines, as part of its fleet modernization strategy, is deploying its fleet of Airbus A350-900XWB aircraft on many existing routes and are using the Airbus A350-900XWB to replace older aircraft types—Airbus A330-300, Boeing 777-200ER and Boeing B777-300ER aircraft in its fleet. In addition, Singapore Airlines has pioneered new long-haul routes with its fleet of Airbus A350-900XWB aircraft. These new routes link the airlines hub at Changi Singapore Airport to Barcelona, Düsseldorf, Stockholm (via Moscow) and Cape Town (via Johannesburg). Future ultra-long-range services are planned to commence in the second half of 2018 and these include the proposed non-stop services from Singapore to Los Angeles and to New York City. To operate the new ultra-long-range services to the USA, Singapore Airlines has ordered a fleet of the new Airbus A350-900XWB ultra-long-range aircraft.

The study found that Singapore Airlines is deploying their Airbus A350-900XWB aircraft on short-haul, medium haul, long-haul and ultra-long-haul services. The flight stage lengths of these services vary considerably with the proposed Singapore to New Jersey's Newark Liberty Airport and Singapore to Los Angeles having the longest stage lengths of 8285 nautical miles (15,336 km) and 7621 nautical miles (14,114 km), respectively. At the time of the study, Singapore Airlines operated an ultra-long-haul service from Singapore to San Francisco and return. The stage length of these services is 7340 nautical miles or 13,593 km. Throughout its history, Singapore Airlines has developed an extensive European network. The Airbus A350-900XWB aircraft is being deployed on many of the airline's services to its key European markets. Due to the distance between Singapore and Europe these flights have long stage lengths. At the time of the present study the longest stage length was recorded on the Singapore to Manchester route at 5917 nautical miles or 10,959 km which was slightly greater than the Singapore to Barcelona route, which has a stage length of 5888 nautical miles or 10,905 km. The Singapore to Amsterdam, Düsseldorf, Milan, Munich and Rome flight stage lengths are 5678 nautical miles (10,516 km), 5612 nautical miles (10,394 km), 5568 nautical miles (10,313 km), 5430 nautical miles (10,056 km) and 5432 nautical miles (10,060 km), respectively. Singapore Airlines also operates a service over a Singapore/Moscow/Stockholm routing and the flight stage length for the long-haul sector from Singapore to Moscow is 4534 nautical miles or 8395 km. The Moscow to Stockholm stage length is third shortest stage length operated by Singapore Airlines with an Airbus A350-900XWB aircraft at 686 nautical miles or 1271 km. Other long-haul services operated by the Airbus A350-900XWB aircraft include the Manchester to Houston service which has a stage length of 4096 nautical miles (75,867 km) and the Singapore to Johannesburg service which has a flight stage length of 4677 nautical miles or 8661 km. The Airbus A350-900XWB aircraft continues from Johannesburg to Cape Town which has a quite short stage length of 687 nautical miles or 1271 km.

Singapore Airlines is also deploying its Airbus A350-900XWB aircraft on long-haul services from Singapore to Brisbane, Melbourne and Tokyo Haneda Airport, which have flight stage lengths of 3316 nautical miles (6142 km), 3253 nautical miles (6025 km) and 2857 nautical miles (5292 km).

Singapore Airlines also utilizes its fleet of Airbus A350-900XWB on several medium haul routes linking its hub at Singapore's Changi Airport with Mumbai, which has a flight stage length of 2116 nautical miles (3919 km) and Hong Kong, which has a flight stage length of 1379 nautical miles or 2555 km. At the time of the present study, Singapore Airlines operated two short-haul South East services with the Airbus A350-900XWB. The Singapore to Jakarta route has a flight stage length of 475 nautical miles (879 km) whilst the Singapore to Kuala Lumpur route has a flight stage length of 160 miles or 296 km.

One of the key airline efficiency measures used in the air transport industry is the available seat kilometers (ASKs) produced per flight. Like flight stage lengths, the greater the flight stage length (distance) the greater the number of ASKs produced. The Singapore to San Francisco ultra-long-range service generates 3.43 million ASKs per flight. Due to the long stage lengths from Singapore to Europe, the airline's European services generate a substantial number of ASKs per flight. The greatest number of ASKs is produced on the Singapore to Manchester route (2.77 million ASKs) followed by the Singapore to Barcelona route with 2.66 million ASKs. The ASKs per flight on the Singapore to Amsterdam, Düsseldorf, Milan, Munich and Rome routes are 2.66 million ASKs, 2.62 million ASKs, 2.60 million ASKs, 2.54 million ASKs and 2.54 million ASKs, respectively. The Singapore to Johannesburg and Moscow services also generate more than 2 million ASKs per flight. The Singapore to Johannesburg services produces 2.19 million ASKs per flight whilst the Singapore to Moscow service produces 2.12 million ASKs. The next greatest source of ASKs comes from the Manchester to Houston service with 1.91 million ASKs produced per flight. The Singapore to Brisbane and Singapore to Melbourne services produce 1.55 million ASKs and 1.52 million ASKs, respectively. The long-haul Airbus A350-900XWB service from Singapore to Tokyo's Haneda International Airport produces 1.33 million ASKs per flight.

The medium haul services from Singapore to Mumbai and Hong Kong produce 992,013 and 646,415 ASKs per flight, respectively. The Johannesburg to Cape Town and Moscow to Stockholm short-haul services produce 321,816 ASKs per flight and 320,551 ASKs, respectively. The short haul services operated from Singapore to Jakarta and Kuala Lumpur produce 222,640 ASKs per flight and 75,141 ASKs per flight. The small number of ASKs per flight on the latter two routes reflect the very short flight stage distance.

The Singapore Airlines Airbus A350-900XWB ULR aircraft have a two-class seating configuration comprising 67 business and 94 premium economy seats. Despite the very long flight stage lengths, the spacious seating configuration directly affects the number of ASKs produced on these ultra-long-range services. Upon commencement, the Singapore to Los Angeles and Singapore to Newark Liberty Airport services will produce 2.27 million and 2.47 million ASKs, respectively.

The deployment of the Airbus A350-900XWB in new markets, such as Düsseldorf and Stockholm, has opened new tourism and trade opportunities. Moreover, the Airbus A350 has the potential to carry a meaningful air cargo load and thus, the addition of new markets benefits not only passengers but also air cargo customers. The non-stop Airbus A350 services also reduce the journey's elapsed time which enables both passengers and air cargo shipments to reach their destination more expeditiously.

A limitation of the present study was that it was restricted to a single carrier—Singapore Airlines—and to its existing fleet of Airbus A350-900XWB aircraft. Singapore Airlines was an ideal case airline as it is highly acknowledged and is the recipient of many prestigious awards. Also, Singapore Airlines has always aimed to operate a modern fleet and the acquisition and deployment of the Airbus A350-900XWB is a real-world example of this policy and strategy. As previously noted, the Boeing 787-8/-9 aircraft are also being deployed by operators on new air routes and to replace older, less efficient aircraft. Thus, future research could conduct a comparative analysis of the Airbus A350-900XWB vis-à-vis the Boeing 787-8/-9 aircraft fleet deployment and the role of these aircraft

types in their operators' route network development. Finally, when the new ultra-long-range Airbus A350-900XWB variant enters commercial service in the second half of 2018 then the deployment of this new aircraft type could also form the focus of a future study which could also incorporate the comparative analysis of the aircraft type vis-à-vis the Boeing 787-8/-9 aircraft.

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